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ENCYCLOPEDIA OF SUSTAINABILITY

THE BUSIN€SS OF SU$TAINABI£ITY

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VOLUME 2

宝库山
BERKSHIRE

BERKSHIRE ENCYCLOPEDIA OF SUSTAINABILITY

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THE BUSIN€SS OF SU$TAINABI£IT¥

Chris Laszlo, Karen Christensen, Daniel Fogel,
Gernot Wagner, and Peter Whitehouse, *Editors*

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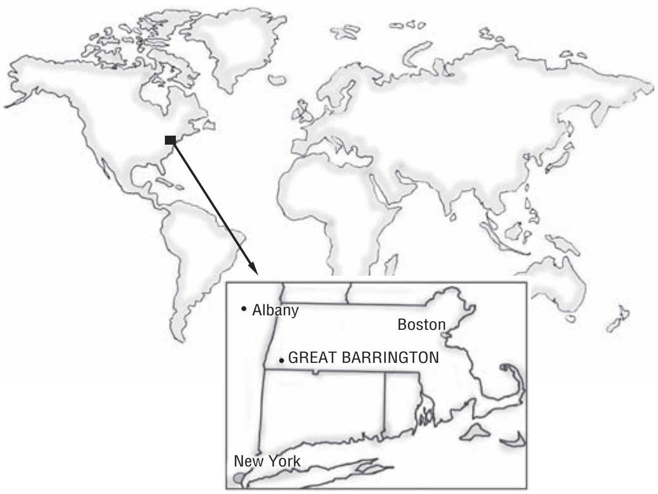

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Publisher's Note

As we publish *The Business of Sustainability*, volume 2 of the *Encyclopedia of Sustainability*, foremost in our minds is the fact that sustainability means working toward a "common future." Businesses large and small have a crucial role to play, and many show indications of recognizing that fact.

This was not always so. I remember when I was caught up in the infamous "McLibel" case, the most expensive and widely publicized attack by a multinational corporation against its critics. In 1989 I was a young American living in London, and my first book, *Home Ecology,* was off to a best-selling start. But a casual reference to McDonald's in a paragraph about fast food brought me to the attention of the major law firm representing McDonald's, which was then attempting to use U.K. libel laws to suppress any and all criticism. They were able to get all the major bookstore chains to return my book to the publishers, merely by telling them that a lawsuit was possible.

That experience, which had considerable financial consequences, did not warm me toward the world of business. My environmentalist colleagues often portrayed this "other" world as a negative force, destructive of the environment and people's lives and health. But I wasn't anti-business (or even particularly anti-McDonald's) then, and over the years I've come to understand that economic activity and commercial innovation are essential forces in human history. Now, as a businessperson myself, I'm thrilled by opportunities to help experts on sustainability share what they know with eager students, citizens, and professionals in government, education, and business. And it's exciting to learn, in contributor Jay Friedlander's article "Fast Food Industry" (page 221), that McDonald's is among the major corporations now looking seriously at "the business of sustainability."

That is the point of this volume: how can we do business in a way that promotes environmental sustainability while ensuring that business (and the economy) doesn't collapse in the process? This is another way to define *sustainable business*—businesses that will grow, create jobs, and promote the common good.

Naturally, at Berkshire Publishing, we're doing all we can to figure out what a sustainable publishing company looks like; using a green printer like Thompson-Shore is a first step, and promoting energy efficiency in online publishing is another.

But printing on paper is not necessarily a bad thing—trees, after all, will grow back, and the forest won't be devastated with proper ecosystem management—and moving solely to online publishing has a frightening number of hidden environmental costs that few people realize (exactly because they're hidden). There are better ways to do business. By organizing what we know and what we've learned today, publishers can spur positive changes in the way we all do business.

Karen Christensen.

Karen Christensen
Great Barrington, Massachusetts

Introduction to *The Business of Sustainability*

The title of this volume, *The Business of Sustainability*, reflects the evolving interface between industry and society in an era of global climate change, resource depletion and ecosystem damage, and growing concern about the future among businesspeople as well as scholars and, of course, citizens across the planet. Corporate leaders are taking a new stand on sustainability, recognizing that there is opportunity—not just regulation and risk—inherent in the need to provide solutions to the world's environmental and social challenges. Given the less-than-ideal state of the world economy going into the second decade of the twenty-first century, opportunity is something that needs to be seized wherever it arises.

According to a 2009 report titled *HSBC Equities and Climate Change*, climate-related revenues are expected to exceed two trillion dollars by 2020; these revenues include energy efficiency and renewable energy initiatives as well as the control of water and waste and pollution mitigation. Businesses that attempt to confront the causes of climate change before the problem grows worse, rather than simply reacting to its results, are positioned to create a healthier, more viable future for generations to come.

Faced with a rapidly growing demand for sustainability products and new business models, companies in a broad range of sectors are using pressures from environmental challenges to innovate and create new sources of competitive advantage. In the words of General Electric's CEO, Jeffrey Immelt, suddenly "green is green." Ray Anderson, founder and chairman of Interface Inc. and author with Robin White of *Confessions of a Radical Industrialist: Profits, People, Purpose—Doing Business by Respecting the Earth*, put it this way: "[Our] sustainability commitments aren't just good for business—they are our business."

To compete in the new market reality, business has to address its impacts on a diverse set of constituents. Failing to do so incurs hidden business risks, from losing customers to facing preemptive government regulation. Conversely, accounting for a company's stakeholder impacts (i.e., the effects a company's actions have on people and its customers, not merely the company's shareholders) enables it to meet rising societal expectations in terms of human health and the environment. Sustainability is not just about a renewed moral agenda to "save the whales." Instead it is being reframed with an explicit pro-business agenda based on the power of innovation to serve seven (and soon nine) billion people without compromising the ability of future generations to meet their own needs.

Business value is no longer limited to compliance or to merely reducing energy costs and waste. New growth opportunities lie in product designs that incorporate environmental intelligence without compromising performance. A small company in Minneapolis, Tennant, sells industrial cleaning solutions made by electrically converting plain tap water to perform like a powerful detergent, without the negative environmental and health concerns associated with traditional cleaning chemicals. IBM is focused on smart electric grids, Philips "green electronics" reached 25 percent of 2008 total sales, and Cisco is positioning its TelePresence videoconferencing as a way to save money and improve collaboration while going green. *The Business of Sustainability* contributor Asheen Phansey writes of numerous examples of businesses making a profit by copying the designs of nature in his article "Biomimicry." While the use of more computers and technology isn't always a solution to the problem (see the entries "Data Centers," "Information and Communications Technologies," and "Telecommunications Industry" for more on this multifaceted issue), these examples illustrate the growing market success of sustainability products that don't require consumers to pay a green premium or to accept a trade-off in quality and performance.

Other companies are finding new profitable opportunities in what is often referred to as the "base (or bottom) of the pyramid," or BOP. This means business in meeting unmet societal needs—for clean water and nutritional foods as well as for access to computers and telecommunications—among the world's 4 billion people who live on less than four dollars per day. This is not to be confused with charity, which, if unfocused, simply throws money at the problem of poverty without offering any long-term solutions. When the poor have the ability to help themselves, good things happen as a result.

Global industry leaders are, in cases such as the U.S. Climate Action Project, lobbying government to raise environmental and health standards (rather than to slow them down) in the hope that they can meet the new standards where their low-cost competitors cannot.

New metrics continue to be implemented in an effort to balance the environment with the social, economic, and political movements of the twenty-first century. China's attempt to calculate its "green GDP" in 2006 was intended to measure the impacts of rapid development on China's environment and the cost of that damage to the country's bottom line. As contributors Jianguo Wu and Tong Wu write in "Green GDP," despite the various flaws in that first attempt to quantify the price of environmental degradation in China, it was an important opportunity to identify the true cost of the country's breakneck rate of development

A major focus of this volume is the related goal of identifying the "true cost" to the environment of doing business the old way, where profits come ahead of people and the planet and such intangibles as a beautiful landscape have no intrinsic value. The more progressive way of doing business is referred to in management circles as the "triple bottom line" approach, a more integrative way of doing business that examines how economic gain, humanity's varied needs, and the environment all tie together; John Elkington discusses this topic in his article of the same name. William Rees, co-developer of the concept of the "ecological footprint," delves into the subject of hidden costs and the value of nature in "True Cost Economics," as do Emma Stewart in "Ecosystem Services" and L. Hunter Lovins in "Natural Capitalism."

Can Sustainability Survive the Recession?

The existence of a volume on the "business of sustainability" reflects a new competitive context transformed by volatile fuel prices, widespread concern over the impact of climate change, and heightened consumer awareness of global sustainability issues, not to mention the added challenges companies face merely staying afloat in uncertain times. The global financial crisis and economic recession that began in late 2007 (some sources will put the exact date somewhat later) have done little to dampen the growth in demand for sustainable products and technologies in sectors as varied as transportation, energy, food, retail, and agriculture. As climate change and other global megatrends continue to challenge business ingenuity, sustainability pressures can be expected to only further drive profitable growth and prosperity. Some industry sectors are ahead of others in this race to be sustainable and help create a healthier future. Some industries, such as the financial sector, are so gigantic and far-reaching that their every move has wide-ranging repercussions for the sustainability movement, as pointed out by Daniel Fogel in "Financial Services Industry." Other industries, such as construction and cement, forestry, steel, and mining, have made strides in recent years that may surprise those who think there is nothing that can be done—or at least nothing that can be done profitably—to improve the environmental impacts of such industries.

The coverage in this volume offers something never before available to researchers, readers, and corporate leaders themselves: a full survey of many industries, issues, and approaches written by a network created during the process of building the volume. In this way we have sought to address a major problem for sustainable business: finding timely, accurate, and accessible information in a business and technological climate that is constantly changing. These winds of change come from all sides. As Steve Rhyne points out in "Climate Change Disclosure," publicly traded businesses in the United States must disclose to the Securities and Exchange Commission the potential risks their businesses face from climate change and legislation stemming from climate change—even when the legislation hasn't yet been passed, or indeed even thought of. Meanwhile, the Carbon Disclosure Project, an international not-for-profit organization with a database of carbon disclosure results from over 2,500 companies in 60 countries, bears witness to the power to change things for the better that a non-governmental framework may yield.

Carbon disclosure is especially relevant to companies such as coal-fired power plants, which may be affected by the availability and costs of raw materials in the event that legislation is enacted that puts a price on greenhouse gas emissions; see John Dernbach's "Cap-and-Trade

Legislation" for more on this topic. Many companies are making the best of the situation by ensuring they are in the vanguard of disclosure, thus giving them an edge over their competitors as the public becomes ever more aware of the activities of the business world. The theme is further explored by Aarti Gupta in her article on "Transparency." Clearly the more knowledgeable a company is about environmental issues, the better positioned it will be to deal with twenty-first-century issues such as climate change and resource depletion. As Benjamin Redekop writes in "Leadership," "a hunter-gatherer community that runs out of food with no alternatives will be the result of failed leadership as much as a modern business that steadily loses money and eventually goes bankrupt because its leaders were unable to foresee changes in the marketplace." Future generations will look back at this time as a turning point.

Given the uncertainties of the world economy in 2010, companies from small businesses to huge multinational corporations need to take advantage of anything they can to stay afloat: it is good news for the Earth that often the same things that are good for the environment are also good for keeping costs down. Streamlining companies' supply chains and means of transportation are two ways to do this (an example of the latter being the United Parcel Service's strategy of routing its drivers in such a way that they entirely forego inefficient left turns). Installing renewable energy in facilities old and new and "remanufacturing" products such as airplane engines that have reached the end of their lifecycles are all examples in which the environment shares the benefits with business (see Nabil Nasr's "Remanufacturing" for more on this fascinating topic).

The Management Gap

According to several *Business of Sustainability* contributors, there is one big gap in today's business world that desperately needs to be filled: management that is well versed in the many-faceted and ever-changing issues of sustainability. As Nicola Acutt writes in "Business Education," "one of the fundamental barriers to effective implementation of sustainable management practices is the lack of human resources—people with the skill sets to help redesign business processes and standards, rethink systems, retrain employees, communicate with customers, or reevaluate finance and capital management. Simply stated, there is a shortage of trained and talented managers with knowledge of, and competence in, sustainable management." As James Elder writes in "Higher Education":

> Business leaders seeking to move their companies toward sustainability have a huge workforce problem. A recent Arthur D. Little study of Fortune 500 CEOs reported that, while 90 percent agreed that "sustainable development is important to their company's future," only 30 percent say they have the "skills, information, and personnel to meet the challenge. "…The Association for Career and Technical Education identified the same challenge in 2008 when it reported that "the need for human capital is proving to be a barrier to the continued growth and expansion in energy efficiency and sustainability.…There must be a greater focus by policymakers and business and industry leaders on providing the training and retraining necessary to help shape this new workforce and ensure the continued pipeline of skilled workers."

If anything will rescue the current world economy from the doldrums, it seems this could very well be a part of it. Filling that management gap would be a huge help.

Yet we are also at a point in the history of our species where growth itself must occur in sustainable ways, not just profitable ones. Population growth is not sustainable as the carrying capacity of the planet is being exceeded. Future prosperity is approaching constraints that may lead to untold further suffering as the separation between the haves and have-nots grows culturally and economically, so undoubtedly this is an area where a generation of leaders well-versed in sustainability issues is urgently needed. The question of where people—especially the poor, who so often are overlooked by environmentalists and corporations alike—fit into the picture is addressed in articles as diverse as "Human Rights," "CSR and CSR 2.0," "Corporate Citizenship," "Poverty," "Base of the Pyramid," "Sustainable Development, " "Social Enterprise," "Natural Capitalism," and "Water Use and Rights." The concept of environmentalism no longer needs to apply only to those in developed nations who can afford the luxury of buying organic, free-range food. With any luck (as well as the application of the advice found in this volume) the old way of doing business—where crops are sprayed with pesticides without regard to what those pesticides do to the soil and to the rivers that wash them away, not to mention the people whose job it is to harvest them—will start to fall away as it becomes more and more evident to consumers and producers alike that by being "smarter" many positive changes can be affected. Given a fair playing field (in terms of transportation, subsidies, the costs of pesticides, etc.), the poor will have access to healthy food just as much as the rich because, given the right changes in the business climate, healthy food will cost less to grow and distribute. Healthy food's "true cost" will come down.

Not only do all those people need affordable, healthy food; they also need ways to stay warm, stay cool, cook their meals, run their businesses, and generally get to where they need to be. The centerpiece of *The Business of Sustainability* (nearly one-sixth of the volume) may well be the section on the energy industries that make all this possible—how things stand now and what's being done all over the world to improve the situation—with input from experts in China, Italy, Great Britain, the United States, Belgium, and Iceland, and an introductory survey article on renewable energy by associate editor Gernot Wagner. Readers unsure of what exactly a gigawatt is and what it means will want to consult the sidebar "What's the difference between a gigawatt and a gigawatt-hour?" on pages 148–149. Topics in the section range from bioenergy to nuclear, tidal, wind energy, and energy efficiency, as well as coal, oil, and natural gas, all of which are players that cannot be ignored. We've tried to be as objective as humanly possible in setting out the positives and negatives of each form of energy.

Because this is a volume on the *business* of sustainability, these articles address not only what the various energy industries are but how they can potentially bridge the gap between being a good idea some day and becoming reality today. Renewables are clearly the future of energy; the trick from a policy-maker's perspective is not to pick any individual winners but to let markets make that decision: if a price is set on dirty, fossil fuel–based energy—ideally by capping global-warming pollution and creating a market for carbon—renewable investments will follow. Once again, people with the skills to develop these technologies are urgently needed.

The question of where our energy comes from and what that means for the planet is especially important given the frustration inherent in international debate with many players, as was the case with the Copenhagen Climate Talks in late 2009 (a subject that will be discussed in more detail in volume 3 of *The Encyclopedia of Sustainability*: *The Law and Politics of Sustainability*). If international bodies have trouble coming up with solutions to the impasse over climate change legislation, then it is up to the marketplace to do so, at least in the short term.

Admittedly, energy consumers have some difficult choices to make. The reason for this goes back (again) to the idea of "true cost" economics: many consumers of energy (which includes pretty much everyone) who balk at the idea of windmills in the distance or nuclear power do so in part because they do not see where their energy currently comes from. The urgent need for change does not seem so urgent when one does not see up close the mountaintops stripped for their coal or the often oppressive societies built on oil wealth; and greenhouse gases, of course, are invisible.

China, which currently gets 80 percent of its electricity from coal and 15 percent from hydropower (including the mammoth and controversial Three Gorges Dam in Hubei Province), is embracing nuclear power, which is not a form of renewable energy but is one that many, including some environmentalists, are warming to. Our goal in all the volumes of the *Encyclopedia of Sustainability* is to provide food for thought so that readers may be armed with the knowledge to make their own informed choices on the many choices thrown their way.

What We Include in The Business of Sustainability

As anyone who spends any amount of time reading or watching the news knows, there is no shortage of negative press on the role business plays in environmental degradation. As editors, we made a deliberate choice to promote a positive view towards the role of business; there are no headwords that intrinsically embody the notion of a tradeoff (if business wins, society must lose, and vice versa). In fact we believe that human beings will only do well in the future if businesses take the lead in promoting necessary changes in thinking, values, attitudes, and behaviors. Contributing authors were encouraged to highlight the value-creation opportunities in their respective areas. Of course, not all topic areas lend themselves to doing so, and some headwords, such as "Cradle to Cradle," "Industrial Design," and "The Natural Step Framework," are about the design of sustainability rather than about the opportunity it presents.

A colleague of ours recently said, "In today's world, every single topic is about sustainability; it is the new *problématique* of our time." While this view may have merit, it makes for a particularly challenging job of selecting the scope of topics. Encyclopedias are by definition comprehensive reference works. In the case of volume 2, there is necessarily some arbitrariness in our choice of headwords. The intention is to provide a broad enough coverage of sustainability to provide a representative overview of the topic as it relates to business and yet a narrow enough selection of topics that readers can get the deep insights they have come to expect from a Berkshire series. Readers are invited to explore the articles herein, starting with the Reader's Guide that appears on page viii, where the articles are broken down into categories for easy reference. We do hope the knowledge contained within these two covers will inspire students, policy makers, future and current leaders, and casual readers alike to many good endeavors, many of them, no doubt, unexpected and wonderful—and profitable.

Chris Laszlo
Karen Christensen
Daniel Fogel
Gernot Wagner
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A

Accounting

In the twenty-first century, many accounting professionals are expected to consider the triple bottom line (TBL)—environmental, social, and financial performance—when preparing statements for businesses; sustainability reports increasingly supplement annual reports. Internal decision makers also rely on analyses that incorporate the TBL. Although formal guidelines do not exist yet, informal accounting and reporting standards are important in helping organizations understand their TBL effect and their stakeholder responsibilities.

Accountants have long had a role in providing the financial information necessary to assess how an organization manages its resources, but the need to summarize and measure what matters, and to attest to its veracity, is no longer limited to just financial performance. As investors and other stakeholders demand greater transparency on the triple bottom line, which measures the environmental and social performance of an organization in addition to its economic achievement, the profession has much to offer. This new obligation, however, will require the profession to think beyond generally accepted accounting principles.

External Reporting

Reporting the financial performance of an organization and attesting to its fair and accurate coverage has been a cornerstone of the accounting profession. In response to greater stakeholder activism and demands for more transparent disclosure of the triple bottom line, many organizations now augment their annual report with a sustainability report. But as they currently stand, generally accepted accounting principles do not always support or encourage disclosure that helps stakeholders assess environmental and social performance or helps managers balance the consequences across the triple bottom line. For example, economic decisions that negatively impact the workforce may provide a short-term boost to financial performance, but they may negatively impact social performance. This creates many important opportunities for the accounting profession.

Sustainability Reporting and GRI

According to a 2007 Social Investment Forum report, 11 percent of the funds under professional management in the United States integrate environmental, social, and governance factors into investment decisions. Sustainability disclosure, however, is not yet required in the United States (although as of late in 2009 the matter was under discussion), which makes it difficult to assess a company's triple bottom line performance. Numerous institutional investors have petitioned the Securities and Exchange Commission (SEC) to require disclosure of environmental, social, and governance (ESG) risk factors and to adopt the Global Reporting Initiative framework. Speaking for over fifty investment groups on 21 July 2009, the Social Investment Forum—a nonprofit U.S. association dedicated to socially responsible investing—urged the SEC to require ESG disclosure in order to promote long-term thinking and rebuild public trust. In the letter, the Social Investment Forum (2009) stated that "investors' efforts to incorporate ESG information into investment decisions have been hindered by a lack of comprehensive, comparable data. Because sustainability reporting among corporate issuers is largely still voluntary, it is far from universal, and often inconsistent and incomplete." This was not the first time such groups have petitioned for more complete disclosure about the risks and opportunities associated with climate change. The group Investors and Business for U.S. Climate Action made a similar petition to the president and members of Congress in 2007.

According to a KPMG International report, over 80 percent of the Global 250 companies issue a separate sustainability report in addition to their annual report (KPMG International 2008). These typically include environmental and social performance indicators, such as tonnes of carbon emissions, pounds of waste recycled, the number of minority-owned supply companies, and working conditions in those companies. Because this is an evolving area still considered voluntary in the United States, the reports are often not audited. Consequently, there may be considerable variability from year to year in company reports and across companies. Another concern is that some companies are using sustainability reports as a public relations tool rather than as meaningful coverage of the company's triple bottom line.

In response to these concerns, the Coalition for Environmentally Responsible Economies and the United Nations Environmental Program founded the Global Reporting Initiative (GRI) in 1997. The GRI framework promotes globally applicable sustainability reporting that discloses economic, environmental, and social dimensions of the organization's activities, products, and services (its triple bottom line). The GRI employs a long-term, multistakeholder process to develop and disseminate sustainability reporting guidelines that can be used by organizations of any size, sector, or location (GRI 2006). The GRI framework relies on fundamental accounting principles such as timeliness, materiality, verifiability, and comparability. Now in its third version, the guidelines are used by over 1,500 organizations. In addition to recommending inclusion of strategy; organizational profile; report parameters; and governance, commitment, and engagement in the sustainability report, the guidelines suggest the inclusion of seventy-nine performance indicators in six different categories: environmental, human rights, labor practices and decent work, society, product responsibility, and economic.

European Union (EU) countries have shown a particularly strong interest in sustainable-development reporting. For example, in France, Germany, Denmark, Sweden, and the United Kingdom, it is mandatory for corporations to disclose some form of environmental and/or social metrics. Sweden, for example, requires all state-owned companies to file independently assured reports that comply with GRI (Waddock 2004). In their 2009 report, the European Sustainability Reporting Association identified an increase in the number of countries requiring sustainability reporting.

In 2006, the GRI moved toward the adoption of XBRL, a standardized business reporting taxonomy that facilitates comparability of its indicators. This should facilitate analysis and intercompany and intracompany comparison. This type of standardization would make triple bottom line analysis easier for research organizations like KLD, an independent investment research firm. According to its website, KLD (2009) analyzes over ninety positive and negative corporate social responsibility (CSR) indicators for more than 3,000 companies and provides it to over 400 clients. KLD was one of four partners that developed the Newsweek Green Ranking of the 500 largest U.S. companies (McGinn 2009).

Greenhouse Gas Reporting

Two events of the early twenty-first century signal that the United States may soon implement a cap-and-trade program for carbon dioxide. First, California passed Assembly Bill 32: Global Warming Solutions Act in 2006, which required the state to achieve 1990 emission levels by 2020. Second, the conclusion of the May 2009 report of the President's Economic Recovery Advisory Board urged President Obama to support a market-based cap-and-trade system that is both economically sustainable and environmentally sound (Doerr 2009).

Greenhouse gas (GHG) accounting and disclosure standards assist firms in understanding and reporting the firm's effect on global warming. As cap-and-trade legislation becomes increasingly likely, companies will need to reduce their emissions and divulge on their impact. Generally, GHG measurement and reporting is a section of a firm's sustainability report that is based on GRI guidelines, which in turn refer to the World Business Council for Sustainable Development's *Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard* for guidance. The mission of this standard is to develop internationally accepted greenhouse gas accounting and reporting benchmarks for businesses and to promote its broad adoption. It consists of three key steps: (1) prepare an inventory of greenhouse gases emitted as a result of the firm's existence; (2) set a greenhouse gas target; and (3) develop a plan to reduce greenhouse gases over time. A common approach is to set a deadline to reduce greenhouse gases to a level that existed for the entity at a previous time. For example, BP (British Petroleum) set a goal to reduce annual emissions to 90 percent of 1990 levels by 2010 (Harold and Center 2005).

The standard does not include a verification process, but if the GHG standard is used as part of the GRI reporting guidelines, it will fall under the GRI verification process. In a manner similar to prepared financial statements based on generally accepted accounting principles, the greenhouse gas accounting and reporting standard is guided by principles, such as relevance, consistency, and transparency, rather than rules. Principles-based accounting allows for utilizing judgment, which is useful for new areas of accounting such as triple bottom line. Because of growing international concern about causes of climate change, a business's measurement, reporting, and planned reduction of greenhouse gases helps support sustainability.

There is evidence that such disclosure does impact company actions. As part of the 1986 Emergency Planning and Community Right-to-Know Act, businesses in the United States were required to report the locations and quantities of approximately 650 toxic chemicals. This data was made available through the U.S. Environmental Protection Agency's Toxic Release Inventory. While difficult to navigate since the data was provided by site rather than by company, the information was used to assess impact and develop reduction goals. In another example, the Financial Accounting Standards Board issued Statement of Financial Accounting Standards (SFAS) 148 in 2003, which required companies to recognize stock-based compensation as an expense and a liability at fair market value. As a result, the use of options was reduced, and companies shifted to issuing restricted stock as a result of required disclosure (Carter, Lynch, and Tuna 2007).

Possible future programs related to greenhouse gases include emissions trading programs, such as the European Union Greenhouse Gas Emissions Allowance Trading Scheme that became effective at the beginning of 2005. Three approaches are available to firms to offset and/or reduce their carbon emissions: allowance-based transactions, project-based transactions, and voluntary transactions. In allowance-based transactions, an emission cap is set, and allowances are issued by regulators to organizations included in the regulations. Trading markets are established, which offer a market-based approach for companies to meet their mandated emission levels. If the business emits more than its allowance, it must purchase the right to emit (recognized as an expense). Project-based transactions provide an opportunity for a business to invest in an emission-reduction project, typically in a developing country (for example, ecosystem preservation and/or restoration in the Brazilian rain forest). This is, however, still an emerging market with many players and a great need for independent verification. The Carbon Offset Provider Evaluation Matrix (COPEM) provides guidance on provider selection as well as a description of the various forms of offset mechanisms (Carbon Concierge 2008). Voluntary efforts, such as partnerships to convert waste into energy, are being taken by many values-driven organizations, such as Clif Bar, Inc. and Interface Carpet Company.

Financial Reporting for Emission Rights

Financial reporting of emission credits is related to emission trading programs; it recognizes whether a firm is holding excess emission credits or whether it has an obligation to purchase credits. The accounting treatment for emissions rights remains unresolved under both International Financial Reporting Standards and generally accepted accounting principles (GAAP) in the United States. Although the International Financial Reporting Interpretations Committee (IFRIC) issued an interpretation on emission rights, IFRIC 3, they withdrew it after intense pressure from the business community and European politicians, who balked at disclosing the financial consequences of applying this interpretation (Deloitte 2008). IFRIC 3 recognized emission credits as intangible assets initially valued at fair value but also required the recognition of the corresponding liability, with the asset and liability shown separately and not offsetting one another (Rogers 2005, 198–199). In the United States, accounting standard setters could not reach consensus on, and subsequently dropped, their 2003 Emerging Issues Task Force project for accounting for emission allowances under a cap-and-trade program, EITF Issue 03-14 (Deloitte 2008, 1).

Regardless, emission credits meet the definition of intangible assets under SFAS 142, Goodwill and Other Intangible Assets. Although a company's emission credits may be reported as an intangible asset, the economic reality is that the obligation to deliver credits to cover actual emissions at the end of a period constitutes a liability (Rogers 2005, 197–199). In the absence of definitive guidance and until formal standards are issued, the Financial Accounting Standards Board and the Securities and Exchange Commission have provided informal guidance on accounting for emissions rights (Deloitte 2008, 4–5).

Accounting for Environmental Liabilities

Liabilities are defined as economic obligations that arise from benefits received in the past and for which the probability, amount, and timing of payment are known with reasonable certainty. In the case of an environmental liability, the benefits received in the past are the products that were produced and/or sold at the time the cause of the environmental liability (e.g., generations of toxic waste) was created. GAAP requires that environmental liabilities be disclosed in the firm's annual report, along with their other liabilities.

Significant reporting challenges arise from environmental liabilities. If there is acknowledgment that an obligation has been incurred, there may be ambiguity about whether the obligation is measurable. Research shows that there is significant variation in the quality of financial statement disclosures on estimated environmental cleanup liabilities. The factors influencing these disclosures include measurability, regulatory enforcement, litigation and negotiation concerns, and capital market concerns (Barth, McNichols, and Wilson 1997). When there is ambiguity with regard to liabilities, management has inherent bias and incentive to understate liabilities to show a healthier financial position (Palepu, Healy, and Bernard 2000). If the obligation is measurable, management records an environmental liability in the financial statements. If is not measurable, the liability will be disclosed as a note to the financial statements. From management's perspective, disclosure may be used as evidence of acknowledgment of the liability in legal proceedings and may put the company at greater risk of losing in court.

Resources exist for the company that wants to better understand its environmental impact. ISO 14000 standards, international management standards developed by the International Organization for Standardization (ISO), provide guidance on how to implement an environmental management system and measure the results. As previously mentioned, the GRI framework includes thirty environmental indicators, such as energy consumed, waste generated, greenhouse gas emissions, water withdrawal, and biodiversity impact. The disclosure of environmental liabilities makes company environmental performance more transparent and may discourage management from engaging in economic activities that damage the environment. For preexisting environmental damage, mandatory disclosure may force firms to recognize the need to account for the damage. Disclosure of current environmental impact may discourage management from engaging in economic activities and operating practices that damage the environment. For example, implementation of sustainable operating practices that reduce the amount of energy consumed reduces expenses as well as environmental risk, which in turn will reduce environmental liabilities.

Financial Reporting of Intangible Sustainable Assets

If GAAP allowed sustainable practices to be reported as intangible assets, management would have incentive over and above the sustainable business strategy incentive to engage in economic activities that give rise to assets that reflect sustainable practices. Examples of sustainable practices that could be recorded as intangible assets include an organization's reputation for sustainable practices, sustainable intellectual capital, a specific strategy to reduce greenhouse gas emissions, energy conservation policy, sustainable component of a company brand, and emission credits. Positive sustainability attributes, such as the examples listed above, can significantly increase the value of an organization (Rogers 2005, 174–175).

If the firm purchases assets that will lead to sustainable practices, they are reported as assets on the balance sheet, either as tangible assets such as plant improvements or as an intangible asset called goodwill. But under International Accounting Standard 38 and U.S. GAAP, specifically SFAS 142, a publicly held firm generally cannot report internally generated sustainable practices as assets. For example, if a firm redesigns a production process to use less water or produce less waste, the expenditures would be handled similarly to research-and-development costs and expensed. Conversely, investment in energy-saving equipment, such as the installation of solar panels, would be capitalized. Expenditures related to developing these assets are normally expensed rather than capitalized. Although the firm creates value from sustainable practices over time, the related asset cannot be recorded because of accounting measurement and objectivity issues. Because accountants historically value reliability over relevance in financial statements (Financial Accounting Standards Board 1980), GAAP does not allow them to record internally generated assets. If a company is purchased at a price that is greater than the fair market value of the identifiable assets because of sustainable practices, this excess is recorded as an intangible asset.

As of 2009, the Financial Accounting Standards Board in the United States and the International Accounting Standards Board do have a convergence project in progress. One of the issues for deliberation is treatment of internally developed intangible assets. It is expected that the future standard (developed jointly by these two boards) would require recognition of internally developed intangible assets.

Full Cost Accounting

In a traditional product pricing model, an organization considers the direct costs (material and labor) of producing goods and adds a charge to cover the indirect costs (manufacturing infrastructure, selling, development, administrative costs, and cost of capital). This approach captures internally generated costs, but it disregards externalities, such as the environmental costs associated with hazardous waste generated during the production process. Beginning in the 1970s, environmental regulations in the United States—the Clean Air Act, the Clean Water Act, and the Comprehensive Environmental Response Compensation and Liability Act—and the Toxic Release Inventory required firms to report their environmental impact. These regulations caused firms to consider the impact their methods of production had on the environment.

In 1995, the U.S. Environmental Protection Agency (EPA) provided guidance for how to "full cost" a product to include environmental costs (U.S. EPA 1995). Recognizing that the "full cost" of providing a product to a customer should include environmental and social costs helps management determine what products to offer and how to price them. On balance, sustainable products are less expensive in the long run because they reduce the risk of costs related to future environmental and social regulation.

In some countries, firms are responsible for the environmental and social costs of their products throughout the product's entire life cycle. For example, two European Union (EU) orders, the Restriction of Hazardous Substances Directive (effective 2006) and the Waste Electrical and Electronic Equipment Directive (effective 2003), require firms to eliminate certain hazardous materials in the design/production phase and to be responsible for the end-of-life disposal/recycling costs of their products. A third EU regulation titled Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), which became effective in 2007, requires companies to provide full disclosure on the chemicals used during the production of its products.

While there have been considerable advances on understanding and reporting environmental impact, assessing social impact has proved more challenging. Earlier efforts tended to focus on employee attributes such as safety records, compliance with Occupational Safety and Health Administration (OSHA) standards, and the percentage of management meeting certain criteria. The GRI framework expands coverage to include community, customer, and cultural sensitivity indicators that encompass the entire value chain. With a planned release of ISO 26000 in 2010, the International Organization for Standardization (ISO) will provide guidance to companies that want to measure and report on their social impact. In triple bottom line terminology, ISO 26000 addresses the social aspect, while the ISO 14000 family addresses the environmental aspect of business operations.

Increasingly, companies are including such criteria in supplier contracts and providing data to their customers. For example, in July 2009, Walmart announced plans to work with universities, nongovernmental organizations, governments, suppliers, and retailers to develop a research-based sustainability product index. The process will require all 100,000 Walmart suppliers to assess and report on their energy, water, resource, and social impact. Walmart's ultimate goal is to provide customers with the information they need to make sustainable purchases.

Numerous firms have begun to report on their efforts to better understand costs. For example, Ford's 2008–2009 Sustainability Report provides a good example of the company's analysis of environmental and social costs incurred along its value chain. Interface, Inc., the world's largest manufacturer of modular carpet, developed their own measurement systems: EcoMetrics to measure their progress towards zero waste, and SocioMetrics to better understand their impact on people (Interface 2008). Included in Interface's report are the cost savings as a result of their sustainability initiatives. Interface also provides an excellent example of the benefits of working with independent organizations to develop standards and metrics by which to assess social and environmental impacts. Interface partnered with NSF International (a nonprofit, nongovernmental organization) using a multistakeholder process to develop the NSF/ANSI 140 standards that define sustainable carpet and establish levels of certification.

Finally, Toyota's approach to understanding the environmental and social costs of producing a product demonstrate the impact this topic can have on making sustainable decisions. Toyota (2008) classifies their environmental accounting into environmental investments, maintenance costs, and eco-efficiency to better understand product costing. These examples illustrate the breadth and depth of environmental accounting.

Outlook for the Future

For external stakeholders, financial disclosures are extended to include environmental and social performance so a more informed analysis of how a company manages its resources and its impacts can be made. Internal stakeholders can better allocate resources and determine how the company's outputs impact external stakeholders when full cost accounting is considered.

To date, much of the leadership on accounting for sustainability has come from EU-based organizations. If the focus of organizations like the International Federation of Accountants (IFAC) and The Prince of Wales Accounting for Sustainability Project (PWAS) is any indication, the world will continue to look to the EU for future guidance. The IFAC (n.d.) has identified five roles for the professional accountant in changing business for a more sustainable future:

- Challenging conventional assumptions of doing business
- Redefining success
- Establishing appropriate performance targets
- Encouraging and rewarding the right behaviors
- Ensuring that information flows to support decisions and to monitor and report performance go beyond the traditional ways of thinking about economic success

Being sustainable requires an organization to take full account of its impact on the planet and its people. The PWAS (2009) mission statement suggests a similar focus: "The Prince's Accounting for Sustainability Project works with businesses, investors, the public sector, accounting bodies, NGOs and academics to develop practical guidance and tools for embedding sustainability into decision-making and reporting processes."

Extending assessment and disclosure to include environmental and social impact so stakeholders both within and outside of corporate walls are better able to make informed decisions is much needed. Accounting professionals, with their collective expertise in performance metrics, analysis, and using numbers to tell a story have much to offer as we challenge conventional assumptions of business and reframe our future to consider environmental and social implications of business and consumption decisions. In the words of former U.S. secretary of the interior Stewart Udall from a much-quoted speech given in 1970: "Over the long haul of life on this planet, it is the ecologists, and not the bookkeepers of business, who are the ultimate accountants."

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See also Cap-and-Trade Legislation; Climate Change Disclosure; Ecosystem Services; Global Reporting Initiative (GRI); Green GDP; Performance Metrics; Stakeholder Theory; Transparency; Triple Bottom Line; True Cost Economics

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Activism—NGOs

Since the mid-twentieth century, nongovernmental organizations—groups without governmental affiliation that promote community service and political change—have become agents of activism and advocacy throughout the world. Their efforts and actions frequently influence public opinion, which often forces businesses to develop more sustainable practices and operations. Initially confrontational, a more cooperative relationship exists today between some nongovernmental organizations and corporations.

The term *nongovernmental organization* (NGO) was introduced in 1945 when the United Nations identified the distinct characteristics of NGOs as being not-for-profit, voluntary citizens groups that are organized on local, national, or international levels and which are concerned with issues in support of the public good. NGOs include a wide variety of independent agencies (excluding companies or corporations, criminal organizations, and guerilla groups) of varying sizes and influence whose goals are to provide community services and engage in political advocacy. Many address issues of sustainability, environmental protection, economic development, social justice, and other quality-of-life issues that affect people around the world (Blackburn 2007, 397). Some well-known NGOs that have been addressing sustainability through varying degrees of activism and advocacy for thirty-plus years are Greenpeace, World Wildlife Fund, Global Exchange, and the Environmental Defense Fund. The question to ask is what effect have NGO advocacy and activism had on the ways in which businesses conduct themselves both nationally and internationally?

Background: NGOs and Business

The concept of a sustainable environment first emerged in 1972 at the U.N. Conference on the Human Environment (Blackburn 2007, 2), yet it took a crisis such as the 1979 incident at Three Mile Island Unit 2, a commercial nuclear-power plant near Harrisburg, Pennsylvania, to ignite the public's attention to the potential environmental and human costs incurred by an industry in desperate need of regulatory oversight, plant-design reform, greater recognition of the role of human fallibility on plant operations, tighter licensing controls, and other safety measures to protect human and environmental health. This awareness has helped fuel the environmental movement into a force to be taken seriously. For example, according to their website, Greenpeace began in 1971 as a team of activists and now has a global membership of 2.8 million supporters worldwide, with national as well as regional offices in forty-one countries.

These activist beginnings of groups like Greenpeace, which focused on exposing the environmental destruction and degradation by large corporations, made many NGOs the "sworn enemies" of big business (Gunther 2007). NGOs, among other citizen groups, played key roles in exposing the polluting practices of such companies as General Electric, DuPont, Dow Chemical, and many others. The goal, therefore, for environmentally focused NGOs has been to "mandate, regulate and litigate" (Gunther 2007) the ways in which businesses use/abuse the environment. One of the more effective ways of doing so has been to shame companies through NGO activism into "implementing 'certification' arrangements—codes of conduct, product guidelines, and monitoring standards that govern and attest to not only the corporation's behavior but also that of suppliers around the world" (Gereffi, Garcia-Johnson, and Sasser 2001, 56). Certification is now apparent in nearly "every major industry targeted by environmentalists, including the chemical, coffee, forest products, oil, mining, nuclear power, and transportation sectors" as well as "the apparel, diamond, footwear, and toy industries, to name a few" (Gereffi, Garcia-Johnson, and Sasser 2001, 57). It can therefore be said that "environmental groups can strongly influence public opinion . . . [and] can offer legitimacy to corporate environmental efforts and assist business organizations in developing effective environmental management policies" (Milliman, Claire, and Mitroff 1994, 1). In fact, as a direct result of advocacy by consumers, stakeholders, and NGOs over the years, many companies—such as McDonald's, DuPont, 3M, Procter and Gamble, Home Depot, Starbucks, and others—have changed their business practices, agreeing to use only products certified as sustainable and ethically produced. (See Conroy 2001; Kirkpatrick 1990; Linton 2005; Millian, Claire, and Mitroff 1994; and International Institute for Sustainable Development 2007 for examples.) This increased influence on companies seems like a good thing to some in that both the companies and the environment benefit—most importantly the environment—while others perceive that such ties make NGOs less effective in terms of them being genuine agents of structural and environmental change.

Supporters of NGO/ Corporate Alliances

According to the *Fortune Magazine* reporter Marc Gunther (2007) the new cooperation between big business and environmentalists is a win-win situation: "Today big companies and activists are at least as apt to hammer out a partnership over a cup of sustainably grown coffee as to confront one another in court," the reason being is that "there is money to be made." He sees big changes ahead, claiming that "we're at the threshold of a different era, one in which smart companies are trying to figure out how to profit by solving the world's big environmental problems." In *The Sustainability Handbook*, William Blackburn agrees, positing that it is possible to have the best of both worlds. His book, written for small and large companies alike, aims to assist businesspeople to "thoroughly understand sustainability and use it where [they] work—use it to protect and grow assets, strengthen financial performance, and shape an organization to be admired by all" (Blackburn 2007, xvii). According to The International Institute for Sustainable Development's online Business and Sustainable Development Global Guide, another benefit is that, through an alliance with an NGO, companies can gain credibility, marketing, expertise, innovation, and networks (Bendell 2007). Yet the question remains as to whether or not this new corporate/NGO alliance and the resulting certifications that address codes of conduct "truly help workers and the environment, or do they merely weaken local governments while adding more green to the corporate bottom line?" (Gereffi, Garcia-Johnson, and Sasser 2001, 56). In other words, is it really a win-win situation, or is some aspect being compromised, most notably the environment?

Critiques of NGO/Corporate Alliances

As businesses have transcended the limits of national borders, making it increasingly difficult for states to regulate labor and environmental practices, thousands of NGOs have stepped in to advocate for international certifications and their enforcement. These global certifications attempt to improve global environmental and working conditions in ways in which the state has proven ineffectual. As a result, advocacy-led certification processes "have arisen to govern firm behavior in a global space that has eluded the control of states and international organizations" (Gereffi, Garcia-Johnson, Sasser 2001, 65), but according to some, "certification remains a blunt and imperfect tool for augmenting the accountability of global firms" (Gereffi, Garcia-Johnson, and Sasser 2001, 57). The reason for this view is that there are no guarantees that the standards set by the certifications will be met since enforcement remains voluntary and the role of the state is preempted or supplanted as the enforcer.

Yet in an era of free trade in which many states do not have or are not able to enforce regulations (as in the case with unions), the scholars Gary Gereffi, Ronie Garcia-Johnson, and Erika Sasser (2001, 65) see certification arrangements "quickly becoming . . . powerful tool[s] for promoting worker rights and protecting the environment." And yet they note that this will only be the case if such certification helps to strengthen rather than weaken "labor and environmental goals within . . . sovereign territory and beyond." Thus the dangers of increasing NGO/business alliances that result in certification arrangements are twofold. Firstly, NGOs may usurp services that should be provided by states, such as health care, education, unions, and environmental laws. Secondly, in their collaborations with corporations, NGOs may overcompromise their commitments to sustainability and other social justice issues, thereby becoming more a part of the problem than the solution. James Petras, a critic of NGOs, argues that in many countries they have become part of the problem by supporting the global neoliberal agenda, by reducing the accountability of states to their citizens, and by co-opting leftist activist, thereby preventing genuine structural changes as opposed to reformist compromises (Petras 1997 and 1999). Sources of funding may also affect the efficacy of NGOs in their commitment to issues of sustainability in opposition to the corporate bottom line (Petras 1997; Guldbrandsen and Holland 2001; Edwards 1993). This critique remains a minority view but one that raises important questions about the benefits of business and NGO partnerships from the perspectives of genuine sustainable and social justice practices.

The Future

It is indisputable that "NGO networks have achieved recognized successes in influencing public policies in the [global N]orth and the [S]outh" (Maria 2006, 160). Whether such influences are seen as positive or as negative depends, of course, on where one is positioned in the complex global picture. If one's goal is to increase the promotion and even the practice of sustainability, then certainly it can be said that the advocacy and activism on the part of NGOs around the world have been beneficial. If on the other hand one's goal is to totally transform from the perspective of sustainability the ways in which production, hence business, is done, then there is still a long way to go, and the journey will continue to be one of struggle (Conroy 2001). As the environmentalist David Orr states regarding authentic as opposed to cosmetic green designs, "institutions and businesses are not set up yet to handle the transition" (Dumaine 2001/2002, 51). Perhaps the best chance of them becoming ready will be as a result of NGO advocacy and activism around the world.

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See also Consumer Behavior; Corporate Citizenship; CSR and CSR 2.0; Fair Trade; Greenwashing; Public–Private Partnerships; Transparency; Triple Bottom Line

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Agriculture

Renewable energy and ecologically friendly forms of agriculture that support soil and water conservation can support the world's population and help sustain the environment. The methods for sustainability in agriculture exist, but choices must be made to depart from present farming trends that continue to pollute surface and groundwater, deplete the soil and nonrenewable resources, and degrade the land.

Sustainable agriculture would feed the world's present and future populations, conserve land, preserve the quality of water that drains the land, and use only fertilizer and energy resources that do not deplete nonrenewable resources. By a more stringent code, it should do nature no further harm. By any definition, sustainability in agriculture requires a departure from present trends.

Present-Day Food Production

An encouraging sign, if taken in isolation, is that today's harvests could feed twice the world's population. Food energy requirements vary with age, stature, and activity, but an average daily allotment of 2,500 calories per person is generous. Average cereal harvests since 2002 could supply 3,200 calories per person. Add an average of 700 calories per person from soybean, oilseed, and nut production; 80 calories from pulse production (peas and most beans); 215 calories from sugar crops; 240 calories from potatoes and other tubers; 78 calories from fruit; 36 calories from wild-caught marine fish; and the subtotal rises to an average of 4,549 calories per person. To that should be added a substantial but hard to estimate contribution from vegetables, freshwater fish, and grazing animals. Reporting of freshwater fish yields is spotty. Information is available on vegetable production, but it does not differentiate yields of vegetables that vary in energy content. Available data on dairy and meat production do not tell how much originates from grazing and how much from feeding grains, which have already been counted (FAO 2004).

Today's harvests are bountiful, yet hundreds of millions go hungry. What happens to the bounty? A third of the cereal harvest feeds livestock, and most of the soybeans and oilseed follow after their oil is extracted. The meat, dairy, eggs, and fish (from aquaculture) thus produced contain anywhere from a third to a tenth of the original energy. Ethanol production in 2008 used 10 percent of the world's sugar (FAO 2009, 3) and 4.5 percent of its grain (author's calculation based on FAO 2009).

The remaining food passes a gauntlet of warehouse vermin, losses in transport and processing, and waste. At the end of a journey that can stretch over thousands of kilometers, it piles up on some plates and barely garnishes others.

Future Demand

At the end of 2009, the world population stood at 6.8 billion, up from 6.7 billion in 2008, and it was growing at 1.2 percent per annum, fast enough to double in 58 years and quadruple in 116. But population growth has been slowing for 30 years and will likely continue to do so.

Despite the shock of HIV/AIDS, the main cause for slower population growth has been a decline in fertility rates. Future population growth depends on how far and how long the trend will continue; its unevenness and its several determinants complicate forecasting. A population with modern medical care replaces its females, and therefore its members, if women average about 2.2 births over their reproductive years. In most developed countries and in much of East Asia, fertility rates have fallen too low to maintain population size. Based on 2007 data, the expected fertility rate ranged from 0.98 in Hong Kong to 7.46 in Niger, and it averaged 1.5 in European countries and 5.5 in the countries of sub-Saharan Africa (U.S. Census Bureau 2009).

Among determinants, birth control programs succeed to differing degrees. Education and rising incomes tend to reduce fertility but interact with cultural factors; women in Europe and East Asia stop having births after reaching a target number, whereas in sub-Saharan Africa delays in starting families account for the small decline that has occurred.

Most projections call for a relative leveling of world population at 8 to 12 billion late in this century, barring large fertility shifts, wars, pandemics, and other surprises (O'Neill et al. 2001). Beyond that point, few forecasters venture. Populations will rise or fall; there is no reason to assume that births and deaths will balance perfectly and produce stability.

Demand for food has been growing faster than population and will continue to do so if the world economy grows. To the degree that developing countries meet their goals, consumption of grain-fed meat and milk will rise. If peak oil (the point at which global petroleum extraction reaches a peak before declining, following a bell curve) has passed, political and economic pressure to produce biofuels should continue.

Land and Soil

Erosion and salinization—the buildup of salt—threaten soil and agriculture. Where they force abandonment of the land, recovery may take decades or stretch into the indefinite future. In the past, when land degraded, the more fortunate cultivators cleared new ground, but that is a limited possibility today. Markets lie distant from the remaining good virgin land, such as tracts in northern Australia and portions of the Amazon floodplain.

Growing cities take land out of production. The trend is ubiquitous, but there are particularly troubling cases. In the United States, average house lots are getting larger as suburbs spread, and over the past fifty years, the urban area has grown twice as fast as the population. China's industries and cities are booming; although urban settlement is far denser than in the United States, so is population relative to cultivable land. While Africa's population is less dense, population growth endangers land by leading to destructive agricultural practices and rapid urban expansion.

Erosion

The risk that wind and water will erode soils increases with the content of silt and sand particles (which do not cling to each other), land gradient, and exposure to strong winds and heavy rains. Semiarid lands are at especial risk; long dry seasons reduce ground cover, and when winds blow or rains come, they strike at exposed soil.

In nature, a balance between formation and loss determines soil depth. Even where agriculture accelerates erosion, formation compensates to a point, but beyond that, the land heads toward eventual destruction. Because soil formation is largely invisible, scientists find the threshold hard to calculate, and estimates differ on the extent of unsustainable damage. What is known is that destructive erosion has long been going on, is continuing, and in many regions, is worse than ever before. The cost to ancient civilizations is still apparent. The loess plateau of northern China has lost most of its original soil, and severe damage is evident on hills around the Mediterranean and Southwest Asia. Wherever measurements and accounts of soil depth provide a basis for comparison, thinning is the rule. Some farmers respond by increasing fertilizer applications, and a literature exists on making subsoil productive, but so long as the conditions that produced erosion remain uncorrected, those approaches are more compensatory than sustainable.

The cost of controls generally increases with their effectiveness. Mulching with straw, leaves, or gravel covers ground, but demands labor, and rarely is enough material available for large fields. Nothing better protects soil than trapping it behind durable terraces and rice paddies; hand-built, rock-faced terraces have retained soil over many centuries on steep hillsides in Yemen, Java, and the Philippines. Mechanized farmers more often adopt the partial measure of plowing along a slope's contours to slow runoff. Grass strips across slopes buttress the effect, but take up space where crops could go. Similarly, the need to maximize harvests discourages shelterbelts of trees and bushes that block wind. One control that takes no extra space and is suited to mechanized farming combines reduced tillage with leaving crop residues on fields until the next planting. Reduced tillage is in use on 23 percent of cropland in the United States, 41 percent in Australia, 50 percent in Brazil, 55 percent in Argentina, and 60 percent in Paraguay (Smith 2005).

Usually the farmer plows with a long, narrow blade that cuts a path for seed planting and leaves the intervening ground undisturbed. Silty or sandy soil expedites reduced tillage—thus, its use on the land that needs protection the most. A drawback is that tillage helps control weeds, and reducing it typically requires increased applications of herbicides.

Salinization

Water picks up more or less salt (shorthand for sodium chloride and other salts) as it runs off land into streams or trickles through soil and rock and enters aquifers. When farmers tap the water and deliver it to their fields, it evaporates at the soil surface and leaves the salt behind; at high levels, it slows or halts plant growth. Excess water applications wash salt down through the soil or into runoff, but the remedy only works in well-drained soils. In too many locations, clay subsoil blocks downward percolation, irrigation has raised the water table to near the surface, or runoff has nowhere to go. Like erosion, salinization is an old problem. It forced agriculture out of much of the lower Tigris-Euphrates plain.

Today salinization endangers more land than ever before, occurring to some degree wherever irrigation makes deserts and semiarid plains bloom. It affects Australia's interior and North America's intermountain basins, where two centuries ago the inhabitants hunted, gathered, and left the soil undisturbed. For thousands of years, farmers along the Nile escaped salinization; the river flooded each year, flushed away salt, and left behind moist soil. That worked until modern Egypt, striving to meet demands for food and cotton, built the Aswan High Dam. Completed in 1970, it supplies water year round, but the ensuing salinization has become a problem in managing irrigation downstream, whereas the Nile's annual floods formerly flushed away excess salts.

A proposed technological remedy is the cultivation of crops that tolerate salt. Cultivation of date palm and barley is a traditional use of moderately saline soils in Southwest Asia and North Africa. Modern selective breeding has produced adapted wheat, banana, and tomato varieties. Plants that tolerate higher salt content, even irrigation in seawater, include pearl millet and productive forage and oilseed crops. There may be no limit to the potential crops if genetic engineers succeed in a current research effort and transfer salt-tolerance to presently sensitive crops.

Enthusiasts claim that salt-tolerant crops will save agriculture on salinized land, but few address the long-term consequences. If the conditions that produced salinization are still present, what will prevent the further accumulation of salt to levels that no plant can tolerate? As for seawater irrigation on dry land, the potential for salinization of soils and contamination of ground and surface water is self-evident.

High Yields and Land Degradation

By improving yields on irrigated land, intensive cultivation methods have often encouraged the spread of irrigation onto land where the risk of salinization is high. Large harvests have repaid large investments, but in some cases led to large-scale degradation The Aswan High Dam is one example, but arguably, the most catastrophic case lies in the basin around the Aral Sea, where the Soviet Union developed vast irrigation projects for the production of grain and cotton from the 1930s to the 1980s. The successor nations of Kazakhstan, Tajikistan, Turkmenistan, and Uzbekistan are paying a price in severe damage to the irrigated area, 87 percent of it in Uzbekistan (Islamov 1998).

In developed countries, farmers' initiatives and reclamation projects have reduced cultivation on the land most at risk, or it was abandoned when yields fell, but the opposite is happening in many developing countries. In sub-Saharan Africa, the elimination of fallows—periods of bush or grass growth that alternate with crops—has removed protection from large areas of fragile soils. Overgrazing threatens semiarid land south of the Sahara. Latin American farming also has its destructive side—the spread of cultivation onto steep hillsides.

Ideally the will to conserve land combines with control over farming methods. In the United States, governments and private parties offer advice, but landowners or renters decide. Many farmers, but not all, have the needed vision. This author saw an Iowa hill farm, once a model of soil conservation, transformed when the farmer abandoned reduced tillage and plowed shelterbelts and grass strips, spreading corn to every corner. According to neighbors, he found out his son wanted no part of farming.

Water

Irrigated fields account for a third of agricultural production, but consume two-thirds of the water diverted from surface bodies or aquifers. Household and industrial users are tightening competition, and the worldwide growth of irrigation has slowed. Because several major rivers cross or straddle national boundaries, water has become a source of international friction.

Irrigation carries an environmental cost, particularly in arid regions. Lakes shrink, the flow in rivers and aquifers dwindles, and salt content increases. In order to meet treaty obligations concerning water quality, the United States sends Colorado River water through a desalting plant before the river enters Mexico. In the Aral basin, irrigation has reduced the Aral Sea to a fourth of its former volume, devastated fisheries, and turned groundwater brackish.

Water conservation begins with covering and maintaining canals, thereby reducing losses in transit. At the field, drip or trickle irrigation (that is, metered delivery to plants or rows) saves up to two-thirds of the water (although it can increase salt accumulation). But these methods require large initial investments. It does not help that irrigation subsidies, $40 billion worldwide each year, keep down the cost of wasting water.

Soil Nutrients

Crop harvests remove nutrients that are essential for plant growth. Lightning, certain free-living soil cyanobacteria and bacteria, and other bacteria that cluster around the roots of legumes (the pea family of plants) "fix" atmospheric nitrogen, which means they add to the soil soluble nitrogen compounds that plants take up through their roots. Gradual disintegration and decomposition of mineral particles make the other nutrients available. Preindustrial cultivators variously depended on the inherent fertility of the best soils, alternated crops with fallows that allowed fertility to recover, recycled nutrients in animal manures and night soil, or imported and dug in organic matter such as grass and leaves. Yields approaching today's best were unusual. Despite the farmers' efforts, low nutrients commonly limited yields, and many of the crop varieties they planted did not respond well to high nutrient levels.

During the nineteenth and twentieth centuries, scientific plant breeding, the identification of plant nutrients, and the manufacture of inexpensive chemical fertilizers made high yields achievable on most well-watered land. At first, chemical fertilizers complemented the older sources of nutrients, but in the past half century, chemical fertilizers have increasingly displaced these traditional sources. The reasons are both ecological and economic. Adding nitrogen in chemical fertilizers suppresses biological nitrogen fixation. Market factors encourage farmers to concentrate on single crops, often at the expense of crop rotations that had added nitrogen or otherwise enriched soils. Cover crops, grown over the winter and plowed under in the spring, have declined in favor of bare ground. Increasingly, and most notably in the United States and Canada, manure goes to waste. Although feedlots and other livestock concentrations deliver substantial quantities to neighboring fields, they typically do so at rates up to ten times greater than what crops can use; the purpose is more disposal than fertilization. Wider distribution would assure optimal manure use, but disincentives include the comparatively low cost of transporting and applying chemical fertilizers.

Excess nutrients reach groundwater and streams. The effects are the same whether they originate in chemical fertilizers or manure, but the abundance of chemical fertilizers has spread and exacerbated this form of pollution. Groundwater nitrates and nitrites are a threat to infant and child health—a widespread one according to the China Environment Agency, the Environmental Protection Agency (United States), the European Environment Agency, and the Ministry of Environment (Japan). Sources include sewage and a few industrial processes, but agriculture is the main source; thus the contaminants peak during seasons of nitrogen fertilizer applications.

In freshwater streams, phosphorus, nitrogen, and iron stimulate blooms of algae that result in depletion of oxygen and a dieback of most organisms, including fish. Even the seas' volume is no protection: research has implicated nitrogen fertilizer runoff in coral reef destruction (Fabricius 2005).

Soluble iron salts from agriculture and industry trigger blooms of the red tide, which kills fish over large stretches of ocean. Nutrients can be removed from water at a cost, but the most effective remedy would be to limit their use.

Fertilizer Resources

Fertilizer resources are nonrenewable with one exception—plants, animals, manures, and chemical fertilizers borrow nitrogen until decomposition returns it to the air, from where the cycle begins again. The other fertilizers are mineral nutrients, taken from high-grade deposits. They end up back in the ground, but in too dispersed a form to recycle.

Farmers apply boron, chlorine, copper, iron, manganese, molybdenum, selenium, and zinc in very small quantities, if at all. Their use, once limited to a few locations—iron on alkaline and sandy soils, several elements in Western Australia—is spreading, as fertilization with other elements and large harvests depletes nutrients that had been adequate. Resources are very large in relation to agricultural demand, but molybdenum and boron could run out because of competing demand from industry. A few countries hold most of the known resources. Three-quarters of high-grade boron resources lie in Turkey, with most of the rest in the United States, a situation that inspired a Turkish novel about an American attack.

Crops require five mineral nutrients in large quantities. Calcium and magnesium are of no concern; there are plenty of both elements in limestone, which makes up whole mountain ranges and lies under vast plains. As for potassium and sulfur, mining is depleting high-grade deposits, but other common rocks contain enormous quantities in low concentrations. Seawater also contains some.

That leaves phosphorus as the Achilles heel of industrial agriculture. It is the scarcest nutrient in relation to agricultural demand. An analysis that takes all known, exploitable resources into account predicts a decline in production after 2040 (White and Cordell 2008).

Practices that would delay a reckoning include monitoring of fields to avoid excessive applications, recovery from wastewater, and effective recycling of manures and treated sewage. At present, no options exist for doing without phosphorus fertilizers.

Ways are available to conserve fertilizer resources. Application rates often exceed what plants can use; soil testing can reduce the temptation to assure a good crop by overfertilizing. Higher fertilizer prices would encourage frugality. A more radical strategy is to increase reliance on trees and other perennials whose deep root systems intercept nutrients moving down through the soil profile. Known as *permaculture* or *agroforestry,* these systems are quite old and are undergoing a modest revival. A caution:

highly productive perennials readily replace some annuals, notably in oilseed production, but there are no similar alternatives for the annual cereals that are the staples of the world food system.

Control of Pests and Diseases

Pesticides and herbicides do not draw upon nonrenewable deposits other than fossil fuels, and their energy cost is comparatively small. But the usefulness of individual agents is limited because target organisms develop immunities. Science has so far produced replacements, but presumably their number is finite. Most insecticides are *broad spectrum*, meaning they kill a wide range of species, not only the targets. By also killing predators, they have allowed minor pests to proliferate and became problematical: leaf-eating spider mites are an example. Trends in industrial agriculture that increase disease transmission and pest proliferation include repeated plantings of one crop and concentration of animals in feedlots, large dairies, and egg factories. A response has been to spray crops more often. Routine feeding of antibiotics to prevent disease, a practice nowhere approved for humans, is common in livestock and has fueled fears that the practice will increase antibiotic resistance in pathogens, such as tuberculosis, that also afflict humans.

Agricultural chemicals escape from fields, enter into ecosystems, and poison wild species, as well as humans. The most notorious cases involved DDT, which persisted in the environment and turned up in Antarctic penguins. There has been a shift toward chemicals that break down in days or weeks, and controls on applications have improved in many countries. Little is known about the long-term impact of low concentrations on land, freshwater, and marine ecosystems.

Alternatives are available. Returning to old methods—crop rotations and dispersed livestock—would reduce the need for agricultural chemicals. Organic farming would eliminate the need, along with chemical fertilizers; one of the great controversies about agriculture today concerns the cost to productivity. A less stringent alternative is integrated pest management and the application of biological and mechanical controls, along with selective use of chemical agents. The goals are to target pests with minimal harm to other species, through careful monitoring and careful choices of agents and application methods.

Energy and Industrial Agriculture

Industrial agriculture relies on fossil fuels. Oil drives farm machinery, moves goods to and from farms, and enters into the manufacture of nearly all pesticides and herbicides. Natural gas is the basis of ammonia manufacture, which is the starting point for most nitrogen fertilizers; their production, distribution, and application form the largest energy input into industrialized agriculture.

World agriculture's energy consumption is rising most rapidly in countries such as China that only a few decades ago relied almost entirely on human and animal energy in their farming. Presumably economic growth in other developing countries will continue the trend. Technologies intended to ameliorate the costs and damage of industrial agriculture further raise its energy cost. In Australia and Iran, a remedy for salinization on poorly drained land is to pump out groundwater so that salt can be flushed from the soil. When high-grade deposits of mineral nutrients run out, substitution of low-grade deposits will require additional energy expenditures. If irrigation and cities empty or pollute rivers, pumps could deliver more water from pristine but distant rivers and lakes. That and desalting seawater, an energy-intensive process, have been proposed as solutions.

By consuming fossil fuels, agriculture contributes to their depletion and to global warming, though to a lesser degree than industry and transport. In turn, carbon dioxide from fossil fuel burning affects agriculture by altering the climate and enhancing photosynthesis and biomass production. After taking warming, precipitation changes, and the direct effects of carbon dioxide into account, the Intergovernmental Panel on Climate Change predicts that an increase in global mean temperature of 1°C to 3°C would lead to a net increase in agricultural production in middle and high latitudes and a net decrease in the tropics and subtropics. At higher global mean temperatures, yields will decline in all latitudes.

Present and Future

Sustainability rests in the eye of the prognosticator. Unbridled optimists draw encouragement from ample food production, the slowdown of population growth, the many farmers who do not yet employ the most productive methods, and continuing developments in agricultural research. Pessimists point to land degradation, spiraling demand, the diversion of resources to growing biofuel production, and the drawdown of nonrenewable resources; survival, they say, depends on reducing world population and demand. Guarded optimists believe that renewable energy and sustainable, ecologically friendly forms of agriculture—better conservation of soil and water, integrated pest management, permaculture, and agroforestry—can support the present world population, perhaps a few billion more. The signs do show that world agriculture in its present form follows an unsustainable path. The question is whether it aims into a blind alley or a road that branches before it ends.

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See also Biotechnology Industry; Ecolabeling; Ecosystem Services; Energy Industries—Bioenergy; Health, Public and Environmental; Rural Development—Developed World; Rural Development—Developing World; Water Use and Rights

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Airline Industry

Aviation contributes approximately 2 percent of total greenhouse gas emissions, a figure which is projected to grow through 2050. Although fuel efficiency has improved by nearly 16 percent since the 1990s, future technologies—including better flight patterns, more-efficient engines, and alternative fuels—have promise for further emissions reductions. The profitability challenges of the early twenty-first century, however, affect the industry's ability to invest in new technology.

Every day, millions of people board planes to reach points all over the world. In 2006, 744 million passengers stepped aboard planes in the United States alone, generating revenues of nearly $164 billion (Air Transport Association 2008). Air travel, once seen as a dream in the 1800s and later a luxury for the rich, is now available to all for fares as low as $40. This has occurred at the same time that incomes and wealth have increased dramatically around the world. Whether for business or pleasure, air travel is now the preferred method of getting where you want to go. But few people consider the impact of their decision to step on a plane on the global environment. A Boeing 747-400 burns approximately 5 gallons (19 liters) of fuel per mile on a 3,500 statute mile (~5,645 kilometer) flight, which totals about 17,500 gallons (66,500 liters) for a flight roughly equal to the flight distance from New York to London (Boeing 2009b). In the United States, a total of nearly 797 billion passenger miles (1,285 billion passenger kilometers) were flown in 2006 (Air Transport Association 2008). Globally, air travel was estimated to be responsible for approximately 480 million tons (~435 million metric tons) of carbon dioxide emitted into the atmosphere in the year 2000 (GAO 2009). With the rapidly increasing onset of global warming, high carbon intensive industries (such as airlines) must find sustainable strategies to maintain growth and profitability or risk further damage to the world's environment.

Historical Background

Early aviation was driven by the creative entrepreneurship of many engineers and hobbyists in the late 1800s and early 1900s. Wilbur and Orville Wright made the first validated human flight in North Carolina on 17 December 1903. After that well-known, momentous flight, airplanes became significantly more reliable and were able to travel farther distances. They were quickly adopted for military uses in World War I. Government investment in aviation rapidly helped the industry develop new planes that were capable of carrying passengers.

Despite these developments, commercial aviation did not appear economically feasible until the 1920s. In that decade, a number of airlines started and failed as expensive ticket prices and reports of crashes jeopardized demand for travel. Even with these circumstances, the number of airline passengers grew from 6,000 in 1926 to approximately 173,000 in 1929 (U.S. Centennial of Flight Commission 2009). Air travel in the 1920s and 1930s was not a pleasant experience: planes were not pressurized, which led to significant ear pain for travelers, and low-altitude turbulence often meant multiple cases of air sickness. Yet customers continued to take to the air in droves as air travel became linked to business transactions. The year 1937 witnessed airline-passenger traffic break the 1 million passenger mark. Transatlantic air travel became possible in the 1940s but was extremely limited. What used to be an unsafe, uncomfortable, and unaffordable new development swiftly became a norm for both the rich and the businessmen of the generation. Additionally, commercial aviation was preparing to take the next innovative step, which would launch air travel into the mainstream.

The introduction of the jet engine in the late 1950s revolutionized air travel. Jet engines offered more speed and comfort to passengers and were cheaper to maintain than traditional piston-driven engines. But jet engines required more fuel than the conventional engine to generate higher air speeds and altitudes. The jet engine made longer flights significantly more feasible and allowed many shorter routes due to easier maintenance requirements for the engines. With this new development, the variety of aircraft types multiplied. Smaller planes handled the new shorter routes, and large wide-body models, such as the Boeing 747, made the longer flights. Travelers could now reach hundreds of destinations whenever they wished. Shortly thereafter, another major movement would vastly expand the number of travelers pursuing those destinations.

Up until the late 1970s, air travel in the United States was highly regulated by the government with six major carriers—United, American, Delta, Eastern, TWA, and Pan Am—dominating certain travel routes. But in 1978 the U.S. Airline Deregulation Act enabled new airlines to enter the market and existing airlines to expand their routes. Europe followed the United States' example with a stream of deregulation acts that culminated in 1997. In the deregulated environment, higher competition quickly drove airfares lower, and airlines found it very difficult to sustain profitability. Eastern, TWA, and Pan Am subsequently went bankrupt. The average airfare in 1992 cost nearly 66 percent less than the average airfare in 1977 (U.S. Centennial of Flight Commission 2009). With these decreases in prices, demand for flights more than tripled from 1975 to 2005. Globally, aviation now transports more than 2.2 billion people and more than 44 million tons of freight (Bisignani 2009). Despite the global recession that began in late 2007, demand for air travel appears poised to continue growing into the distant future as global incomes rise and distances between people continue to shrink.

Challenge of Sustainable Growth

Because of the amount of fuel consumed on each flight, greenhouse gas emissions are a significant issue for the aviation industry. It is estimated that commercial aviation is responsible for 3 percent of global-warming emissions; this may grow to as much at 5 percent by 2050 as demand for air travel increases (Milmo 2008). With concentrations of carbon dioxide, methane, and nitrous oxide higher in today's atmosphere than at any time in post–Industrial Revolution history, any significant source of emissions must be evaluated closely. At the same time, this rise in pollutants corresponds to a significant increase in global warming in the last 150 years. Just since the 1970s, temperatures have risen on average by 1°F (or approximately .56°C), which correlates closely with the global boom in aviation (United States Environmental Protection Agency 2009).

It should not be thought, however, that air travel is the primary party responsible for increased greenhouse gas emissions. The transportation industry as a whole contributes approximately 20 percent of total carbon dioxide emissions globally, with road transit accounting for 74 percent of industry emissions and aviation and air freight accounting for only 13 percent (United States Environmental Protection Agency 2009). In fact, planes can typically be more fuel efficient than many cars. A Boeing 747 will burn about 5 gallons of fuel per mile over a 3,500 mile flight (or approximately 12 liters per kilometer during a 5,632 kilometer flight). The 747 can also carry more than 500 people on a flight, which means that the 747 is typically traveling about 100 miles per gallon (42 kilometers per liter) per passenger (Boeing 2009b), which translates to significantly higher fuel efficiency compared to individuals traveling in cars. Overall, U.S. airline fuel efficiency has improved from an average of 48 available seat miles (an industry measurement of an airline's capacity equal to the number of seats available multiplied by the number of miles flown) per gallon (20.4 kilometers/liter) in 1981 to an average of 58 seat miles per gallon (approximately 24.6 kilometers/liter) in 2008 (GAO 2009); nevertheless, some operating challenges have diminished the rate of improvement. Airlines face multiple challenges when it comes to operating more sustainably. In terms of financial performance, airlines have struggled to generate profits since deregulation in the 1970s. In the last fifteen years in the United States, airlines have generated nearly $2 trillion in total revenues but produced a negative $32 billion in total profits. According to the Bureau of Transportation Statistics (2009), even in the days of steady profitability during the 1990s' economic expansion, airline net-income profit margins maxed out at 4.72 percent in 1997. Since 2001, it has become an even greater struggle to remain profitable—the industry generated positive profits in only two out of eight years, and losses totaled over $55 billion (Bureau of Transportation Statistics 2009). In times of economic expansion, high fuel prices adversely affect airline profitability; during economic downturns, customer demand declines. While these results are certain to concern shareholders, they pose significant challenges to the environment as well.

Because airlines are forced to operate under such tight margins and cash-constrained positions, it is often difficult for them to invest in new technology for retrofitting existing planes as well as investing in newer fleets with better technology provided by manufacturers such as Boeing and Airbus. This leads many airlines to operate fleets that include planes thirty-five to forty years old, such as the DC-9 airplanes. These aging fleets are generally less fuel efficient than modern planes and engines. With poor financial performance, it is difficult for airlines to order lighter, more fuel-efficient planes that could carry more passengers with a lower overall fuel burn even though planes are usually leased to airlines with financing offered by manufacturers (Carey 2009).

The economic recession that began in late 2007 led to even more difficult conditions for airlines, which are forecast to lose nearly $80 billion in customer revenues in 2009 (Bisignani 2009). While airlines are rapidly reducing flights and scaling down capacity, it does not look as if they will be able to take advantage of lower oil prices and improve their operating profits. Despite these conditions, airlines are taking a number of measures to reduce their impact on the environment.

Sustainability in Aviation

Due in part to the steep rise of fuel costs before the recession and in part to efforts to decrease total carbon emissions, major airlines have taken a number of steps to reduce their carbon emissions footprint.

- Maximizing Capacity—While the main reason for maximizing capacity is to maximize revenue, full capacity flights also reduce the amount of carbon emissions per person. During the recession that began in late 2007, airlines reduced the number of flights available to ensure that airplanes were as full as possible.
- Introducing Winglets—Winglets, vertical attachments on the end of the wing, were originally invented by National Aeronautics and Space Administration (NASA) researchers in the late 1970s and early 1980s in response to the high gas-price shock of the 1970s. More recently, high fuel prices drove many airlines to invest in retrofitting their existing fleet with winglets. Winglets are estimated to improve fuel efficiency by as much as 7 percent (NASA 2008).
- Continuous Descent Approach—Utilizing a new descent approach to airport runways with their landing procedures has allowed airlines to use lower engine-power levels and burn less fuel on the aircraft's descent.
- Reducing Flight Weight—Airlines evaluated everything that goes on a flight, including carpet, seats, and fuel requirements, to see if it was possible to shed extra weight. An extra 1,100 pounds (455 kilograms), the equivalent of six passengers, can lead to an additional fuel burn of 66 to 110 pounds (30 to 50 kilograms) on a 90-minute flight. For 3,000 hours of flying, this represents an additional cost of $40,000 to $70,000 per plane.
- Ground Power—Planes once used engines on the ground to support power systems and air conditioning on the plane in between flights. Now, airline crews increasingly use "drive-up" ground-power units that provide electricity directly to the plane from a fuel-efficient generator.
- Engine Washing—Airlines found that simply washing engines with pressurized water can remove a lot of buildup.
- Emissions Offset Programs—Many large U.S. airlines, including Delta, American, United, and Continental Air Lines, have introduced voluntary carbon offset programs with partners like The Conservation Fund and Sustainable Travel International to give customers the opportunity to purchase carbon offsets for their flights. These airlines often provide incentives, such as additional frequent-flier miles or matching donations to funds contributed by customers.

These measures began to have some positive effects on fuel consumption as the International Air Transport Association (IATA) reported that fuel efficiency improved by nearly 16 percent from 2001 to 2008 (IATA 2009, 2). In 2008, airlines were carrying 20 percent more passengers and consuming 3 percent less fuel than in 2000. But anticipation of higher future demand leads many experts to believe that fuel consumption and emissions will continue to rise. Therefore, airlines and airline manufacturers are continuing to look for more potential solutions to increase fuel efficiency while governments are simultaneously considering new policies to reduce airline emissions.

Government Regulations and Aviation

Despite improvements in fuel efficiency over the past ten years, airlines must find new ways to reduce their contribution to climate change. It takes a significant amount of time to process greenhouse gas emissions out of the atmosphere, so adding more every year extends the effects of these emissions for years to come. Governments are beginning to take a much more proactive stance in managing these emissions. There are two particular mechanisms in particular that governments are considering to reduce emissions.

Carbon Tax

A carbon tax is a tax on any fuel containing carbon-based elements, such as coal, oil, and natural gas. The carbon tax would be implemented in the upstream production process where it is extracted from the ground, which would then lead to higher downstream prices for all industries that rely on these fuels. This higher price essentially acts as an excise tax, much like current taxes on alcohol and tobacco. A carbon tax theoretically would encourage individual businesses and consumers to use less and shift their spending to other goods.

While proponents of a carbon tax argue that it could be phased in gradually so the effects would not introduce a significant price shock, airlines are especially sensitive to increases in fuel costs because they represent 30 percent of the airlines' operating costs. Opponents of a carbon tax point out that fuel prices are already subject to increase, as they did in the summer of 2008, due to rising global demand. Some airlines, such as Virgin Airlines, have indicated they would be willing to pay a carbon tax as long as it was fairly applied (Environmental Leader 2008).

Cap-and-Trade Carbon Trading System

A cap-and-trade system works through a series of limits set on high emissions companies (such as electricity providers and airlines). The company would use emissions permits for each ton of carbon emissions that it releases into the atmosphere. Carbon permits would initially be auctioned off to all major producers of emissions, creating a new revenue stream for the government. The credits could be traded from more efficient producers, who generate emissions below their limit, to those producers who need to purchase more credits in order to offset their emissions. Essentially, this system creates more incentives to reduce total aggregate emissions by encouraging large emitters to become more efficient or switch to cleaner fuel sources. This type of trading system worked very well in reducing sulfur dioxide and the incidence of acid rain in the United States during the 1980s and 1990s.

As of 2009, plans are in motion to institute a cap-and-trade system in the airline industry. The European Union (EU) has set a goal of implementing an airline cap-and-trade system by 2012. It expects this program to initially reduce emissions by 3 percent from their 2004–2006 level, steadily growing to a reduction of 15 percent of all carbon emissions (EurActiv 2009).

Outlook for Sustainability in Aviation

Proposed regulations have led airlines to recognize the need to become more sustainable in their operations. Many U.S. airlines, including Delta, American, and Southwest, have published sustainability reports in the past. In these reports, they often highlight new recycling initiatives and efforts to increase fuel efficiency. However, there is still room to improve in environmental measurement practices. UPS (n.d.) is one of the few companies in the United States to report total emissions for its operations: 15.4 million tons (14 million metric tons) of carbon dioxide emissions, of which 53 percent is driven by jet-fuel consumption. American Airlines also tracks their total emissions, which consisted of 30.1 million tons (27.7 metric tons) of carbon dioxide emissions in 2007 (AMR n.d., 23). Many European airlines are very advanced in their sustainability reporting. For instance, Air France-KLM's 2009 report documents their improvements in grams of carbon dioxide per passenger per kilometer, down from 107 grams (3.7 ounces) in 2000 to 95 grams (3.3 ounces) in 2008.

In the future, more airlines will need to report their total carbon footprint as regulation of emissions becomes much more prevalent. Impending cap-and-trade regulation for airlines in the EU will force airlines to measure their emissions on flights involving a European departure or arrival. Airlines are unsure of the impact such legislation will hold. For example, Delta Air Lines, the largest airline in the world by revenue, recently stated in its 2008 annual report:

> We expect that such a system will impose significant costs on our operations in the European Union. Similar cap-and-trade restrictions are being proposed in the United States. In the event that U.S. legislation or regulation is enacted or in the event similar legislation or regulation is enacted in other jurisdictions where we operate or where we may operate in the future, it could result in significant costs for us and the airline industry. At this time, we cannot predict whether any such legislation or regulation would apportion costs between one or more jurisdictions in which we operate flights, which could result in multiple taxation or permitting requirements from multiple jurisdictions. Certain credits may be available to reduce the costs of permits in order to mitigate the impact of such regulations on consumers. At this time, we cannot predict whether we or the aviation industry in general will have access to offsets or credits. We are carefully monitoring and evaluating the potential impact of such legislative and regulatory developments. (Delta Air Lines 2009, 9)

The airline industry clearly understands the risk posed to its business by a cap-and-trade system, yet they also recognize the value that improving sustainability and fuel efficiency can have on their bottom line. Airlines that are able to innovate and reduce their emissions will be better positioned to thrive in this new environment of potentially higher costs.

A number of technological developments will also help the airline industry reduce their total emissions.

Improved Engine Efficiency

Engines in development will likely rely on geared turbofans developed by NASA and Pratt & Whitney to reduce fuel consumption by as much as 12 percent (Pratt & Whitney 2009). Other potential improvements include open rotor engines and distributed power generation systems, but these technologies are long-term improvements that are still being researched for feasibility.

Airframe Enhancements

With high fuel prices, airlines took a number of steps to make planes lighter by reducing the weight of current on-board items (e.g., catering carts, carpet, water, and blankets), replacing old seats with lighter seats, and adding baggage restrictions. For instance, American Airlines contends that reducing flight weight by 100 pounds would save them nearly 1.1 million gallons of fuel (American Airlines 2009). Aircraft manufacturers further perpetuated this idea and are developing lightweight composite materials for the body of aircrafts. Boeing's new 787 is expected to consist of nearly 50 percent carbon-composite materials, which will help the 787 become nearly 20 percent more efficient than similarly sized planes (Boeing 2009a). Additionally, new electric systems are being employed that will replace hydraulics and significantly lighten planes. Airbus is also currently researching new oscillating wings that could reduce air friction considerably.

Flight Operations Improvements

The U.S. Federal Aviation Administration (FAA) is developing a new air-traffic management system known as NextGen that will allow pilots to craft more efficient flight paths to their destination. This system will also help pilots use real-time weather information to avoid delays and use tailwinds efficiently. This system is already showing significant reductions of greenhouse gas emissions and saving millions of dollars at airports such as Atlanta, Phoenix, and Dallas-Fort Worth (Federal Aviation Administration 2009).

Additionally, Boeing has performed some work that is immediately applicable to reducing airline emissions across its fleet. Boeing developed a new Tailored Arrivals program, which gives airline crews the most efficient flight path by taking into account factors such as aircraft performance, air traffic, airspace, and weather. A one-year pilot program at San Francisco's airport reportedly decreased fuel consumption by 1.1 million pounds (nearly 500,000 kilograms) and reduced carbon emissions by 1.6 tons (1.45 metric tons) (Boeing 2008).

Alternative Fuels

Four airlines have recently completed tests of biofuels (an alternative to fossil fuels composed of or produced from biological raw materials) mixed with jet fuel in standard jet engines. Potential sources for airline biofuel include switchgrass, jatropha oils, and algae, among others. Continental Airlines (2009) recently performed a test with one engine using traditional jet fuel and another engine using a fuel of half jatropha- and algae-derived fuels mixed with jet fuel. The results showed a dramatic reduction of 60 percent to 80 percent emissions for the biofuel-based engine and 1.1 percent increase in fuel efficiency (Continental 2009). However, several steps need to be taken to determine if biofuel may be commercially viable and to understand other environmental considerations associated with second-generation sources of biofuel.

Outlook for the Twenty-First Century

Although some innovations soon may be adopted into modern aviation, advances in technology are difficult to obtain and must pass strict safety standards. Boeing has experienced numerous delays in launching the new 787 and continues to push back its delivery date over two years because of needed changes, such as reinforcement of the aircraft body near its carbon-composite wings. Even though existing orders number more than 800, it is unclear when Boeing will be able to deliver the planes. Despite the significant promise of new technologies, innovation is expensive, and aging fleets and existing processes will be difficult to replace in an industry that struggles to maintain profitability in the economic environment of the early twenty-first century.

The economic recession that started in late 2007 will make it difficult for airlines to take on new investments and generate profits. Capacity will continue to shrink in an effort to keep planes full at stable prices. This could lead to further consolidation in the industry as airlines with lower cash balances seek to be acquired or restructured. Regardless, the aviation industry is well aware of the new environmental expectations placed on them by upcoming regulations such as the EU's emissions trading program. The airline industry is often viewed as slow and bureaucratic, but in order to succeed in this new economic climate, airlines will need to innovate quickly to get ahead of their competition. Those who are best able to adopt new technologies, maximize their revenue per flight, and operate with a lower carbon footprint will be best-suited to survive.

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See also Automobile Industry; Cap-and-Trade Legislation; Design, Industrial; Energy Efficiency; Energy Industries—Oil; Investment, CleanTech; Steel Industry; Travel and Tourism Industry

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Automobile Industry

Long vilified as a major contributor to air pollution, noise pollution, and global warming, the automobile industry and the car itself are undergoing change. Alternative fuels and Earth-friendly materials, along with a measured response to the demands of ecoconscious consumers and the challenges of remaining economically stable, are transforming the industry.

Several factors contribute to the lack of sustainability in the automobile industry, but the most obvious is the impact of carbon emissions on urban air quality and on global warming. Attention is usually directed at the technologies that comprise the automobile itself—and these are certainly important. The underlying business model is also a cause for concern because the industry was struggling to be profitable even before the global economic crisis that began in late 2007.

Brief History of the Industry

The automobile industry emerged at the turn of the twentieth century in the industrial nations of Europe and the United States from several diverse antecedent industrial sectors, including those making railway equipment, armaments, bicycles, textile machinery, and horse-drawn carriages. The automotive industry is now the leading manufacturing sector in many industrial nations.

The development in 1876 of the four-stroke internal combustion (gasoline-powered) engine, usually credited to the German inventor Nikolaus Otto, allowed people to consider the automobile as a means of motorized personal transportation. The first practical gasoline-powered, three-wheel car was developed by another German, Karl Benz, in 1885. The modern automobile and the business model of the industry today, however, was the result of several key innovations in the United States (Raff 1991; Nieuwenhuis and Wells 2007; Batchelor 1994):

- The standardization of parts, the detailed division of labor into short work cycles, high levels of vertical integration, and the moving assembly line producing in large numbers to give manufacturing economies of scale was pioneered by Henry Ford for the Ford Model T (from 1908 onward).
- The all-steel body architecture developed by Edward Gowan Budd allowed for the complete enclosure of the vehicle body and for paints to be baked onto the body (first used in 1915 by Dodge Brothers).
- The marketing innovations developed by General Motors (GM) from 1920 onward with the "M" divisional structure, the concept of multiple brands grouped under single ownership, the use of credit finance to purchase cars, and the annual model change cycle kept up demand for new cars.

Collectively these innovations allowed the creation of an industry characterized by high capital costs that were recovered by high production volumes to give low per-unit prices in the market. In turn, this provided the basis for the competitive exclusion of many hundreds of low-volume craft producers. The focus on low manufacturing cost resulted in a characteristic business model, most obvious in the United States, in which the market was expanded by continuous reductions in the inflation-adjusted price of new cars. Factories became large and centralized, and the spatially extensive market was reached by having long distribution distances to dispersed franchised dealerships.

From the early 1920s onward, competitive processes underpinned by core innovations resulted in a characteristic industry structure with three main categories of automobile manufacturer:

- The mainstream, high-volume (or mass) automobile manufacturers typified by GM, Ford, and later by companies such as Renault, Volkswagen, Fiat, Toyota, and Nissan, occupied the center ground of the market with a broad range of new cars. They sought to achieve profitability through cost reduction at very high volumes, with total volumes measured in millions of units per annum.
- The specialist or prestige manufacturers typified by many European producers, such as Bayerische Motoren Werke (BMW), Mercedes, Volvo, Jaguar, and Alfa Romeo, occupied distinct market segments with a narrower range of cars. They compensated for the lack of economies of scale by seeking to achieve a premium price that allowed cost recovery on volumes of 60,000 to 500,000 per annum.
- The niche manufacturers of the type represented by companies such as Ferrari, Lotus, Aston Martin, and Rolls Royce often employed alternatives to the all-steel body but built automobiles in much lower volumes, typically fewer than 5,000 per annum.

While the automobile has been subject to many innovations since the 1920s, the core technologies and business model have remained unaltered. Economic pressure on the industry has resulted in mergers and acquisitions that cut across and eroded the distinctions of the main categories of manufacturers noted in the list above. The automobile industry requires large investments both in production equipment and product design, as well as a strong brand and distribution network. As a result, it is not easy for new entrants to break into the market. Historically, new entrants have emerged out of protected market spaces (such as Hyundai in South Korea) and may be expected to do so into the future (such as Tata in India or SAIC in China).

New Practices and Innovations

Automobile manufacturing and the automobile itself are largely premised on stable technologies that have been developed incrementally over many years. The primary development trajectory of the industry has been one of seeking efficiency improvements rather than radical change (Cusumano 1984).

Since 1990, the major innovations with respect to manufacturing have been in regard to the organization of labor. The influence of the Toyota production system has been profound—not least because of the continuing market success of the company. (Although in January of 2010 a problem with sticking accelerators in several of the company's brands caused an enormous worldwide recall; the final tally of the damage done to the company's finances and reputation is unknown as this article went to press, but is estimated to be several billion dollars.) As a result many companies adapt, adopt, or emulate the production practices of Toyota through activities such as team working and quality circles, and more widely through measures such as just-in-time (JIT) components delivery systems. (JIT systems aim to increase profits by reducing excess inventory levels and their associated carrying costs.) The larger role assigned to suppliers of key materials and component subassemblies have resulted in a greater level of innovations from these suppliers (Womak, Jones, and Roos 1990).

The main developments in terms of new practices and innovations for social, environmental, and political sustainability in the mainstream industry include the following:

- new working practices premised on the concept of the labor bank whereby workers "bank" extra hours worked in times of peak demand to pay for temporary layoffs during times of slack demand
- automation of production processes, from design right through to delivery sequencing
- new geographic locations for production of both components and complete vehicles, notably in India and China
- alternative fuels, in particular those derived from biomass (bioethanol, biodiesel) that are virtually carbon neutral, and also compressed natural gas
- improvements in gasoline and diesel engine design, such as the common rail diesel concept, high-pressure fuel injection, turbocharging, and improved engine management systems that result in more efficient engines
- hybrid engine designs (e.g., Toyota Prius, Honda Civic hybrid) that combine an internal combustion engine with an electric motor and battery pack, thereby allowing lower fuel consumption and fewer carbon emissions in the typical urban driving pattern
- some experimentation with lightweight vehicle structures (e.g., Audi A8 and A2 models) or city cars (e.g., Mercedes Smart)
- green-branding strategies, such as the Renault eco^2 concept, which seek to create market value out of environmental improvements
- long-term experimentation in hydrogen fuel cell vehicles that offer zero emissions at point of use (e.g., California Fuel Cell Partnership)
- pure battery electric vehicles (e.g., TH!NK, Tesla)
- fringe experimentation in concepts such as ultracapacitors, flywheels, and compressed air engines

Sustainability Challenges

The core vehicle technologies with the internal combustion engine and the all-steel body are the primary determinants of the sustainability performance of the automobile over the lifecycle of production, use, and disposal. Alternatively no matter what the actual technology that constitutes the automobile or its fuel, it could be argued that a fundamental change in business model is required to make the industry and automobility sustainable—though this is a more contentious position.

The economic crisis that has unfolded since late 2007 has been particularly severe for the automobile industry worldwide; a large decline in new automobile sales in an industry that was already characterized by endemic overcapacity has resulted in losses and bankruptcy for vehicle manufacturers and suppliers. Some commentators think it's necessary to break the path dependency in the industry and bring forward a new era of sustainable automobility or to rethink mobility in general (Urry 2007). Others—particularly auto industry leaders and those in government and trade unions—take the view that the existing industry must be helped to survive in its current form over the short term if it is to survive in the long term. Hence the basic sustainability challenge to be faced by the industry (and the communities traditionally associated with automobile production) from 2009 onward is simple economic survival. The following issues are also of key concern with respect to the sustainability of the automobile industry:

- air quality in urban areas
- carbon emissions and global warming
- peak oil and other material supply issues
- recycling of material from scrapped cars
- deaths and injuries
- congestion and spatial dispersal
- overproduction
- car culture, known as automobility, and how different geographic environments require different sustainability solutions

Air quality concerns have been an issue for the automobile industry since California started regulating exhaust emissions in the mid-1960s. Since then, regulations to limit the amount of toxic material in exhausts (nitrogen oxide, sulfur oxide, volatile hydrocarbons, and particulates) have been introduced around the world and made progressively more restrictive. Lead in gasoline was phased out because of recognition that it caused brain damage in exposed populations. In 1998 the World Health Organization (WHO) estimated that in the European Union there were some 80,000 premature deaths per year because of atmospheric pollution from cars, with an additional economic burden caused by hospitalization for respiratory and cardiovascular diseases and effects on patients with chronic bronchitis and asthma. The same source noted that in Europe the proportion of the population exposed to traffic noise levels above 65 decibels increased from 15 percent in the 1980s to 26 percent in the early 1990s. Other sources have now produced noise maps that illustrate the growth of this problem. High levels of background noise are associated with stress, inability to concentrate, sleep disturbance, and high blood pressure.

Carbon emissions from the combustion of gasoline or diesel are the current focus of regulatory concern because such emissions contribute to global climate change. The heavily motorized United States contributes about 25 percent of all global carbon emissions, of which 41 percent is attributable to combustion of petroleum products and about 25 percent is attributable to automobiles. The "carbon burden" of automobiles in the United States for the year 2000 was 302 million metric tons of carbon (EDF 2002). (The carbon burden is the statistically calculated amount of carbon dioxide emitted by a group of motor vehicles, based on their fuel efficiency.) In 2004 U.S. cars and light trucks contributed an estimated 314 million metric tonnes of carbon equivalent; the United States has 5 percent of the world population, 30 percent of the world's automobiles, and contributes 45 percent of the world's automotive carbon dioxide emissions (DeCicco, Fung, and An 2006). (Such measurements are often difficult to pinpoint given different methods for collecting data.) The average light truck emits three times its weight in carbon dioxide (CO_2) every year. Standards and approaches vary widely as well, and it has proven difficult to establish an enforceable set of CO_2 emission limits (ICCT 2007). The European Union had agreed on a target with the European automobile industry in 1998 to reduce average CO_2 emissions for new cars to 140 grams of carbon dioxide per kilometer driven (g/km CO_2) by 2008, but this target was not achieved; in 2008, the average was 157 g/km CO_2 (Clean Green Cars 2008).

The production and use of automobiles consumes vast quantities of raw materials: oil, of course, but also rubber, steel, aluminum, copper, platinum, and tin. The automotive industry accounts for about 25 percent of flat steel production worldwide and up to 85 percent of rubber production. The problem of peak oil (Aleklett 2007)—wherein available reserves and production worldwide are set to decline while demand continues to grow—is in this sense a particular case of a more general sustainability problem with the automobile. It is highly material intensive.

In general, the average car has about 75 percent metallic content, and this has nearly always been recycled (or more accurately downcycled) into other products. The remainder, "automotive shredder residue," has long constituted a disposal problem. In the European Union, a directive is in force to compel 95 percent recyclability by 2015. Problems remain with respect to car tires where, despite many technical innovations, an economically viable and environmentally robust disposal route that can cope with the sheer volume of waste tires produced has yet to be developed.

Deaths and injuries from automobile use are not often seen as an issue of sustainability, but, in fact, this is a matter of great concern, particularly in countries experiencing strong growth in rates of automobile ownership. The WHO uses a measure called "disability-adjusted life years" to calculate this social cost and has identified road traffic deaths and injuries as the third most important global health concern (WHO 2004). As for the vehicle itself, much progress has been made by combining passive safety measures such as seatbelts and crumple zones, for example, and active safety measures like antilock brakes, with advanced technologies such as collision avoidance radar. On the other hand, in emergent markets most of the victims are not inside the car but walking or cycling on the road network.

Traffic congestion carries a substantial social cost in wasted time and resources, although the calculation of this cost is somewhat controversial. Widespread automobility has enabled suburbanization and urban sprawl and hence has resulted in inefficient spatial infrastructures that are extremely enduring. In this regard, automobility creates automobile dependency, which is difficult to reverse. Negative consequences are associated with this dependency, including the environmental cost of physical infrastructures (in Los Angeles, thought to be the most automobile-centric city in the world, it is thought that 70 percent of the land area is given over to the car), and a human cost in terms of social alienation, obesity, and lack of spatial awareness. In countries where rates of motorization are growing rapidly, infrastructures and support services of all sorts struggle to keep pace, thereby exacerbating air quality, safety, and congestion problems. Until the economic crisis of late 2007, the general expectation was for a world vehicle population of 1 billion by 2010. It is worth noting that extra-urban road networks can become barriers to the movement of wildlife, creating ecological "islands" of slowly declining vitality.

Overproduction is rarely identified as an issue for sustainability, but it is actually the key to many of the problems with the contemporary pattern of automobility. Overproduction arises from the capital-intensive business model used in the industry and the constant search for higher volumes to drive down per unit costs. The consequence is then oversupply, made manifest by high rates of depreciation in the real price of new cars—typically over 50 percent of value is lost in the first three years. Ultimately, the consequence of oversupply is that cars are prematurely scrapped because their economic value has become so low, rather than because they are technically unable to function. If individual vehicles had greater longevity, then fewer new cars would need to be produced as replacements.

There are important differences in cultures of automobility around the world with diverse practices and preferences when it comes to using automobiles, some of which are affected by geographic characteristics such as climate and topography. As an example, compare the cultural associations, driving styles, and operational environments between the U.S. "light truck" segment with the Japanese Kei minicar segment. Both are considered "automobiles" in their respective domestic markets, and as such often used for personal automotive transport. They both, however, reflect very different ideas as to what constitutes motoring or indeed a car itself. Kei cars are suited to the narrow roads and tight parking spaces of urban Japan; U.S. light trucks have a highway infrastructure designed around their dimensions: roads are wide, and parking bays can accommodate four Kei cars. In addition, U.S. driving styles have evolved around the use of automatic gearboxes, large low-revving V8 engines, power steering, soft suspension, and to some extent a commercial application for those engaged in farming or plumbing, building, and similar trades. This comparison illustrates how enduring cultural differences militate against world car concepts as transcendent designs, and that the automotive industry is well short of being truly globalized. In turn, this links to points made later in the article to the effect that it will not be possible to pick single technology winners in the search for a sustainable automobile industry.

Meeting Sustainability Challenges

The automotive industry has confronted many of its sustainability challenges with some success. The period since mid-2008, however, has exposed the limits of conventional strategy responses, in particular the recourse to mergers and acquisitions to create ever-larger industrial groups. Previous attempts at this strategy have often floundered: most famously the attempted merger of Daimler with Chrysler and the alliances with Hyundai and Mitsubishi that sought to create a truly global conglomerate of brands.

Moreover, one of the more successful attempts to meet the sustainability challenge, the Mercedes Smart ForTwo model, adopted no radical engine technology but involved dramatic new packaging to produce a remarkably compact vehicle that carries two adults emitting less than 120 grams of carbon dioxide per kilometer.

New sciences, such as industrial ecology, and associated tools, such as lifecycle analysis, have been important in developing consistent and comparable metrics of sustainability performance by which to evaluate and direct technical change (Frosch and Gallopoulos 1989; Graedel and Allenby 1998). Alternatively the technologies that constitute the automobile continue to evolve to the point where radical breaks with the incremental development path of the past are now evident. The key problem is one of transition (Struben and Sterman 2007): how does the industry introduce these new technologies into the marketplace in a manner that is profitable and not disruptive to either the established industry or the societies that depend upon automobility (Nieuwenhuis and Wells 2003)?

There are clear technical and economic limits to all the alternatives that might displace the core automobile technologies in a quest for greater sustainability. In this respect there are multiple criteria that alternatives must attain to be successful. These include the following:

- cost, both for initial purchase and operation
- reliability
- sufficiency of supply (e.g., an emergent problem with lithium battery packs and for the platinum required for fuel cell catalysts) and of a supplying industry
- suitability of supporting infrastructure (e.g., with hydrogen storage and delivery for fuel cell vehicles)
- a more or less comparable performance with normal cars in terms of range, payload, acceleration, safety, and comfort, for example
- acceptance from regulatory authorities
- meeting consumer expectations of automobility

These challenges are not just technical. The industry approach has been to develop multiple solutions to the sustainability challenges. For some this has generated confusion when it comes to forecasting which technology will emerge as transcendent in the years to come (NAIGT 2009). Focusing on such confusion overlooks a more important underlying theme: technical diversity as a means of meeting the sustainability challenges facing the automobile.

In addressing the need to make novel technologies financially viable, vehicle manufacturers have started to adopt green-branding, or subbranding, strategies. A good example is that of the Renault eco^2 subbrand. In essence, this tag is applied to any car in the Renault range that meets three criteria: it emits less than 130 g/km CO_2; it is made in a factory certified to the international environmental standard ISO14001; and it is 95 percent recyclable. An alternative vision is the one offered by BMW with its "efficient dynamics package." This is a suite of efficiency improvements applied to various models intended to reduce carbon dioxide emissions, but the vehicles are not labeled to indicate this, even though the term appears in their marketing literature.

Future Outlook

The economic and environmental outlook for the automobile industry, and indeed the automobile itself, is more uncertain now than at any time in the last one hundred years. Caught within the twin forces of economic privation and growing environmental pressure in an era of economic austerity, the industry can no longer rely on conventional prescriptions and strategies. Some industry leaders have predicted that just six very large automotive groups will dominate the industry in the future, but events since 2007 have been witness to the break up of the existing groups (e.g., Ford selling off Jaguar, Land Rover, Aston Martin, and now probably Volvo, while reducing ownership in Mazda). If these large groups emerge the following can be envisaged:

- VW-Porsche (VW, Porsche, Audi, SEAT, Skoda, Bugatti, Lamborghini, Scania, Bentley);
- Renault-Nissan (Renault, Nissan, Dacia, Infiniti, Samsung);
- Toyota (Toyota, Hino, Daihatsu, Will, Scion, Lexus)
- Fiat-Chrysler (Fiat, Lancia, Alfa Romeo, Chrysler, Aberth, Ferrari, Maserati);
- Hyundai (Hyundai, Kia, Asia);
- Daimler (Mercedes-Benz, Smart, Maybach, Freightliner).

Consolidation of the industry is a contentious issue. The fate of U.S. companies such as GM and Ford and their constituent brands remains uncertain, as does the prospects of India's Tata, China's SAIC, Russia's AvtoVAZ, and others around the world.

Perhaps two key themes will be significant. First, the economic, social, and environmental problems cannot be resolved by the industry alone. The future is going to be one of pooled risk and shared destiny with multiple partnerships among businesses that have long been in the industry, and often those that are new to it. These partnerships, more than ever, will involve direct collaboration with government at all levels, with government playing a much more directing role than before (Sperling and Cannon 2007; Ryan and Turton 2007).

Second, the sustainability problems faced with respect to automobility around the world are not all the same, and neither is the potential for resolving those problems. Sustainable automobility is likely to be much more sensitized to the specifics of locality. Hence sugarcane ethanol may be an excellent low-carbon solution for Brazil, just as palm oil biodiesel may be for Malaysia or geothermal hydrogen fuel cells for Iceland, but none of these solutions will work everywhere.

Equally, the sustainable automobile of the future may cut across traditional segment and regulatory boundaries as some of the more imaginative "category killers," such as Carver (a tilting three-wheeled vehicle with an automatic balancing system stabilizing the passenger compartment) or Tango (a high-speed electric car with superior maneuverability for urban driving) have done. Automobile design is likely to evolve toward more use-specific designs rather than the general-purpose automobiles of the contemporary era. With this specialization will come further fragmentation of the market, thus eroding attempts to achieve economies of scale but also making possible higher rates of vehicle ownership.

The shape of this diverse future is already emerging. One example is Project Better Place, a highly innovative package put together by a company from California that is seeking to install electric vehicles and infrastructures in locations as diverse as Ireland, Denmark, Israel, and California. The company brings in vehicle manufacturers such as Renault-Nissan, government agencies, electricity providers, finance specialists, companies to make recharging equipment, and others to kick-start electric vehicle ownership and infrastructures in one go.

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See also Airline Industry; Consumer Behavior; Design, Industrial; Energy Industries—Bioenergy; Energy Industries—Oil; Investment, CleanTech; Manufacturing Processes; Public Transportation; Steel Industry

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B

Base of the Pyramid

The Base of the Pyramid refers to the huge proportion of humanity who are mired in poverty, as well as to the business strategies that are evolving to connect this segment of the population into the formal global economy as consumers, suppliers/producers, and entrepreneurs.

A concept developed in the late 1990s, the Base (bottom) of the Pyramid, or BOP, refers simultaneously to the socioeconomic demographic representing the 3–4 billion poorest people inhabiting the globe and to the private-sector business models meant to address the poverty of these people. The idea of the BOP as a business opportunity came about as a convergence of two streams of thought within strategic management. The first is premised on a new model of global economic expansion within international business that uses innovation and technology management. This perspective challenges assumptions regarding the source of innovation and creativity—shifting it from home offices and headquarters based in developed nations to subsidiaries and competitors based in developing countries. The second stream of thought is a model of the global economy that emerged from work on organizations and sustainability. This view describes the global economy as consisting of three distinct demographic categories (the layers of the pyramid) that transcend geographic boundaries, organized by the sustainability challenges that each faces (Hart and Milstein 1999).

Three Layers of the Pyramid

The first demographic category, the tip of the pyramid, is composed of the "mature" economy made up of the world's wealthiest individuals who represent about 15 percent of the global population. These individuals are able to afford all the goods and services they need as well as any or most of what they might want. Although these individuals tend to be found mostly in developed countries, a good percentage exist in less-developed countries as well. The challenge and opportunity for business is to develop goods and services that reduce the large environmental footprint that occurs through consumption in this market. Business can achieve this by applying renewable forms of energy, "green" building and design, and other advancements that offer significant reductions in energy usage, toxicity, and emissions.

The second demographic group represents the aspiring middle class that makes up approximately 20 percent of the global population. While found in many countries throughout the world, the majority of this demographic reside in China, India, Brazil, and other countries undergoing rapid economic transformation. These individuals are able to afford most goods and services they need and some of those they want. The challenge for businesses here is to develop innovative products and services that prevent further contributions to environmental degradation as the aspiring economy develops. Most efforts by companies to penetrate emerging economies are attempts to adapt the mature economy's expensive products and services to make them more affordable. They often do this by introducing earlier-generation technologies or stripped-down product offerings into the marketplace. Such products—for example, cars without catalytic converters—may be cheaper, but they are also dirtier. The incremental revenue generated from sales of such products is often lower than expected, and the impact on the environment can be high.

The third group represents the "survival economy" made up of the nearly two-thirds of humanity, living all over the globe, who earn between $1 and $3 a day. (It should be noted that poverty lines set by specific income levels suggest definitive levels at which poverty does and does not occur; such figures tend to conceal the variety of circumstances affecting the human condition.) Demographically, this is the BOP. These individuals are barely able or unable to meet their most basic needs, such as clean water, health care, education, housing, and nutrition. For the most part, the economic system has overlooked, ignored, or even exploited this market segment. Existing business models, products, and services have little relevance in this market because the logistical, cultural, technical, and political characteristics are so different from the mature economy for which the products were developed. What goods do exist are usually more expensive and of lower quality than comparable items available to the wealthy. The *poverty penalty* is a term used to describe the premium the poor have to pay for basic services—such as water, electricity, and sanitation—that are often of inferior quality to those available at lower costs to the rich (Prahalad and Hammond 2002).

BOP as a Business Opportunity

While the term BOP itself refers to the socioeconomic demographic of the world's poorest, the paradigm of the BOP that is being taught in many management education programs refers to private-sector activity where poverty is addressed when low-income markets become engines for entrepreneurship and business growth. This view is very contentious for those suspicious of the motivations of companies, such as Unilever and Procter & Gamble, who have been pursuing BOP initiatives. The concern is that such initiatives are simply another way to sell unnecessary goods to poor people in a way that extracts what little wealth exists in those markets. Other concerns are that successful BOP strategies will lead to increased consumption patterns that place even more pressure on critical ecosystem services and further environmental decline.

Another viewpoint, however, promotes BOP ventures as a way to unlock the latent vitality and ingenuity of robust, informal markets, thus releasing the poor from economic imprisonment. This view rejects the idea of the poor simply as a source of revenue for new business growth and instead sees the poor as capable partners and resources for technology development and innovation. The BOP is not advocated as simply the opportunity for increasing sales through the marketing of existing products and services in forms that are smaller and cheaper than their upmarket cousins (e.g., sachets and single servings of products such as shampoo or detergents). Instead, the BOP is conceptualized as a holistic, long-term investment process in business model innovation. It is based on partnerships and need-based product and service development as articulated by the poor themselves and built on the local resource base, infrastructure, and cultural institutions. The most progressive concepts of BOP business are premised on the idea that the poor can provide markets for commercializing next-generation technologies that offer social, environmental, and economic value. For example, high-tech cookstoves can allow people to use the sun's energy to prepare meals rather than requiring the poor to further deplete vital wood supplies or breathe in noxious fumes from dung, kerosene, or coal.

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See also CSR and CSR 2.0; Development, Sustainable; Fair Trade; Investment, Socially Responsible (SRI); Poverty; Social Enterprise; Triple Bottom Line; United Nations Global Compact

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Bicycle Industry

The bicycle industry includes everything from the design and manufacture of bicycles and accessories to sales, maintenance, and repairs. Compared to motorized vehicles, bicycle production, distribution, and use consume little energy and produce few emissions. Any improvements in the sustainability of the industry, however, must come from improving production processes and promoting biking as a viable alternative to driving automobiles.

Bicycles—two-wheeled, human-powered conveyances—were introduced in their current form in the late 1800s. They were rapidly adopted all over the world, both for recreation and for utilitarian travel. Bicycles continue to be popular today for both of these purposes. An estimated one billion bicycles are currently in use worldwide.

The invention of the bicycle has been credited for a number of social and economic advances. Bicycles made it easy to cover long distances, placing dwellings at the urban outskirts within reach of urban jobs and thereby fostering suburbanization. Women learned to cycle and their new freedom of movement and the self-reliance that came with it played a role in women's emancipation. Ball bearings, pneumatic tires, and metalworking and mass production processes originally developed for bicycles were later put to use in automobile and aircraft manufacturing. Cyclists lobbied for better roads, and the paving they secured soon served transit and automobiles as well.

Today bicycles are used for a variety of purposes including recreation, exercise, touring, commuting, shopping, courier and other delivery services, policing, and competitive sports. They are a major travel mode in a number of countries. In Chinese cities, more than half of daily trips are by bicycle (Gardner 2008; IBF 2010). Bicycle travel is also high in India and other Southeast Asian countries. In the Netherlands and Denmark, some 20–30 percent of travel is by bicycle (IBF 2010). Elsewhere utilitarian bicycling (i.e. bicycling as a form of commuting) is less prevalent, but individual cities in the United Kingdom, Germany, Italy, and France have made great strides in increasing bike travel in recent years. Latin American cities such as Bogotá and Santiago have also successfully promoted greater bike use.

In the United States, bicycling is a significant travel mode in many university towns, but bikes nationwide account for about 1 percent of utilitarian travel (Gardner 2008). A number of U.S. cities, however, have been making concerted efforts to increase utilitarian cycling. New York City, San Francisco, Los Angeles, and Chicago are among the cities that have invested in bike facilities and programs to encourage bike use, recognizing its health and environmental benefits and its efficiency for the many urban trips that are one to four miles in length.

Bicycles and bicycling are a significant industry, involving bicycle designers, manufacturers, producers and distributors, retail sales outlets, and manufacturers of specialized accessories such as helmets and bike clothing. In addition, because most bicycling occurs on public streets, roads, and bike paths, government agencies that plan, design, and implement bike facilities and regulate bike use are important actors.

Bicycle Production

While hundreds of companies produce bicycles worldwide, stock sales and consolidations since the 1980s have resulted in far fewer companies than brands. For example, Schwinn, for many years the largest American bicycle manufacturer and retailer, underwent two bankruptcies and was eventually purchased by Pacific Cycle, a distributor that sold GT and Mongoose bikes as well as its own brand name.

In 2004, Pacific Cycle in turn was acquired by Dorel Industries, which subsequently purchased Cannondale bikes, SUGOI performance apparel, and, more recently, several bike retail-specialty stores in the United Kingdom. Likewise, Cycleurope (part of the Swedish conglomerate Grimaldi Industri) sells bikes under the brand names Bianchi, Crescent, DBS, Everton, Gitane, Kildemoes, Legnano, Micmo, Monark, Puch, and Spectra—all independent bike producers in earlier times.

Bike manufacturing also has become highly concentrated in a few countries in recent years. Only a few decades ago bike producers were also bike manufacturers, and bicycles were manufactured in many countries around the world, including the United States, Canada, Italy, France, Spain, England, Germany, Greece, Austria, Belgium, Russia, Finland, the Czech Republic, Australia, Japan, China, and India. Since the 1980s, however, many bike companies have moved substantial portions of bike manufacturing to lower-cost factories in Asia. Today manufacturing is heavily concentrated in the People's Republic of China, Taiwan, and India, which together accounted for an estimated 82 percent of the 124 million bicycles manufactured worldwide in 2007 (NBDA 2008).

For example, the Taiwanese company Giant, the world's largest bicycle manufacturer, builds not only the bikes sold under its own name but also the Cycleurope brands. Trek, a major brand in the United States, once built its bikes in Wisconsin, but now gets many of its bikes from Asia. Kuota, a brand developed by the Italian company Sintema, gets its frames from the Taiwanese manufacturer Martec.

A few high-end and specialty bike companies, such as the Italian company Colnago, the French company Time, and the U.S. companies Seven and Litespeed, continue to manufacture many or all of their bike frames themselves. Other high-end bicycle companies purchase frames from Asia, but do their own bicycle design and assemble the bikes back at home. For example, the Spanish company Orbea uses Martec to manufacture the frames it designs, finishing the bikes in Spain. Typically, if 60 percent or more of the value added—assembling the bicycle—is in the country, it will be labeled as made in that country.

The sustainability of bicycles is largely a function of their manufacturing, assembly, distribution, and sales processes. A lifecycle analysis (LCA) would account for energy, emissions, and other impacts at each step, from choice of materials and the resulting resource extraction through the disposal of the bike at the end of its useful life. A more complete sustainability analysis would consider the equity and health impacts of labor practices. Such analyses are country- and design-specific and are only now beginning to be carried out, but it is clear that the more sustainable the design choices and manufacturing processes, the more sustainable bicycles will be.

Bicycle Sales

The United States alone purchases about 15 percent of all the bicycles produced in the world, averaging nearly 19 million bike purchases a year. U.S. sales value in 2007 amounted to $6.1 billion (NBDA 2008). The bicycles sold include children's toys as well as adult bikes. The adult bike market includes a variety of bicycles for specialized uses, terrains, and riding preferences.

Bicycles are sold by mass merchants (big box discount stores and national or international chain toy stores and department stores), as well as by chain sporting goods stores, hardware stores, and independently operated bicycle shops. They also are available by mail order and through the Internet. Children's bicycles and other less expensive bikes ($300 or less) are often bought from the mass merchants, while higher quality and specialized bikes, priced from $300 to $2,000 or more, are most often bought from bicycle specialty shops and sporting goods stores.

According to the U.S.-based National Bicycle Dealers Association, of the bikes purchased in the United States in 2007, 73 percent were from mass merchants, with 17 percent from specialty bike stores, 7 percent from chain sporting good stores, and 3 percent from all other retail sources. Mass merchants, however, accounted for only 36 percent of the total retail dollars for bikes, mostly because their sales are predominantly for children's bikes. Bike specialty shops captured 49 percent of total retail sales dollars for bikes, with sporting goods stores accounting for 9 percent (NBDA 2008).

Recently, electric bicycles, or e-bikes, have been growing in popularity. Some 21 million of these battery-powered vehicles were sold in 2007, most of them in China; only 120,000 e-bikes were sold in the United States in 2007, but that total is expected to grow in the near future (NBDA 2008). E-bikes require less physical effort than a pedal-powered bike and can reach considerably higher speeds, allowing longer distances to be traversed. Naturally, they reduce the exercise benefit from biking, and the speed differential between e-bikes and conventional bikes has become problematic in some Chinese cities. Concerns have been raised as well about e-bikes' environmental sustainability. E-bike battery production, use, and disposal are an added environmental burden compared to a conventional bicycle. On the other hand, e-bikes are far more environmentally friendly than other private motorized transportation, including motorbikes, motorcycles, and automobiles.

Bicycling's Role in Sustainability

Bicycling can be a significant contributor to economic, social, and environmental sustainability, whether the bike is used for recreation or for travel purposes. The economic contribution from bikes is not only a matter of bike sales; in some countries the sale of related goods and equipment is significant. In the United States, for example, retail sales of bicycles amounted to $2.86 billion in 2007, whereas sales of tires, other parts, clothing, and shoes for cycling added another $3.24 billion (NBDA 2008). Those numbers do not include totals for sales and service. Furthermore, in many countries, bike maintenance and repair are important economic activities. In the United States, specialty bike shops usually offer such services; in developing countries, bike repair is often an independent, owner-operated business enterprise.

Utilitarian cycling has economic benefits for users as well. In many cities, bicycling can be the fastest way to travel, saving users time compared to other modes. Users also can save money by using a bicycle instead of some mode of motorized travel. For example, if a bike is used instead of an automobile for a six-mile round trip, a traveler in the United States or European Union (EU) would save several dollars a day in auto operating costs. At that rate, the savings would pay for a mid-priced bike (about $500) in less than a year.

Cycling also has indirect economic benefits. To the extent that utilitarian cycling removes cars from the road, it can reduce travel time for other motor vehicle users. Furthermore, bicycling can be supported with modest infrastructure investments; a bicycle takes up a fraction of the road space of an automobile and its parking requirements are also modest. Studies in Chinese cities have shown that one bike lane can carry as many people as several lanes of auto traffic. In the United States, bike lanes have been created from overwide streets and highways and by turning unused railway beds into paved trails, both low-cost strategies that can be used to reduce automobile congestion.

Bikes also produce environmental benefits. For example, the energy required to produce and transport the food required by a cyclist is a tiny fraction of the energy needed to power even an energy-efficient car. Likewise, compared to other vehicles, a bike uses far fewer natural resources and its production embodies far less energy. Bikes also consume very little urban space, have no tailpipe emissions, and are quiet.

Barriers to Bicycling

A major concern raised about biking has been bike safety in mixed traffic flows. In most countries bicycles are classified as vehicles and are subject to rules of the road, including traffic laws. Some countries and certain states in the United States have fine-tuned traffic laws for bicycles to reflect their unique size, maneuverability, and stopping and starting characteristics, but others have emphasized separation of bikes and motorized traffic.

In many countries, whether bicycles should be directed to use designated bike lanes or bikeways is a hotly debated issue. Bike lanes and off-road bike paths are often proposed as a safety measure, but cyclists themselves disagree on whether they are a valuable aid to cycling or a way of pushing cyclists off the streets to facilitate motor traffic. Some argue that separate lanes make the inevitable intersections of bikes and traffic more difficult, actually worsening bike safety. The issue is an important area of research, with centers in Sweden, Denmark, the Netherlands, the United Kingdom, and the United States specializing in the topic.

Other strategies aimed at improving bike safety and comfort are usually less controversial. They include traffic calming, contraflow bike lanes on one-way streets, and bike priority treatment at intersections. (Bike priority treatments describe various methods of making bike travel safer, such as instituting "no turn on red" restrictions and installing "advanced stop lines," which permit bicyclists to line up ahead of traffic while stopped at a red light.) In addition, educational programs for both cyclists (on safe biking) and motorists (on bicycle awareness and safe driving in mixed traffic) are being undertaken, with both governments and nonprofit organizations providing leadership.

A second potential barrier to utilitarian biking in some countries, including the United States, is the sheer length of many trips. The dense land-use patterns found in many Asian and European cities and suburbs make biking a realistic option for many trips because the distances are short.

If the aim is to encourage greater bike use for work, shopping, and personal business, these activities must be located within reasonable distance of residential areas, preferably no farther than one to two miles. Land use planning that promotes mixed-use development in town centers can create opportunities for biking. Such centers also can be transit hubs, opening up the opportunity to use bicycles as an access mode to transit for longer trips. Locating secure bike parking near stores and transit stations is an important element of this strategy.

Experiences in Sweden, Denmark, Germany, and the Netherlands indicate that bikes will be used by a variety of travelers if there is an attractive set of destinations within a ten- to fifteen-minute bike ride. In the United States, the university towns of Berkeley, California, and Cambridge, Massachusetts, have emphasized nonmotorized modes of travel and have seen high levels of bike use for shopping trips as well as for transportation to work and school. Good urban planning, not only for bike facilities but also for coordinated land uses, can greatly aid in the promotion of bicycling.

Practices that Promote Bicycling

Several innovative practices can promote greater use of bicycles. One strategy that has greatly expanded bike use in a number of cities is bike sharing. A few programs have been organized on a membership basis, but in the most common program design, anyone can obtain a bike for a small fee from bike stations located throughout the service area, returning it to another station at the rider's destination. Programs have variously been organized by municipalities, by advertising agencies, and by transit operators. The programs have been highly successful in such diverse places as Copenhagen, Helsinki, Montreal, and Washington, D.C., though in some cases, such as Paris, bike theft has been a serious problem.

A second strategy that can expand bike use and increase transportation sustainability more generally is to permit bikes to be carried on mass transit systems, allowing the bicycles to be used as access modes at both ends of the trip. Bus companies such as AC Transit in Oakland, California, have installed bike carriers on their buses to facilitate this. Rail transit systems in the San Francisco Bay area and Los Angeles also accommodate bikes in some cars at some times of day.

A third strategy is the development of bike boulevards, a network of streets where bikes and motor vehicles share roads and street design is optimized for bike use. The bike boulevard is given priority at minor intersections and bike priority treatments are installed at intersections with major arterials to aid crossing and turning. The bike boulevard with its assortment of "treatments" aims to give cyclists parity with motorists while providing safe and convenient connections to major destinations. It also aims to increase motorist awareness of cyclists.

Bicycling as a Sustainability Measure

Bicycling is an energy-efficient, nonpolluting, fast, low-cost means of travel, one that is eminently appropriate for communities that wish to promote sustainability. Changes in the industry are concentrating on manufacturing in a few countries, but are also expanding retail activities to include clothing and bike equipment as well as bicycles themselves.

Although bicycle travel is environmentally friendly, the process of designing, producing, and distributing bicycles has room for improvement. Efforts are currently underway to begin collecting and reporting on the overall sustainability of these processes. This involves assessing the choice of materials in the bike's design, tracking emissions and energy use in materials production and manufacturing, examining waste management practices at manufacturing and assembly sites, documenting labor practices and worker health and safety records, accounting for the impacts of global transportation of bike parts and finished bikes, and considering the potential for recycling of the bicycle and its components at the end of their useful lives. Greater commitment to a fully sustainable bicycle is being sought from corporations worldwide.

Government can be a partner with the bike industry, providing the facilities on which bikes travel. Measures that improve bicycle safety and create environments where many activities can be reached by bike are helping more people choose cycling. Innovations that create better access to bikes and better bike network connectivity also can encourage more biking.

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See also Automobile Industry; Design, Industrial; Health, Public and Environmental; Lifecycle Assessments (LCAs); Manufacturing Practices; Municipalities; Public Transportation; Smart Growth; Supply Chain Management

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Biomimicry

Biomimicry is the strategy of using inspiration from nature and living organisms for design and problem solving. As an important component of a sustainable design ethic, biomimicry utilizes many of nature's best characteristics, including low toxicity, energy efficiency, and biodegradability. While existing in concept much earlier, the term biomimicry *was introduced in 1997; Velcro is a well-known example.*

The term *biomimicry* refers to the practice of designing materials, processes, or products that are inspired by living organisms or by the relationships and systems formed by living organisms. It is part of a class of problem-solving tools that use nature for inspiration, which also includes *biomimetics* and *bionics*.

Biomimicry is an important component of a sustainable design ethic, as designs inspired from nature are often less toxic in their materials, more efficient in their use of materials and energy, more reusable and biodegradable, and derive more of their power from the sun.

Historical Development

Janine Benyus is widely credited as having coined the term *biomimicry,* which she defined as "the conscious emulation of life's genius" (1997, 2) in her book, *Biomimicry: Innovation Inspired by Nature*. She was not the first to employ or write about the practice of looking to nature for design inspiration; researchers cite examples as old as attempts by the Chinese to make artificial silk earlier than 1000 BCE (Vincent 2001). In an early recorded reference to natural design inspiration, Leonardo da Vinci wrote that "human ingenuity . . . will never devise any inventions more beautiful, nor more simple, nor more to the purpose than Nature does" (Leonardo da Vinci 1970, 837).

In the modern era, Jack Steele of the U.S. Air Force used the term *bionics* at a USAF meeting in 1960 to describe "the science of systems which have some function copied from nature, or which represent characteristics of natural systems or their analogues" (Vincent 2001, 51). In 1969, the inventor and biophysicist Otto Schmitt used the similar term *biomimetics* in a paper titled "Some Interesting and Useful Biomimetic Transforms" (Bar-Cohen 2005); a definition for *biomimetics* subsequently appeared in *Merriam-Webster's Dictionary* in 1974:

> [T]he study of the formation, structure, or function of biologically produced substances and materials (as enzymes or silk) and biological mechanisms and processes (as protein synthesis or photosynthesis) especially for the purpose of synthesizing similar products by artificial mechanisms which mimic natural ones

These developments suggest that innovators were beginning to devise systematic procedures for looking to the natural world to inspire technological design.

Perhaps one of the most celebrated examples of such biomimetic innovation was the invention of the Velcro brand hook-and-loop fastener by the Swiss inventor George de Mestral in 1941. On a hunting trip with his dog in the Alps, de Mestral observed burrs from a burdock plant clinging to his clothing and his dog's fur. He examined their hooks under a microscope, noticing how they adhered to the loops in his clothing, and determined that he could use this pattern from nature to make a novel adhesive device; he spent over a decade developing the Velcro fastener. Velcro fasteners have since been used from space applications to children's apparel (Velcro 2009; Stephens 2007).

The American inventor Buckminster Fuller (1895–1983), who was passionate about the problem of human sustainability on Earth, was one of the first to link the study of nature-inspired design to the cause of sustainability. The Buckminster Fuller Institute still teaches courses on Nature's Design.

This research set the stage for Benyus to synthesize the theory of nature-inspired design in *Biomimicry*. Indeed, the majority of her book is an exploration of contemporaneous biomimetics research across many fields and the visions and values of the scientists conducting this research. To further develop these ideas, Benyus and her colleague Dayna Baumeister founded the Biomimicry Guild in 1998, a for-profit consultancy dedicated to helping companies effect biomimicry. The Biomimicry Guild continues to do this work and maintains itself as the centralized arbiter of the practice. Its nonprofit affiliate, the Biomimicry Institute, works to promote biomimicry through education and conservation efforts.

Through her book and her subsequent work, Benyus furthered the field of biomimetics by making three extremely important contributions.

1. She defined *biomimicry* as a distinct design practice and innovation framework, above and beyond the separate technical research initiatives collectively termed *biomimetics*.
2. She inextricably linked this new design ethic to the burgeoning sustainability and sustainable-business movements.
3. She popularized nature-inspired design to the mainstream reading public.

Biomimicry Methodology

Perhaps because of the prior history of related ideas, many new developments and existing concepts are characterized as biomimicry that can better be described otherwise.

The practice of biomimicry is often erroneously understood as attempting to duplicate nature; the word itself seems to imply this from its construction from the Greek *bios* (life) and *mimesis* (imitation). For example, a product designed to simply resemble a living organism may be cited as an example of biomimicry. Unless the form also inspires the functionality of the design, this biomorphic design (Fletcher 2008) is actually an instance of *biophilia*, the "innate tendency to focus on life and lifelike processes" (Wilson 1984, 1). The use of this innate human attraction to natural shapes, forms, and concepts is a marketing tactic, not a conscious sustainable design practice. The resonance between the ideas of biomimicry and biophilia was well-established by the time Benyus and E. O. Wilson came together to deliver a joint keynote address at the 2008 Greenbuild International Conference and Expo in Boston.

Through subsequent work, Benyus and others have identified two levels of nature-inspired design that are deeper than simple biomorphic design. *Bio-utilization* occurs when the designer uses part or all of an actual living organism in his design solution, such as harvesting silk from a silkworm. In *bio-assistance*, or more simply called domestication, the designer controls a living organism in order to produce a desired material or outcome, such as breeding silkworms to produce silk fibers. While both of these are examples of using nature to solve problems, they are not examples of *learning* from living organisms or natural principles to inform the problem-solving process (Benyus 2007; Faludi 2005a). Many forms of biotechnology and genetic engineering follow one or both of these approaches (Winston 2009).

Conversely, the true "biomimics," as Benyus terms the practitioners of biomimicry, do not blindly copy the forms, materials, colors, or behaviors of organisms. True biomimics seek to understand and adopt nature's underlying principles—thus Benyus's definition as the *conscious* emulation of life's genius. An illuminating example comes from the long quest toward human flight: by scaling up a bird's flying abilities to human size—flapping wings and all—as did the early ornithopters, one cannot generate enough lift to render a person airborne; but by understanding the mechanism of airflow over the bird's wing, these flight capabilities can be mimicked to effect human airborne transport (Robbins 2002).

Biomimicry as a Design Practice

The Biomimicry Guild recognizes two distinct pathways for biomimicry as an innovation tool: "challenge to biology" and "biology to design," which are analogous to the more well-established technology-commercialization pathways of "market pull" and "technology push."

A challenge-to-biology situation, the market-pull innovation pathway of the biomimicry world, occurs when a company or individual identifies a specific design challenge and searches for potential solutions to this challenge that occur in nature. The challenge for which natural inspiration is being sought could be as broad as, How does nature store energy? or as specific as, How does nature make a nontoxic, water-soluble red dye at room temperature?

An example of this market-pull innovation is the 2005 Bionic concept car from Mercedes-Benz, for which designers from the company looked for natural inspiration from the ocean to create a more efficient automobile. Visiting an aquarium, they found that the tropical, shallow-dwelling boxfish (*Ostracion cubicus*) has both an extremely low drag coefficient and a very rigid exoskeleton as it lives in conditions of changing currents and "high traffic." The designers worked with biologists to mimic the boxfish's aerodynamic form, and they developed a process to minimize material use in low-load areas while reinforcing high-stress areas to "grow" a car frame that mimicked the fish's bony structure (Daimler 2008). These measures resulted in a car design that has a 25 percent lower drag coefficient than the most aerodynamic production car, the Honda Insight (Phenix 2007); elements from the Bionic were also used in a 2009 series of alternatively fueled Mercedes-Benz concept cars (Vella 2009).

In contrast, a biology-to-design situation—biomimicry's technology push—occurs when a biologist, ecologist, naturalist, or any casual observer of nature perceives a natural phenomenon and seeks to invent a product or technology that takes advantage of the phenomenon. One example of this approach is Lotusan paint, made by Sto Corporation. The leaves of some plants, such as the sacred lotus (*Nelumbo nucifera*), have a particular hydrophobic surface topography that causes incipient rainwater to remove dirt particles as it rolls off the surface; using this so-called Lotus Effect, Sto created an exterior paint that is passively cleansed during rain showers (Barthlott and Neinhuis 1997).

A third possible approach to innovation through biomimicry is the use of patterns and systems in nature to inspire solutions. For example, while man-made technology most often solves problems by manipulating the usage of energy, nature more often uses information and structure (Vincent et al. 2006). Patterns in nature have been used for product design, such as the Entropy carpet tile developed by Interface Inc., a modular carpet manufacturer in the United States. Interface's lead designer, David Oakey, developed a method of infusing randomness of color and pattern into carpet tiles, obviating the need to match dye lots when replacing soiled tiles—a property he explicitly borrowed from the forest floor (Schwartz 2007).

Framework for Innovation

Biomimicry is a useful innovation framework for several reasons.

First, by providing a different perspective on a design challenge, biomimicry can spur creativity among a design team looking for a new approach to an old problem.

Secondly, recognizing that certain challenges in engineering, architecture, product design, and other fields have already been surmounted by a prior design—a living organism—is an important first step to achieving the result. For example, the knowledge that the abalone, a sea snail, makes a stronger, more shatter-resistant ceramic in its shell than our current manufacturing methods has inspired the development of stronger man-made ceramics (Lin and Myers 2005).

Third, looking to natural solutions can suggest actual mechanisms toward a design solution. For example, Dr. Kaichang Li of Oregon State University conducted research into the adhesive properties of byssal threads, proteins secreted by mussels to adhere securely to rocks despite salt corrosion, wave action, and constant wetting and drying. Li found that soy proteins can be modified to behave like these byssal threads (Liu and Li 2004), an innovation used by Columbia Forest Products to make a nontoxic adhesive called PureBond that replaces the more traditional, and more toxic, urea formaldehyde.

Finally, solutions in nature are developed with an ecosystem context. Many of the design constraints that living organisms face—such as a production "cost," generally in the form of energy expenditure (Vincent 2001)—are similar to the constraints faced by product designers. By mimicking one or more mechanisms of a natural solution, designers explicitly or implicitly leverage the ecosystem context from the organism, often resulting in higher material and energy efficiencies, lower costs, and/or decreased toxicity than traditional solutions. Many of the examples described herein exhibit these improved eco-efficiency characteristics.

This last benefit of biomimicry suggests its place in the growing sustainable business movement.

Role in Sustainable Business

The most important distinction of the biomimicry methodology from the biomimetics research that preceded it is that it provides a systematic framework for sustainable design. As the authors Paul Hawken, Amory Lovins, and L. Hunter Lovins noted in *Natural Capitalism*, "[T]he economics of resource productivity are already encouraging industry to reinvent itself to be more in accord with biological systems" (1999, 15).

Benyus observed in her book that the diverse examples of biomimetics research she had investigated had several common threads, suggesting such broader generalizations: nature runs on sunlight, fits form to function, recycles everything, and banks on diversity (1997, 7). In subsequent research, Benyus and others have developed these empirical observations into fundamental tenets that reflect nature's sustainable strategies. The Biomimicry

Guild calls these tenets "Life's Principles," which describe life as, for example, being locally attuned, exhibiting resilience, using available free energy, using benign manufacturing, recycling all materials, and optimizing rather than maximizing (Biomimicry Guild 2009). Others who have proposed unified principles of sustainable design based on nature include Stephen Vogel and Kathryn Davis (2000) and Nathan Shedroff (2009a).

Biomimicry is intended to be one in a suite of tools for green design, complementing other tools such as green chemistry (Makower 2008) and life cycle assessment (Shedroff 2009b). There are other frameworks based on sustainable values with which biomimicry shares a conceptual basis of being based in observations of nature, such as the permaculture movement (Grover 2007).

Controversies, Criticism, and Limitations

Biomimicry implicitly relies on the theory of evolution. Although Benyus made several references to evolutionary adaptation in her 1997 book, the Biomimicry Institute (2009) tries to play the part of the agnostic: "Although biomimicry is founded on the scientific concept of evolution, perhaps you may be able to replace the concept of evolution or 'nature's genius' with a concept or belief that results in the same idea—that life on earth today embodies a virtually infinite reservoir of sustainable solutions." In practice, since biomimicry arises from the science of biology, few practitioners can speak about biomimicry without referring to the scientific principles of evolutionary adaptation and natural selection.

Some critics have suggested that biomimicry adds unnecessary complexity to otherwise obvious green design concepts. Auden Schendler, quoting Dr. Michael Brown of the *Journal for Industrial Ecology*, remarks that biomimicry "seems to be about making goals that are simple and straightforward—avoid toxics, strive for closed loops, minimize energy, and so on—into something that requires a consultant to explain how you should imitate nature" (Schendler 2009, 188).

Biomimicry practitioner and lecturer Jeremy Faludi much more strongly supports the practice of biomimicry, but notes (citing the works of Kevin Kelly and Stephen Vogel) some tactical limitations of solutions arrived at by using biomimicry. For example, nature has a tendency toward short-term generational bias since evolution does not tolerate any failed generations; more pragmatically, the need for natural solutions to be continuously maintained or rebuilt can challenge product development—although this can actually be useful for products that require biodegradation or planned obsolescence (Faludi 2005b).

Future Promise of Biomimicry

To date, biomimicry has enjoyed success as a product development framework, with dozens of products commercialized and over a thousand potential product strategies identified as of 2009 (AskNature 2009). Biomimicry will increasingly become a more mainstream tool for product innovation—whether through the integration of biologists onto design teams, as the Biomimicry Guild advocates, or through the more complete translation of the biomimicry methodology and biological information to nonbiologists.

Biomimicry's greatest promise, however, lies in the translation of the deep principles of nature into business processes for sustainable innovation (e.g., Faludi 2005b) and sustainable entrepreneurship (Stroud 2009). This can be accomplished through codified principles for corporate sustainability that are based on nature's empirical models (e.g., Werbach 2009). Benyus has said that "now is an opportune time for global businesses to develop profitably around some of the ideas nature offers" (Benyus and Pauli 2009); this transition will come from professionals who strategically integrate nature's principles into corporate value propositions and business values.

The evolution of the biomimicry framework as a prototype for sustainable business is reflected in its increasing coverage in mainstream business periodicals, including *The Economist* (9 June 2005, 6 September 2007), the *Wall Street Journal* (11 January 2008), and *BusinessWeek* (11 February 2008). The biomimicry concept is also being used in an increasing number of MBA courses to educate future business leaders, such as those taught by Hunter Lovins and by Nathan Shedroff at the Presidio Graduate School, by Tom McKeag at the University of California at Berkeley, and by Asheen Phansey at Babson College (Di Meglio 2009).

Built on ancient foundations of human innovation inspired by nature, the potential of biomimicry to transform the business world toward greater sustainability has just begun to emerge over the last decade. The major challenges of the twenty-first century—climate destabilization, resource consumption, ecological toxicity—will prove fertile ground for the development of solutions using biomimicry in all spheres of industrial practice and business innovation.

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See also Biotechnology Industry; Chemistry, Green; Design, Industrial; Education, Business; Investment, CleanTech; Lifecycle Assessments (LCA); Natural Capitalism

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Biotechnology Industry

Modern biotechnology combines life sciences knowledge with innovative technological techniques to benefit society. Key biotechnology disciplines are fermentation, applied use of enzymes and plant-cell culturing, plant breeding and crop protection, genetic engineering, and drug development. Its benefits include the reuse of some manufacturing waste products and replacement of petroleum-based chemicals. But it also creates wastes, particularly wastewater, and controversy surrounds its safety.

Biotechnology is not new; it has been suggested that humans have unwittingly used microorganisms for about eight thousand years to make beer and wine. Modern biotechnology, however, is firmly based on advances in the life sciences, or the study of living things. Therefore biotechnology can be broadly viewed as scientific expertise and innovative technological prowess connected to the life sciences in order to benefit society. But the public's perception of biotechnology has often been shrouded by concerns about the cost to society of any negative impact that might arise from it. For instance, there have been persistent public debates and fears about the safety of genetically modified foods (Leung and Alizadeh 2009).

Global warming and the continued depletion of nonrenewable natural resources such as fossil fuels threaten economic growth and development in the twenty-first century and beyond. Innovative solutions to help in the quest for sustainable economic growth could come from the life sciences and might present the biotechnology industry with new commercial opportunities. In the world of living things, there are examples of ongoing natural recycling and the regeneration of resources. For instance, fallen leaves in autumn support the growth of soil bacteria and fungi, enabling the release of nutrients contained in the leaves back into the soil for plants to use later. But the biotechnology industry faces many challenges, including the need to develop more energy-efficient industrial processes that generate less waste and pollution during the manufacture of consumer products.

Essential Characteristics

The question of how well or whether the biotechnology industry can help build a sustainable economy can best be answered with a better understanding of the essential characteristics of biotechnology. An important biotechnology is fermentation, which is a natural biological process that converts an input—raw, complex materials (usually biological and renewable in nature)—into simpler products. The classic example of fermentation is beer, in which the starch in barley grains (made of thousands of glucose molecules) is converted into ethanol (a two-carbon alcohol) with the help of an agent—brewer's yeast. The product, ethanol, is a main component in beer.

The biotechnology mechanisms that are used to generate products depend on agents from living things (for example, beneficial microorganisms, enzymes, or genes), which are also natural and renewable. This biological means for product generation is environmentally friendly because bioprocesses typically operate without the use of harmful chemicals, and they are efficient in conditions that are normally compatible with living things. Like most industrial processes, the use of water in biotechnology is an environmental concern since clean, drinkable water is a limited natural resource. Hence a major bottleneck for the biotechnology industry is the need to use water resources more effectively: to develop cleaner processes that produce less waste or polluted water and to invent a means to recycle wastewater generated in industrial processes.

Biotechnology Applications

An examination of a few examples of the biotechnology industry's products will help us evaluate the industry's relationship with the goal of the sustained use of natural resources. (More comprehensive documentation of the various activities of the biotechnology industry is listed below in Further Reading.)

Fermentation

The fermentation industry is perhaps one of the oldest and most influential biotechnology industries found worldwide. The business of manufacturing fermented foods—such as cheese, beer, wine, and soy sauce—forms an important part of many economies. The general principle of fermentation also underpins the commercial production of many food additives such as citric acid (added to canned foods as a preservative) and monosodium glutamate (better known as MSG), a popular food flavor enhancer.

Sir Alexander Fleming (1881–1955), who won the Nobel Prize in Physiology or Medicine in 1945, discovered penicillin, an important biotechnology product. Since then it has been a weapon against bacterial infections, largely due to the fermentation of the antibiotic-producing penicillium fungi being a reliable drug-production technology. In the food and antibiotic fermentation process, a key required input is a supply of sugar for the target microorganisms to use to grow and produce the products of interest. Since this sugar does not have to be in a pure form, the cost of the fermentation process has been reduced considerably by the innovative use of sugars from a less expensive source, such as waste products from another bioprocessing industry. For example, citric acid fermentation has been fueled by the waste sugar from molasses production, which typically contains sugars sourced from sugarcane-processing factories.

The fermentation industry may help the waste disposal problem of another industry. And while biotechnology solutions are being developed to minimize or prevent pollution problems, biotechnology's industrial processes themselves can generate both the target products and unwanted materials or wastes, including wastewater. Another important waste stream (the flow of waste from creation to disposal) that results from the biotechnology industry usually consists of spent biomass (dead microorganisms) and/or biomaterials (complex organic materials). For example, the simple biotechnology deployed for urban treatment of raw sewage involves a bed of microorganisms through which raw sewage seeps. The microorganisms therein can feed on nutrients contained in the raw sewage. Globally on an annual basis, raw sewage treatment facilities generate huge quantities of spent microbial biomass in the form of sludge, which is unsightly, smelly, and invariably forms a complex with high levels of different health-hazardous heavy metals such as cadmium and lead. Disposal or reuse of sewage-derived sludge is problematic and remains largely unresolved. This is by no means an isolated problem associated with the biotechnology industry; it needs to be taken more seriously in any plan for future economic development.

Enzyme and Microorganism Technologies

Growing microorganisms is also a renewable biotechnology method and a dependable source of useful enzymes. The isolated enzymes are central to numerous well-known, innovative applications. A good example is the development of biodetergents. In one commercial formulation, a protease (an enzyme to break down protein into its soluble component parts called amino acids) isolated from a bacterium (*Bacillus subtilis*) has been found to work in detergent-like or alkaline (high pH) conditions. This bacterium was incorporated into washing powder, giving it better cleaning power, particularly with protein residues such as bloodstains left on dirty clothing. Generally, washing with warm water and this biodetergent is recommended since the protease works best at higher temperatures. A second generation of biodetergent is possible based on a discovery that another protease can work at an ambient (room) temperature. Washing without the need for warm water can lead to savings in electrical energy consumption and a lower electricity bill for the consumer.

Selective Plant Breeding

The biotechnology industry based on the use of plants and animals has as much impact on humans as that based on the use of microorganisms. For example, the purpose of plant breeding is to combine desirable traits (characteristics) carried separately by two different plants into a new, genetically improved variety of plant based on sexual reproduction, which is a natural biological process. The basic plant breeding technique is to facilitate the fusing together of the male sex cell (pollen) from one plant that has one set of desirable traits and the female sex cell (egg) that has a different set of desirable traits. After fusing, a single cell forms from which a whole plant (a hybrid carrying both sets of desirable traits) forms.

While hybrid plant production is no doubt commercially important, plant breeding has also given rise to what is widely known as the "green revolution." The geneticist and plant scientist Norman Borlaug (1914–2009), a Nobel Peace Prize winner in 1970, conducted innovative plant breeding experiments to develop wheat varieties that can yield several times more grains than other varieties using the same amount of land. The new varieties also perform better than traditional varieties in drought-prone areas. The U.S. economists Robert Evenson and Douglas Gollin estimate that from 1960 to 2000 the green revolution succeeded in raising the health status of 32 to 42 million preschool children; infant and child mortality would have been considerably higher in developing countries without these agricultural improvements (Evenson and Gollin 2003). If there is any lesson to be learned from this green revolution, it is that we need to feed the world's population without the expense of clearing natural landscapes for additional agricultural production areas. The success in growing enough food to feed the increasing global population, however, depends on inputs such as inorganic phosphate, other fertilizers, and other crop protection agrichemicals. This is not a sustainable practice and represents some challenging issues for the agricultural biotechnology industry in the twenty-first century.

Genetic Engineering

An innovative way to manipulate DNA molecules, widely known as the recombinant DNA technique, was developed and made public in 1973 by the genetic engineers Stanley Cohen and Herbert Boyer. The technique enables biotechnologists to cut out a DNA fragment from any organism and then join it to another DNA fragment from any organism of choice. In 1978, this innovation was first used in ensuring the world's supply of clinically prescribed human insulin. DNA fragments containing the genetic information to build human insulin were joined to the DNA of a laboratory-grown bacterium (*Escherichia coli*), which multiplies at an amazing rate, doubling its population size every twenty minutes. The recombinant bacteria are used to produce human insulin following the genetic instructions of the human insulin inserted into the bacterial DNA. This marks the entry of biotechnology into drug and vaccine production. According to the Biotechnology Industrial Organization (2005), biotechnology is a $30 billion a year industry that has produced some 160 drugs and vaccines. Although the power of recombinant DNA technology has been shown in health care applications, its impacts when applied to the quest for a sustainable economy remain to be seen.

In 1983 it was reported that an antibiotic-resistance gene isolated from bacteria by using the recombinant DNA technique was successfully inserted into a tobacco plant, conferring antibiotic resistance, a new trait, to the plant. This method of inserting a gene from any organism (not just from another plant) into plant cells and thereby creating a plant with a new trait (called a transgenic plant) is not a natural biological process. It is an innovation of biotechnology also known as plant transformation. Unlike plant breeding techniques, there was no prior experience with this new technology. Consequently many public debates concerning its safety and other issues have arisen.

Crop Protection

Crop plants can suffer substantial reduction in productivity because of weeds, viruses, bacteria, fungi, and insect pests. Chemicals including herbicides, fungicides, and insecticides have been widely used in modern agriculture. Many of these chemicals can persist in the environment and could adversely affect it. For example, one of the well-known controversies concerns the use of the pesticide DDT, a chlorine-containing insecticide. Since the 1940s, its use in killing mosquitoes was linked to ridding much of the Western world of malaria, which mosquitoes spread. Mounting concerns about the persistence of DDT in the environment and its alleged links to toxicity to birds and other wildlife have largely contributed to its complete ban in United States since 1972. Whether the ban is justifiable or even desirable, controversies like this create opportunities for other approaches, such as alternative crop protection measures aimed at reducing or avoiding foliar spraying of synthetic pesticides. Such approaches appear to be more sustainable means of crop plant protection.

The generation of transgenic cotton, soybean, and corn plants with genes conferring insect resistance, for example, is a new means of crop protection with the aim of replacing or minimizing the use of chemical insecticides. This at least eliminates the potential health hazard to growers who apply insecticides to safeguard crop production, and therefore farm income, from damages to crops by insect pests. A gene with the necessary information to make a protein that is poisonous to the main insect pests of cotton, corn, and other plants has been copied from a naturally occurring soil microorganism called *Bacillus thuringiensis* (Bt) and used to genetically engineer these plants. Feeding on these genetically engineered plants by target insects will lead to the breakdown of their gut walls and eventual death, although some fear that nontarget insects might also be adversely affected. Worldwide, growers planted more than 12 million and 20 million hectares of Bt cotton and Bt maize, respectively, in 2008 (Naranjo 2008). Large-scale commercial deployment of Bt crops between 1996 and 2005 was estimated to reduce the volume of insecticidal active ingredients by 101.5 million kilograms over the past ten years while increasing farm income by $9.87 billion worldwide (Naranjo 2008).

In the twenty-five years since the first transgenic plant was created, there has been no documented occurrence of hazards of epidemic proportion caused by transgenic plants to humans or the environment. But biosafety assessments of genetically engineered crop plants have identified some issues of concern. For example, experiments have shown that Bt rice plants can form hybrids with weedy wild rice relatives in fields. Some of these hybrids resembled the weedy parent but with extra fitness, being more resistant to insect pests, due to the unplanned transfer of the Bt gene. There is a real concern that the genetic engineering of crop plants, particularly with fitness-enhancement genes such as insect-resistance genes, might unwittingly lead to the accelerated evolution of so-called superweeds that are more difficult to control and could severely spoil agricultural productivity. Therefore more-widespread public acceptance of a role for transgenic plants in crop protection still awaits more long-term data regarding their safety to humans and the environment.

It is important to uphold vigorous biosafety assessments of transgenic plants during their development to minimize any negative effects on the environment and human health that might arise from the development and use of transgenic plants. Most scientists have already agreed that a guarantee of zero risk associated with the creation and use of transgenic plants is not possible (Lemaux 2008, 2009; Batista and Oliviera 2009). Besides, it remains to be seen if public perception of transgenic plant technology will improve and lingering fears can be allayed in the long term.

Plant Cell Culture

Before plant transformation was invented in 1983, plant biotechnologists used other tools to create income and minimize the depletion of natural resources and degradation of the natural environment. Many plants are known to have valuable compounds that can be used for drugs, cosmetic applications, or other purposes. For example, a naturally occurring purple pigment known as *shikonin* is found in the roots of mature wild plants native to Far East countries such as China, Japan, and Korea. It has been a folklore remedy for wounds and burns. It is now confirmed to have antibacterial and anti-inflammatory properties, and in Korea and Japan it is used chiefly as a natural (in preference to synthetic) pigment in lipsticks. A sustainable natural-product production strategy is to clone the cells of a target plant and then operate large-scale cell-culturing biotechnological processes. Plant cell cultures are renewable and can be scaled up to meet demand relatively easily and with minimal impact on the natural plant populations and the environment. In 1984, a commercial plant cell culture biotechnology was started to produce *shikonin*; this technology is superior to chemical synthesis in terms of process productivity and reducing the need for environmentally unfriendly chemicals such as the organic solvents commonly used in chemical synthesis. Despite this commercial success story, more research is needed to properly assess the economic feasibility of using plant cell culture biotechnology for producing other valuable natural products (including the effective anticancer drug Taxol) from plants.

Drug Development

The majority of the biotechnology industry workforce is in biomedical fields, given that health care is undeniably a top public concern. The public has great expectations of biotechnology for breakthrough treatments or cures for most human diseases and genetic disorders, expecting new drugs that cannot be made using existing chemical means. Many would say biotechnology has not fulfilled these promises. A mere several hundred biotechnology drugs (pharmaceuticals made using living systems) have been approved by the U.S. Food and Drug Administration since 1980. Notable examples of these, which only target some high-profile diseases, include Eli Lilly's Humulin (recombinant insulin for type 1 diabetes management), Amgen's Epogen (anemia treatment), Genentech's Avastin (colorectal cancer therapy), and Abbott Lab's Humira (rheumatoid arthritis drug). Many well-known diseases such as Parkinson's disease and most genetic disorders are still in need of better treatments or cures.

Industry's Response to Global Issues

Research and development in the biotechnology industry during the early twenty-first century includes projects connected to many global issues. They shed light on possible roles for the biotechnology industry and barriers to its involvement in the quest for a future sustainable economy.

The world's economy is run on fossil fuels that eventually will be depleted. We have come to depend on petroleum in our energy consumption and as an inexpensive source of starter chemicals (commonly called feedstock) to manufacture a variety of consumer products such as plastic bags and fabrics. These products, once consumers discard them, tend to last in the environment and fill up the landfills faster than we can build new ones. Biotechnology might provide innovative solutions to this problem. An example of research in this direction is genetically engineered sugarcane or other grasses to divert some of the plant's carbon metabolism to the production of a biodegradable plastic. Use of biodegradable plastic containers and bags could reduce the volume of waste in the landfills. This biotechnology is in its infancy, however, and much more research is needed to determine whether it can be scaled up to a level of economic feasibility and productivity efficiency that can replace petrochemical-based plastic.

Researchers are investigating converting plants that are not traditionally used as food for humans and animals into a source of biofuels and a renewable feedstock of chemicals to replace the petroleum-based feedstock. Algae, jatropha, and other plants that have diesel-like plant oils are the front-runners as renewable biological sources for biofuels.

Innovative biotechnology solutions for better biomass recycling or reuse depend on taking wastes from agricultural-, wood-, and food-processing facilities (including breweries using the appropriate enzymes from microorganisms and plants) and breaking them down primarily into sugars. These can be used to generate ethanol, a biofuel, or to replace petroleum-based chemical feedstock for chemical industries. But this plant biotechnology industry sector faces stiff competition from the development of many alternative renewable energy technologies such as wind turbines, hydrolakes, and solar energy capture.

Global warming was a main agenda item for the United Nations General Assembly in September 2009. This phenomenon is a potential threat to crop plant productivity and therefore a potential threat to world's food supply; many people fear unacceptable price hikes will ensue. Plant biotechnology research could lead to innovative strategies on how to mitigate the threat. We need to breed or engineer more drought-resistant crop plants that can also cope with higher growth temperatures and higher ultraviolet radiation levels. Plant biotechnology, particularly plant tissue culture, should also be applied to help rare and endangered plants meet the challenges of global warming (Leung 2009).

Environmental pollution arising from human activities such as mining must be reduced or remediated. The diverse biochemical abilities of microorganisms might be harnessed to develop cleaner mining technologies or practices. There is also the possibility of applying the natural processes of plants (a green process called phytoremediation) to remove toxic heavy metals from soils and waterways. For example, Chinese bracken ferns have the ability to remove excess arsenic from polluted environments. These are, however, not quick fixes to pollution problems as natural bioremediation processes typically take years to yield acceptable results.

Future Prospects

The biotechnology industry has addressed humans' diverse needs, including food (both quantity and quality), industrial and household chemical commodities, and the treatment of diseases. Increased government and commercial investment in the biotechnology industry, particularly in the medical field, will advance. We can expect big gains, for example from ongoing stem cell research, in learning from the human genome since its entire sequence was deciphered (but was not fully interpreted) in 2000, and in product and service development for cancers and genetic disorders. The biotechnology industry has much research to do if it is also to meet the challenges of sustainability and thus the quest for a global, environmentally sustainable bio-economy in the future.

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See also Agriculture; Biomimicry; Chemistry, Green; Consumer Behavior; Ecolabeling; Energy Industries—Bioenergy; Health, Public and Environmental; Marketing; Pharmaceutical Industry; Water Use and Rights

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Building Standards, Green

Green building standards have been developing around the world as a means of assessing and improving sustainable building. These standards address issues such as energy use, efficient resource use, ecological sustainability, and pollution. The development and use of assessment tools to measure the "greenness" of buildings help practitioners achieve consistency, meet targets and standards, and compare their projects' achievements.

During their construction and operation, buildings are responsible for a range of environmental and other impacts: raw materials are extracted and processed to construct buildings, and heating, lighting, and cooling equipment consume energy. But the result is the creation of safe, healthy buildings that provide us with shelter. Growing pressure to reduce energy consumption (particularly energy produced from fossil fuels), prevent resource depletion, and improve the overall sustainability of the built environment means there is a need to better account for how we construct and use buildings so that the scale of these impacts can be reduced. For this reason, green building standards have been evolving as a means of benchmarking and improving performance. The scope of this term encompasses standard setting and assessment.

Setting Appropriate Standards

The term *green building* can be interpreted in two ways. It may refer solely to environmentally conscious building, or it may be understood in the broader sense of sustainable building, taking into account social and other issues. The latter interpretation is more commonly the case; the main issues (or impact categories) generally held to be the most important in sustainable building, and which need to be addressed in standard setting, are as follows:

- energy use and carbon dioxide (CO_2) emissions—during construction and operation of the building
- efficient resource use and disposal—including materials, water, waste, and recycling
- transport emissions—consisting of fuel emissions and pollution from vehicles
- ecology and pollution—considering air, water, and land ecosystems, and the biodiversity of species
- development scale—involving social and economic impacts on the community
- health and well-being—including safety on site, indoor air quality, and ethics

The principle of setting standards, in any context, is usually to ensure that consistency, comparability, and quality are established, maintained, and monitored. In the case of green buildings, the idea might be to set appropriate levels of achievement for the completed building (for example, in postoccupancy evaluation), building products (for example, using lifecycle assessment), or even for a part of the process. This may be done in relation to the issues listed above (for example, to establish minimum standards in energy efficiency, recycled content, or travel distances from factory to building site).

In some countries, such standard setting emanates directly from government in the form of building codes or regulations that exist alongside other standards relating to buildings such as fire safety, structural integrity, or access for disabled persons. It may also arise from planning law, specific client requirements, or conditions of development for particular sites. Importantly, in some cases aspects of these standards may be mandatory, and in others aspects may be voluntary; governments can set absolute targets for energy consumption and have done so across Europe. Building approvals can therefore rest on the satisfactory attainment of these targets.

A vast range of political, climatic, and cultural pressures influence what "green building" means in a particular context, so it is very difficult to give a sense of the overall, global position on green building standards (although there are some commonalities such as energy use, carbon emissions, and resource efficiency). This problem has been acknowledged within the international standard-making community; for example, in Europe work is under way to harmonize assessments for buildings, but it is clear that individual countries or even regions and states may wish to pursue their own priorities alongside an overall framework. This is appropriate because sustainable development is not about a one-size-fits-all solution—context is important.

Commonly Used Assessment Tools

In response to both mandatory and voluntary standard setting, a range of assessment tools has been developed for use in the measurement of sustainable buildings, albeit they work in slightly different ways; different weightings, for example, may be applied in accordance with national policy or legislative priorities. The aim of these tools is to help practitioners achieve consistency, meet targets and standards, and compare projects' achievements. Although many hundreds now exist, including Green Star (Australia), CASBEE (Japan), and GBTool (software), two principal assessment tools are used around the world—LEED Green Building Rating System and BREEAM.

LEED (Leadership in Energy and Environmental Design) Green Building Rating System was developed in the United States in 1994, released in 1998, and is now used extensively. LEED is based on a single approach within which a range of building types can be evaluated, including new buildings, interiors, homes, neighborhoods, and existing buildings. It assesses against a list of categories (sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation and design process, some of which include prerequisite items), and then it awards points and gives an overall rating (no rating, certified, silver, gold, or platinum).

BREEAM (Building Research Establishment Environmental Assessment Method) was developed in the United Kingdom in 1990. It is used as the basis for a large suite of BREEAM versions geared specifically to nonresidential building types such as retail, health care, courts, offices, prisons, industrial buildings, and schools; there is also an international version. BREEAM evaluates buildings against a set of criteria (management, health and well-being, energy, transport, water, materials, land use and ecology, and pollution). It also awards points and assigns an overall rating (pass, good, very good, excellent, or outstanding). In the United Kingdom, all new public buildings must achieve a rating of excellent; around the world, an estimated 100,000 buildings have been certified to meet BREEAM standards.

While these assessment tools help manage the building process successfully, they have been criticized for reducing sustainable building to a "tick / check box" exercise that undermines the integrated nature of the subject.

Outlook for the Future

Building codes and standards on energy consumption, resource efficiency, and other impacts are likely to increase, putting more pressure on the construction industry to devise new ways of building. In tandem, tools like LEED and BREEAM will most likely continue to develop, grow in use, and become more accepted as part of the normal practice in developing sustainable buildings.

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See also Cement Industry; Energy Efficiency; Facilities Management; Lifecycle Assessments (LCAs); Municipalities; Property and Construction Industry; Smart Growth

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Cap-and-Trade Legislation

One approach to controlling greenhouse gas emissions, "cap-and-trade" places caps, or limits, on allowable emissions (set by the government) but permits participating facilities to buy and sell, or trade, "allowances" on the open market. The most prominent example in U.S. law is the acid rain control program in the 1990 Clean Air Act Amendments. Cap-and-trade legislation is now being promoted to help mitigate global climate change.

Cap-and-trade legislation is intended to directly reduce emissions of a particular pollutant into the environment. The trading feature of this legislation is attractive to economists and others because it can significantly reduce costs. Cap-and-trade programs are a prominent feature of existing and proposed climate change mitigation efforts.

Acid Rain Control

The most prominent example of cap-and-trade legislation in the United States is the acid rain control subtitle in the Clean Air Act Amendments of 1990. This legislation, which reduced sulfur dioxide emissions at a fraction of the projected cost, has been used to support the use of cap-and-trade provisions in international and national climate change programs.

The Clean Air Act was adopted originally in 1970 and has resulted in significant reductions in a variety of pollutants, including particulates, nitrogen oxides, and lead. The primary focus of the Clean Air Act is to ensure that the level of these pollutants in the ambient or outdoor air does not exceed a level that is "requisite to protect public health." Once pollutants fall to the ground or onto the water, they are not of concern under this part of the Clean Air Act. The problem, of course, is that sulfur dioxide and other pollutants settling onto the ground or surface waters acidify these environments, impair fish and insect life, and damage soil, forest, and crop productivity. The cap-and-trade provisions in the subsequent 1990 amendments were intended to reduce the total amount of sulfur dioxide that is emitted or loaded into the environment (not just the atmospheric concentration of that pollutant). And they were expected to do that as cheaply as possible.

The 1990 amendments required coal-fired electric-generating plants in the Midwest and Northeast to reduce their sulfur dioxide emissions by roughly 50 percent between 1990 and 2000. (A coal-fired power plant burns coal to generate electricity.) The legislation did that by setting a cap on overall emissions for 2000 that was roughly half the 1990 level. This cap was translated into corresponding caps for individual facilities.

Electric-generating facilities were not required by law to meet their cap—their mandatory lower level of emissions—in any particular way. They could install conventional air pollution controls, "wash" coal (removing impurities) before burning to reduce sulfur dioxide emissions, switch to less sulfur-intensive fuels (for example, from coal to natural gas), install a more efficient boiler, encourage energy savings by their customers, or do something else. The choice was entirely up to the operators of these facilities, and the U.S. Congress expected that they would choose the cheapest means to do so.

In addition to these options, they could trade, or buy and sell, allowances. (An allowance is permission to emit, for instance, one ton of sulfur dioxide in a calendar year.) A basic premise of the legislation is that the costs of sulfur dioxide control—measured in dollars per ton of avoided emissions—vary from plant to plant. Thus some facilities may be able to reduce their emissions for fewer dollars per ton than other plants, and they may be able to do so even while reducing their emissions below the required cap. Under the 1990 amendments, the plant with the lower control costs can sell its excess emissions—in the form of allowances—to the plant with higher control costs.

Consider two plants, A and B, both of which have a cap that is 100 tons below current levels. Control costs at plant A are $30 per ton, and control costs at plant B are $70 per ton. Without trading, costs to meet the cap would be $3,000 for plant A and $7,000 for plant B, for a total of $10,000. With trading, plant A could reduce its emissions by 200 tons, and plant B could buy the "excess" reduction of 100 tons (in the form of 100 allowances) for a lot less than $7,000. (In a well-functioning market, competitive pressure will drive down the cost of allowances.) Thus plant A offsets some of its costs by selling allowances, and plant B is able to comply for a lower cost than it would otherwise pay. While cap-and-trade programs are often called trading programs, there would be no need or incentive to trade without the cap.

The 1990 amendments have worked as intended. Costs have been less than half of what was expected, and emissions were reduced more than required. During this same period, U.S. gross domestic product and electricity generation also increased. According to a 2009 article by the Environmental Defense Fund, the program "has demonstrated that environmental protections need not compete with economic well-being."

Kyoto Protocol

In 1992, the United States became the fourth country in the world to ratify the United Nations Framework Convention on Climate Change (UNFCCC), which establishes an international legal structure to address climate change but does not establish any binding or numerical emission limits. When the parties began negotiating a protocol (a separate agreement under the convention) to set binding emission limits, the United States used its experience under the Clean Air Act to advocate trading mechanisms as a way of reducing costs. When this protocol was finalized in 1997 in Kyoto, Japan, it required developed countries to reduce their greenhouse gas emissions by 5 percent from 1990 levels by 2012. The required level of emissions reductions varied by country; the United States would have been obliged to reduce its emissions by 7 percent from 1990 levels, and western European countries (including the European Union) were required to reduce their emissions by 8 percent.

The protocol is in effect; it has been ratified by all developed countries except (ironically) the United States. (In 2001, President George W. Bush expressly repudiated the Kyoto Protocol "because it exempts 80 percent of the world, including major population centers such as China and India, from compliance, and would cause serious harm to the U.S. economy.")

The Kyoto Protocol also contains several different emissions trading provisions to decrease the costs of those reductions. The Kyoto Protocol allows emissions trading between developed countries. As a result, these parties can take advantage of cost differences that exist between them (Article 17). The protocol also allows another form of emissions trading between developed countries, known as "joint implementation." Under joint implementation (Article 6), a developed country enters an agreement with another developed country to carry out an emissions reduction project in that other country and counts those reductions toward its own obligations. The protocol also created the clean development mechanism (CDM), an innovative kind of trading program (Article 12). The CDM allows developed countries to receive credit toward their required reductions for any reductions based on projects undertaken in *developing* countries. The twin purposes of the CDM are to assist developing countries "in achieving sustainable development" and to help developed countries meet their emissions reduction requirements. The CDM is particularly attractive because of the great difference between costs in developed and developing countries. One consequence of the Kyoto Protocol is the European Union's development and implementation of an emissions trading system.

The use of trading mechanisms in an international setting has raised a number of implementation and methodology issues:

- For both joint implementation and the clean development mechanism, the emissions reductions from the project must be "additional to any that would occur in the absence of the certified project activity" (Article 12.5(c)). It has often been hard in practice to determine that. As a consequence, credit may be given for reductions that would have occurred anyway.
- For many projects, such as carbon dioxide reductions that are achieved through forestry, it is difficult to directly determine the exact reductions that are being achieved. Reductions are calculated based on models and projections, which may or may not be reasonably accurate. By contrast, the power plants subject to trading in the United States are subject to continuous emissions monitoring, so it is relatively easy to determine the actual reductions being achieved.
- The U.S. legal system contains a great many mechanisms assuring the integrity and enforceability of legal agreements, including the regulatory system on which they are based. In many developing countries, legal systems are less well developed and corruption is widespread. In consequence, it may be harder to enforce agreements

for reductions or guarantee the integrity of reductions claimed to be achieved in those countries.

At the end of 2009, international negotiations were being conducted for a successor agreement (or agreements) to the Kyoto Protocol. A successor agreement is needed because the compliance period for the Kyoto Protocol ends in 2012, and there is no international agreement for emissions reduction after that. One possibility is a second cap-and-trade agreement built on Kyoto that requires further reductions in greenhouse gas emissions.

European Union Emissions Trading System

The European Union has established the world's first international trading system for carbon dioxide emissions—the European Union Emissions Trading System (EU ETS). The system was established to help EU Member States comply with their Kyoto Protocol commitments. The EU ETS is set up to operate in three phases, or "trading periods." The first period, a trial period, ran from 2005 to 2007. Its purpose was not to meet Kyoto targets but to gain experience with emissions trading. The second period continues from 2008 to 2012, which coincides with the Kyoto Protocol. The third period will extend from 2013 to 2020.

Within the EU, the system raises several important implementation questions. One is whether the EU or member states will allocate allowances. Under the EU ETS, member states allocate allowances in the first and second periods, while the EU will do so in the third period. Another issue is whether allowances are allocated for free or auctioned. While the bulk of allowances are now allocated for free, there is a movement toward greater use of auctioning. Still another question is whether enforcement is done by the EU or member states. Although the system is EU-wide, enforcement is undertaken by member states. According to the European Environmental Agency (EEA), EU emissions in 2008 declined for the fourth consecutive year. If planned and existing measures are fully implemented, and member states take advantage of the clean development mechanism and other provisions of the Kyoto Protocol, the EEA projects that the EU will overachieve the 8 percent reduction target set in the Kyoto Protocol.

U.S. Regional Initiatives

Ten northeastern and mid-Atlantic states participate in the Regional Greenhouse Gas Initiative (RGGI), which has developed a model rule to establish a cap-and-trade program for electric utilities. The ten states are: Connecticut, Delaware, Maine, New Hampshire, New Jersey, New York, Vermont, Massachusetts, Rhode Island, and Maryland.

The overall environmental goal for RGGI is for each state to adopt a carbon dioxide trading program for emissions from fossil fuel–fired electricity-generating units having a rated capacity equal to or greater than 25 megawatts. These states together have negotiated a model rule that is being used, in each state, as the basis for the program. Power plants are an attractive starting point because they have already experienced the sulfur dioxide trading program under the Clean Air Act. Emissions reductions are to occur from 2015 to 2018, at a rate of 2.5 percent annually for each of the four years. By 2018, each state's base annual emissions budget is to be 10 percent below its initial budget.

Similarly, the Western Climate Initiative (WCI) involves a regional emissions cap for multiple economic sectors and a cap-and-trade system. The WCI is comprised of seven western States (Arizona, California, New Mexico, Montana, Oregon, Utah, and Washington) and four Canadian provinces (British Columbia, Manitoba, Ontario, and Quebec). The goal of the WCI is to reduce greenhouse gas emissions by 15 percent from 2005 levels by 2020.

Proposed U.S. Legislation

As of January 2010, comprehensive climate change legislation, based on cap-and-trade, is nearing passage in Congress. On 26 June 2009, the House of Representatives passed the American Clean Energy and Security Act (H.R. 2454). On 5 November 2009, the Senate Environment and Public Works Committee approved a somewhat similar bill, Clean Energy Jobs and American Power Act (S. 1733).

The heart of both bills is a cap-and-trade program for greenhouse gas emissions. The House bill would require the United States to reduce its greenhouse gas emissions by 83 percent from 2005 levels by 2050 (which equates to a 69 percent cut from 1990 emissions levels by 2050).

Both bills would create a cap-and-trade program for "covered entities." The term includes all electric power plants as well as factories and other facilities that produce 25,000 tons of carbon dioxide or carbon dioxide equivalent (gases such as methane and nitrous oxide). These facilities are responsible for about 85 percent of U.S. greenhouse gas emissions.

These reduction requirements create an emissions cap or limit for covered facilities, and the level of this cap declines over time. Covered facilities can meet this cap more or less as they see fit—for example, by becoming more energy efficient, switching to a less carbon-intensive fuel (from coal to natural gas), or using more renewable energy. Another option for covered facilities is trading, or purchasing emissions allowances. Like sulfur dioxide controls under the Clean Air Act, some facilities will be able to reduce their greenhouse gas emissions on a per-ton basis more cheaply than others. Those that do can trade or sell their "excess" reductions—in the form of allowances that are equal to one ton of carbon dioxide or carbon dioxide equivalent—to facilities where control costs are greater.

A cap-and-trade system such as that contained in these bills should lead to a price on carbon that would have ripple effects throughout an economy. (Though politically less likely, a carbon tax would have the same effect.) The price would be reflected in the market price for allowances. According to conventional economic wisdom, the economic pressure created by a cap-and-trade program should lead to less use of fossil fuels, greater use of less-carbon intensive fuels, and other changes that would result in lower greenhouse gas emissions.

The House and Senate bills contain a great many ther provisions, to be sure. Many of these are directed at making sure that the emissions trading market is transparent, reliable, and functions smoothly. Others are directed at ensuring that the price of allowances doesn't get so high that the program becomes unaffordable for many facilities. Some provisions allow covered facilities to purchase "offset allowances" in the United States, primarily from foresters and farmers, to meet their emissions caps. Offset allowances are allowances generated by non-covered facilities in the form of reduced greenhouse gas emissions or increased carbon sequestration or storage. The bills would also establish a system of national emissions reporting.

For climate change legislation, cap-and-trade provisions raise the following issues:

- How to allocate allowances. Under the Clean Air Act, allowances are allocated for free. Under RGGI, many states are auctioning some or all of the allowances. Utilities prefer free distribution of greenhouse gas allowances because, they say, it reduces their costs. It may also make it easier to pass the legislation. The argument for auctioning, by contrast, is based on the idea that the government shouldn't give away something of value, and that it should not give an economic advantage to existing companies.
- Distribution of proceeds from the sale of allowances. To the extent allowances are sold rather than given away, the government could use or distribute the money for a variety of purposes—including fostering energy efficiency, retraining workers who are adversely affected, and research and development. Alternatively, some or all of the proceeds could be distributed to individual taxpayers as a kind of rebate, either on a one-time or continuing basis.
- How to treat existing regional initiatives such as RGGI and WCI. While there is understandable interest in using federal legislation to create a national cap-and-trade system, many believe that federal legislation should accommodate the time and investments already made in those programs.
- The extent to which cap-and-trade measures need to be supplemented with other rules. Because of market imperfections, the economic pressure caused by a cap-and-trade program will not always have the desired result. According to the economist Robert Stavins (2007), consumers often do not purchase products that are more energy efficient because they undervalue the economic savings of those products. In addition, the person with the ability to achieve greater energy efficiency (for example, the landlord) is frequently not the person who pays the energy bills (typically the tenant). The incentive, in other words, writes Stavins, is not directed at the person with the ability to make decisions that will reduce greenhouse gas emissions. Beyond that, he says, the price signal provided by a cap-and-trade or tax program is not likely to lead to sufficient investment in the variety of different research and development activities needed to mitigate climate change. Finally, while a cap-and-trade program can surely reduce the costs of emissions control, it is less likely to lead to more immediate environmental, social, and economic co-benefits than a performance standard of equivalent stringency. According to David Driesen, an author and professor of law, experience under the Kyoto Protocol shows that buyers of emissions allowances are primarily interested in reducing their costs, not in fostering or capturing the other benefits that may come from a use of a particular policy or measure (Driesen 2008). These limitations in a stand-alone cap-and-trade program strengthen the case for energy-efficiency policies, for measures that would drive greater levels of private investment, and for programs that would generate substantial economic, social, and environmental benefits in addition to greenhouse gas reductions.

These issues are addressed, to some degree, in two manners. First, other federal laws already indirectly address greenhouse gas emissions in ways that would complement federal cap-and-trade legislation. The Energy Independence and Security Act of 2007, for example, requires automobiles and light trucks (including sport-utility vehicles) to achieve a combined standard for model year 2020 of at least thirty-five miles per gallon. Second, while the comprehensive climate change bills before Congress include cap-and-trade provisions, they also include a great many other provisions, some of which address these issues. The House bill, for instance, would establish a national energy efficiency program for buildings, would strengthen existing requirements for energy efficient lighting and appliances, and would foster energy efficiency in transportation and at industrial facilities. Still it is not clear whether such provisions would overcome the limitations of cap and trade.

Beyond these issues, there is a lingering question about whether a carbon tax would be a better approach. Cap-and-trade legislation would achieve a definite reduction because of the cap. By contrast, the emissions reduction effect of a tax is difficult to determine in advance. On the other hand, a tax is more economically efficient because it would apply to all sources of greenhouse gas emissions, rather than just those identified in the legislation itself. The comparative cost of the two programs would depend on their design details—how allowances are allocated and similar issues. A 2008 survey of economists by the General Accountability Office found that eleven favored cap and trade while seven favored a tax.

Implications

Cap-and-trade legislation has made it possible to achieve greater reductions of many pollutants, for a lower cost, than was previously thought possible. While it is understood to be a market mechanism for improving environmental quality, it is important to recognize that an old-fashioned "command-and-control" rule—capping emissions from each covered facility—provides the impetus for trading. Cap-and-trade legislation is thus best understood as a blend of traditional regulation with market-based regulation. It is an effective and indispensable tool in the quest for sustainable development.

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See also Automobile Industry; Airline Industry; Climate Change Disclosure; Development, Sustainable; Energy Efficiency; Energy Industries (*assorted articles*); True Cost Economics

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Cement Industry

Cement is a key component in concrete, the second most consumed material in the world. The global cement industry is responsible for 5 percent of all man-made carbon dioxide emissions, which originate primarily during the manufacturing process. Although demand for cement will surely continue to grow, the industry is taking steps to reduce its environmental footprint and have a positive social impact.

Concrete is the second most consumed material (after water), and it shapes the built environment in every country around the world. An estimated 25 billion tonnes of concrete are manufactured globally every year (WBCSD 2009a). This equates to approximately four tonnes of concrete for every human on the planet. Because it is durable, reliable, versatile, fire resistant, low cost, and requires relatively little maintenance or repair during its life, more concrete is used in construction around the world than any other building material, including wood, steel, plastic and aluminum (WBCSD 2009b).

The key component in the production of concrete is cement. Cement is the essential "glue" in concrete, which is formed when cement mixes with aggregates (such as crushed stone or gravel), sand, and water. To avoid the cost of transporting a relatively heavy, inexpensive product over great distances and because of the ubiquitous availability of cement's raw material (limestone), cement industry operations are found almost everywhere. Any industry with a widespread distribution of employees using energy-intensive production processes—like the cement industry—will impact the environment and societies around their facilities, and it must therefore consider sustainability issues to ensure long-term success. The cement industry is no exception.

In 2008, global cement production was 2.8 billion tonnes, of which nearly 50 percent was in China (Harder 2009). By 2012, the global demand is predicted to reach 3.6 billion tonnes, with gains of 7 percent per year forecast for India, Indonesia, Malaysia, Nigeria, and Vietnam (Cement Americas 2008). Some key players in the global cement industry include CEMEX (Mexico), China National Building Material Company Limited (China), HeidelbergCement (Germany), Holcim (Switzerland), Italcementi (Italy), Lafarge (France), and Taiheiyo (Japan).

Sustainability in the Cement Industry

Sustainability for the cement industry, like all industries, is a case of managing to maximize the positive impacts of its product while continuously reducing the environmental footprint of its operations. There are several topics that require inclusion in discussions about sustainability and the environment in the cement industry.

Carbon Dioxide Emissions

Approximately 5 percent of man-made carbon dioxide emissions originate in the cement industry (Battelle Institute 2002, 15). According to the World Business Council for Sustainable Development (WBCSD), about 55 percent of this occurs in the calcination process in the cement kiln, in which limestone is converted to an intermediate material called "clinker." During this process, temperatures reach about 1,450°C, and carbon dioxide is emitted as a by-product of the chemical change as the calcium carbonate in limestone becomes calcium oxide. Approximately 40 percent of carbon dioxide emissions result as fuel is burned to achieve these high kiln temperatures, while a small part of the carbon dioxide comes from electricity use, mostly for grinding the clinker into fine powder (WBCSD 2009a).

The use of concrete can also have positive effects on emissions over its lifetime however. A well-designed concrete building typically consumes 5–15 percent less energy than an equivalent building of lightweight construction and requires less internal heating and cooling services. Over its lifetime, concrete slowly absorbs carbon dioxide from the air (carbon sequestration). It has a high albedo effect, meaning many solar rays are reflected and less heat is absorbed, which results in cooler local temperatures and a reduced "urban heat island" effect in which a metropolitan region remains warmer than surrounding rural or less developed areas.

Other Emissions

Other than carbon dioxide, the industry does not generate appreciable amounts of other greenhouse gas emissions. Emissions like dust, organic pollutants, and nitrogen and sulfur oxides, however, do need to be managed. Regulatory limits on these emissions have been set in most countries and typically become more stringent over time. Many of these emissions are monitored continuously to ensure emission limits are being met.

Alternative Fuels and Raw Materials

The industry can compensate for some of its carbon footprint through the use of alternative fuels and raw materials. Whereas industrial or domestic waste is often burned in incinerators, it can instead be co-processed in a cement kiln, providing fuel to help reach the 1,450°C kiln temperatures needed for making cement and some other valuable raw materials, like iron. This could decrease industry dependence on fossil fuels and the associated impacts of developing these resources.

Impacts on Land and Communities

Cement plants are generally located close to the quarries from which they obtain the raw materials for production. When operations in any limestone quarry are started, there are significant impacts on the surrounding landscape and communities: noise, vibrations, and ecosystem changes for example. For large cement plants (manufacturing 3,000 tonnes or more per day), limestone reserves of 100–150 million tonnes are required. Cement companies can work to minimize their impacts through practices like locating plants away from large cities and towns, areas with significant biodiversity or cultural value, or from protected areas, and by implementing ongoing rehabilitation plans during and after quarry operations.

Demonstrating that a company is a responsible local operator will help it maintain the "license to operate" that every company needs to obtain before quarrying can begin or continue, and it will improve employee loyalty and pride.

A cement operation can have positive benefits for the immediate area as well, because cement is produced and supplied locally. Jobs are created and local infrastructure developed. This can be particularly beneficial in remote locations in developing countries, where there may be few other opportunities for economic development.

Collaborative Industry Efforts

Sustainability issues often move beyond a single country's boundary, and so they must be addressed internationally. Collaboration on sustainability issues is crucial for success. Policies and regulations, particularly around climate issues, must be adopted in collaboration with the industry itself to ensure policies are fair and practicable and to allow the industry to develop sustainably. For example, there are four main ways the industry can address carbon dioxide emissions, but only one—energy efficiency—is primarily under industry control. Other means depend heavily on national government policies and on the outcomes of ongoing research and development.

The Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development is a voluntary industry-driven initiative. It was formed in 2002 following a three-year research project into the industry's environmental and social impacts. It has a twenty-year vision of a sustainable cement industry, and a CEO-endorsed Agenda for Action that commits members to set targets and publicly report progress targets across a range of sustainability issues. All companies report annually on varied Key Performance Indicators (KPIs) around the sustainability issues on which they collaborate. In 2009 the CSI had eighteen member companies with operations in more than one hundred countries, all key global cement producers; collectively this represents about 30 percent of world production (WBCSD 2009a).

Numerous guidelines have been developed by CSI, trade associations, and individual companies (often in collaboration with nongovernmental organizations or other partners). These cover issues such as emissions reductions, fuel and raw materials use, and environmental and social concerns through the lifespan of a quarry and cement plant.

Outlook for Future Generations

There are several key sustainability issues facing the cement industry, and the industry will continue to work on minimizing its negative social and environmental impacts. It must do this as demand for cement and concrete continues growing, and it must work to spread sustainable practices into emerging markets and developing countries. Concrete is expected to remain a key construction material far into the future. The cement industry will need to look at its whole supply chain in more detail, from the provision of raw materials to the end use, recycling, and disposal of concrete, and how it impacts the environment and societies through use of its product right up to its end use as concrete.

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See also Building Codes, Green; Energy Industries—Coal; Facilities Management; Manufacturing Practices; Mining; Property and Construction Industry

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Chemistry, Green

The aim of green chemistry is to reduce the hazards associated with the manufacture, use, and disposal of chemicals and chemical products. Leading the way in green chemistry research and application are academia and industry. Although the term green chemistry *dates from the 1990s, the 2005 Nobel Prize in Chemistry was awarded to three chemists for their work, begun in the 1970s, on reducing hazardous waste in forming new chemicals.*

Chemical manufacturers convert raw materials into the chemicals needed for a wide variety of products in many industries, such as agricultural chemicals, cleaning products, paints, textiles, rubber and plastics, and pharmaceuticals. It is a major industrial sector; in 2007, worldwide chemical sales were estimated to be €1.8 trillion, or US $2.6 trillion (Cefic 2009). The industry has been centered in Western Europe, North America, and Japan, nicknamed "the Triad," but that is changing. In 2007, the European Union, previously the leader in chemical sales, slipped to second place behind Asia due to the industry's growth in China and India (Cefic 2009). In 2009, the U.S. chemical industry generated $689 billion in sales and accounted for 10 percent of America's exports (American Chemistry Council 2009).

Chemical manufacturing can generate hazardous byproducts and waste. Green chemistry emerged as foresighted scientists recognized that proper attention to initial molecular design could eliminate the hazards and waste of many existing industrial processes. Green chemistry has been defined as "the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products" (Anastas and Warner 1998, 11). Green chemistry surfaced as a focus in the 1990s, accompanied by the publication of a set of twelve green chemistry principles by Paul T. Anastas and John C. Warner. These principles include such ideas as it is better to prevent waste than to clean it up afterward, chemicals should be designed explicitly to minimize toxicity to human health and the environment, and energy use should be minimized. Or, as paraphrased by the research and advocacy group Clean Production Action (2009, 1), "The goal of green chemistry is to create better, safer chemicals while choosing the safest, most efficient ways to synthesize them and to reduce wastes."

Origins

The term *green chemistry* emerged in the United States in the 1990s, building on earlier academic interest in both the United States and the United Kingdom. Professor Terry Collins launched what may have been the world's first course on green chemistry in 1992 at Carnegie Mellon University in Pittsburgh, Pennsylvania. The principal publications articulating the concept and its applications were developed by Paul Anastas, then at the U.S. Environmental Protection Agency (EPA), and John Warner, initially at Polaroid Corporation and later at the University of Massachusetts, Boston. The EPA was working to implement the Pollution Prevention Act of 1990, which established a national policy to prevent or reduce pollution at its source whenever feasible. Anastas introduced the EPA's green chemistry program in 1991. This was followed in 1995 by the launch of the Presidential Green Chemistry Challenge, a feature of which is the annual presentation of Presidential Green Chemistry Challenge awards. The awards, presented during a multiday green chemistry research conference, highlight successes in research, development, and industrial application of new technologies.

They are awarded in such categories as academia, small business, alternative synthetic pathways, alternative chemical manufacturing processes, and designing safer chemicals. For example, in 2003 the award for designing safer chemicals was given to Shaw Industries Inc. of Dalton, Georgia, one of the largest floor-covering manufacturers in the United States. Shaw won the award for the development of EcoWorx carpet tile. EcoWorx replaces carpets backed with polyvinyl chloride (PVC), a chemical that poses an environmental and human health hazard throughout its lifecycle, from manufacture through disposal. As described in a case study prepared by the University of Virginia Darden School of Business in collaboration with the Investor Environmental Health Network (2010), Shaw was able to produce carpet that not only was recyclable but also maintained the properties of virgin material throughout the recycling process at a reduced cost. Decreased input costs were further boosted by savings in manufacturing and transportation expenses as a result of the 40 percent reduction in the weight of the product. The product was so successful that it completely replaced Shaw's PVC-based product.

Academic Centers

Work on green chemistry techniques in academia long predates the formal use of the term. This is reflected in the presentation of the 2005 Nobel Prize in Chemistry

The Twelve Principles of Green Chemistry

1. **Prevent waste:** Design chemical syntheses to prevent waste, leaving no waste to treat or clean up.
2. **Design safer chemicals and products:** Design chemical products to be fully effective, yet with little or no toxicity.
3. **Design less hazardous chemical syntheses:** Design syntheses to use and generate substances with little or no toxicity to humans and the environment.
4. **Use renewable feedstocks:** Use raw materials and feedstocks that are renewable rather than depleting. Renewable feedstocks are often made from agricultural products or are the wastes of other processes; depleting feedstocks are made from fossil fuels (petroleum, natural gas, or coal) or are mined.
5. **Use catalysts, not stoichiometric reagents:** Minimize waste by using catalytic reactions. Catalysts are used in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and work only once.
6. **Avoid chemical derivatives:** Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.
7. **Maximize atom economy:** Design syntheses so that the final product contains the maximum proportion of the starting materials. There should be few, if any, wasted atoms.
8. **Use safer solvents and reaction conditions:** Avoid using solvents, separation agents, or other auxiliary chemicals. If these chemicals are necessary, use innocuous chemicals.
9. **Increase energy efficiency:** Run chemical reactions at ambient temperature and pressure whenever possible.
10. **Design chemicals and products to degrade after use:** Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.
11. **Analyze in real time to prevent pollution:** Include in-process real-time monitoring and control during syntheses to minimize or eliminate the formation of by-products.
12. **Minimize the potential for accidents:** Design chemicals and their forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.

Source: Anastas, Paul T., & Warner, John C. (1998). *Green chemistry: Theory and practice*. Oxford, U.K.: Oxford University Press.

to Yves Chauvin (France), Robert H. Grubbs (United States), and Richard R. Schrock (United States) for their work on reducing hazardous waste in forming new chemicals, which they began in the 1970s. The Nobel Prize committee stated their process "represents a great step forward for 'green chemistry,' reducing potentially hazardous waste through smarter production" (Nobel Foundation 2005).

Centers of academic research on green chemistry have been established in the United States and overseas. For example, Warner, co-author with Anastas of the twelve principles of green chemistry, organized the world's first doctoral program in green chemistry in 2001 at the University of Massachusetts, Boston. He subsequently moved to the University of Massachusetts, Lowell, before establishing his private laboratory, the Warner Babcock Institute for Green Chemistry, in Wilmington, Massachusetts. Anastas, after having co-founded and served as director of the American Chemical Society's Green Chemistry Institute, was named the first director of Yale University's Center for Green Chemistry and Green Engineering. In the United Kingdom, the Green Chemistry program at the University of York, directed by James Clark, has for many years sponsored a consumer newsletter and an annual conference on green chemistry. In 2007, Beijing University of Technology hosted the Eighth International Symposium on Green Chemistry in China (Yale's Center for Green Chemistry and Green Engineering and the Chinese Academy of Sciences's Institute of Chemistry were co-organizers) and a ninth was convened in Hefei in 2008. The International Union of Pure and Applied Chemistry sponsored the Second International Symposium on Green/Sustainable Chemistry in 2006 at India's University of Delhi, and the Birla Institute of Technology and Science (BITS), Pilani, India, is hosting a national conference on green and sustainable chemistry in February 2010.

Corporate Interest

The mainstream pharmaceutical industry has been especially active in green chemistry, motivated by a desire to reduce the substantial waste created in the manufacture of pharmaceutical products. The magnitude of the opportunities for waste reduction was signaled in the 2002 Presidential Green Chemistry Challenge Award for alternative synthetic pathways presented to Pfizer Inc., who redesigned its process for manufacturing the antidepressant Zoloft. It eliminated the need to use four toxic solvents when synthesizing the drug, along with 830 metric tons annually of other waste chemicals (US EPA 2008).

The pharmaceutical industry, in collaboration with the American Chemical Society (ACS) Green Chemistry Institute, has convened the Pharmaceutical Roundtable. The members of the roundtable collaborate to inform and influence research agendas, incorporate green chemistry principles into education, and develop tools to facilitate the implementation of green chemistry and green engineering in industry. Among its noteworthy activities, the roundtable sponsors a focused-research proposal competition designed to foster new chemical synthesis processes to replace existing ones.

Pfizer has been a green chemistry pioneer among pharmaceutical companies. The company has recognized the importance of thoroughly integrating green chemistry concerns throughout its management structure, from research to scale-up through to manufacturing. Pfizer has a full-time green chemistry leader with companywide responsibility and a corporate green chemistry policy and steering committee responsible for its strategic plan, communications, policy making, and performance monitoring. Pfizer also has site-level green chemistry teams developing management objectives and providing incentives to staff.

Government Interest

Other than the EPA's modest green chemistry program and some research funded by the National Science Foundation (NSF), the U.S. federal government has not invested in green chemistry in a meaningfully coordinated or focused manner. Green chemistry offers the promise of moving society beyond its twentieth-century "brown" chemistry footings. This older chemistry yielded remarkably useful societal benefits but also bequeathed a legacy of contaminated manufacturing sites and occupational and environmental health woes. To address this underinvestment, the Green Chemistry Research and Development Act was introduced and passed with bipartisan support in the U.S. House of Representatives in 2004 and 2006, but it went no farther when the U.S. Senate failed to act. The 2008 version of the legislation—introduced but not enacted—would have authorized federal spending of $165 million over three years for research and development grants by the EPA, NSF, and two other federal agencies. As of February 2010, Congress had not enacted the legislation.

In the absence of meaningful federal action, some state governments are moving ahead with programs of their own, in much the same way they are taking meaningful action on climate change and product safety to compensate for federal inaction in those realms. Some states are motivated by the promise of the economic benefits that green chemistry investments can yield. This is most evident in California, where the University of California, Berkeley, produced the report *Green Chemistry in California: A Framework for Leadership in Chemicals Policy and Innovation* at the state legislature's request (Wilson, Chia, and Ehlers 2006). The report recommended that California develop a comprehensive chemicals policy that, in various ways, would provide greater incentives for corporate investments in green chemistry. In April 2007, California's Department of Toxic Substances Control launched the California Green Chemistry Initiative, a multiagency, multistakeholder series of symposia and workshops that led to recommendations for a state-level green chemistry policy and program. The California legislature subsequently enacted legislation establishing such a program.

In October 2006, Michigan governor Jennifer Granholm signed an executive order, Promotion of Green Chemistry for Sustainable Economic Development and Protection of Public Health, which directs Michigan's Department of Environmental Quality to establish a green chemistry support program to promote and coordinate state green chemistry research, development, education, and technology transfer activities in Michigan.

The state of Maine clearly views green chemistry as an economic driver. In October 2007, Maine's economic development and environmental protection agencies, in collaboration with Maine companies and environmental health activists, convened a conference, "Growing Maine's Green Economy: Better Living Through Green Chemistry." They discussed expanding Maine's economy by replacing hazardous materials in consumer products with safer alternatives. The participants focused primarily on replacing petroleum-based chemicals with biobased ones, including making biobased plastic from Maine potatoes. In April 2008, Governor John Baldacci signed related legislation, the so-called Kid-Safe Products Bill, which requires Maine to publish a list of chemicals of high concern that have been identified by another government agency as dangerous to children based on specific criteria. It also requires Maine to name at least two chemicals or groups of chemicals of high concern as "priority chemicals" because they are likely to expose Maine's children to harm or they have been banned in another state; manufacturers must report products sold in the state containing a priority chemical. The bill allows Maine to restrict the sale of such products if safer alternatives are available at comparable cost. The conference and the legislation together reflect a combined carrot-and-stick approach to reducing human health and environmental hazards: squeeze down on "known bads" and provide incentives for "more goods."

Other members of the chemical industry's Triad have taken similar steps to encourage green chemistry. On 1 June 2007, the European Union (EU) enacted EC 1907/2006, the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation. The regulation requires the chemical industry to identify and register the risks of their chemicals in a central database. In addition, the authorization process can require phaseouts of the most hazardous chemicals in favor of less hazardous ones. The regulation is being instituted over eleven years and applies to chemical manufacturers in the European Union as well as to those who export to EU countries.

To meet the goal of promoting science and technology that was established in its 1995 Science and Technology Basic Law, the Japanese government developed the Second Basic Science and Technology Plan in 2001. The Council for Science and Technology Policy implements the plan; one of its missions is to address environmental science and technology issues, mostly recycling and remediation, although a portion goes to developing technology to safely manage chemicals. The Green and Sustainable Chemistry Network (GSCN), a task force within the council, began issuing the GSC Awards in 2001 to individuals and companies that promote green chemistry in Japan (Rubottom 2004).

Challenges to Implementation

In December 2007, Harvard University's Center for International Development published a working paper, *Overcoming the Challenges to the Implementation of Green Chemistry*. The paper was a product of a collaborative project among Harvard, Yale, and the ACS Green Chemistry Institute. Based on interviews and a multistakeholder workshop, the paper identifies barriers to the implementation of green chemistry and actions that can be taken by government, academia, nongovernmental organizations, and industry to alleviate these factors. The researchers determined that there are six major classes of barriers to the implementation of green chemistry: economic, regulatory, technical, organizational, cultural, and definition and metrics. The workshop participants (including the author of this encyclopedia entry) identified six major action themes for addressing these barriers:

1. Create incentives for the development and implementation of innovations
2. Consider policies to shift focus to hazard reduction

3. Facilitate linkages, networks, and collaborations
4. Act as a facilitator for multistakeholder initiatives
5. Promote actions that make environmental and health impacts a larger part of the decision calculus
6. Support research, knowledge creation, and educational efforts to support green chemistry across a range of disciplines and problem areas

Some of the more specific barriers include a lack of chemists and engineers with appropriate training; a lack of regulatory incentives for greener alternatives; a lack of understanding in sales and marketing teams; an insufficient awareness in the larger chemical community and among consumers; and a lack of widely applicable metrics for measuring levels of "green."

Some of the specific steps that can be taken to overcome barriers include developing specific curriculum materials for both chemists and nonchemists, including green chemistry in continuing-education programs, providing tax incentives for replacing old technology, and reducing product registration fees and approval timelines for green innovation.

Looking Ahead

Green chemistry offers the potential benefits of reducing environmental and human health costs. Where green chemists can mimic nature's ability to produce strong, hard products without large amounts of pressure and energy (e.g., spider webs and marine-animal shells) will reduce energy and manufacturing costs. Where products are designed to be inherently less toxic or nontoxic will reduce industry overhead costs now dedicated to managing risks from hazardous products and processes. Green chemistry also can offer competitive advantages in increasingly competitive global markets. The *New York Times* columnist Thomas Friedman (2007) stated this concisely on 14 February 2007, at the twenty-fifth anniversary dinner for the World Resources Institute in New York City, when, in alluding to green technologies in general, he said, "China's going to go green.... [O]nce they produce those technologies...they'll come our way and clean our clock in the next great industry of the twenty-first century if we remain asleep at the switch....Green China ultimately is going to be a bigger challenge to us than Red China."

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See also Biomimicry; Biotechnology Industry; Design, Industrial; Investment, CleanTech; Manufacturing Practices; Pharmaceutical Industry; Zero Waste

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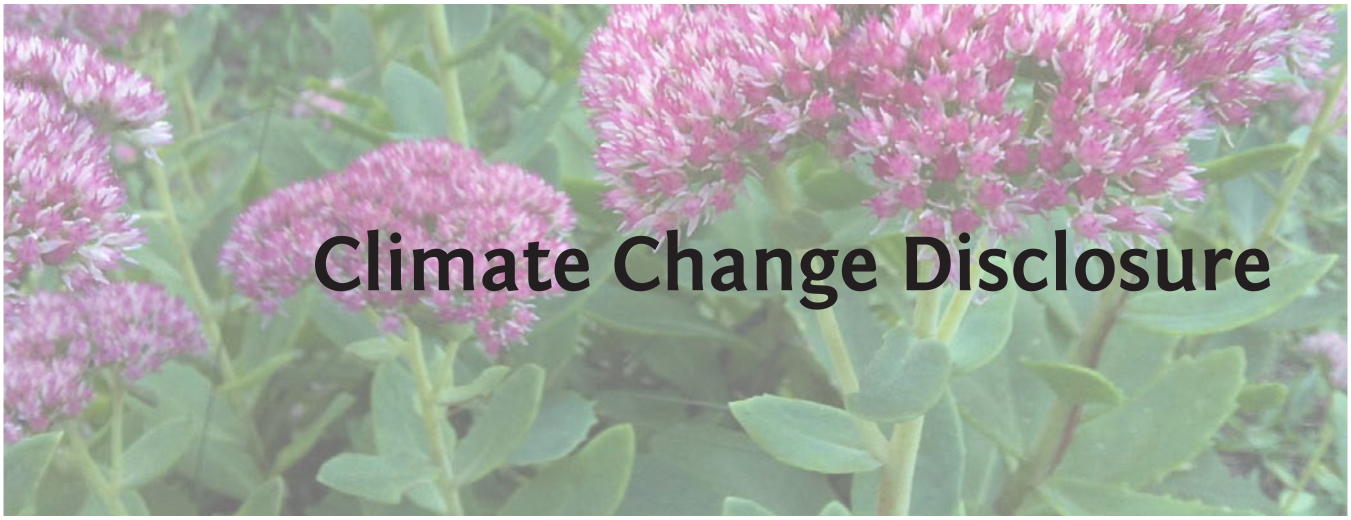

Climate Change Disclosure

Publicly traded companies in the United States are required to disclose to the Securities and Exchange Commission any material information about how climate change and its consequences may affect their operations and financial results. Assessing the materiality of climate change and its consequences to a company is complicated because governmental policies and regulations (including proposed ones), court decisions, public expectations, and marketplace competition have all been evolving, with the pace accelerating in 2009.

As public attention to climate change continues to build and more climate change initiatives are proposed, businesses face a variety of challenges. One challenge faced by public companies is the need to assess how climate change and its consequences affect disclosures to investors. In the United States (the focus of this article), the rules of the Securities and Exchange Commission (SEC), the agency in charge of regulating the securities industry, govern a public company's disclosure obligations. (Private companies generally have no such disclosure obligations.) The SEC rules provide, among other disclosure requirements, that a public company divulge material risks and "known trends or uncertainties" that may be material to the company. Accordingly, a company must consider making disclosures about future matters even though their timing and impact may be uncertain. A company's consideration of climate change and its consequences is particularly complicated because this is a rapidly evolving and dynamic area. On 27 January 2010, the SEC approved an interpretive release confirming that the consequences of climate change, if material, are to be described in SEC filings and setting forth disclosure guidance to provide clarity and to enhance consistency of reporting.

The number of U.S. public companies including some level of climate change disclosure in their SEC reports has been increasing every year. As a result of the SEC's recent interpretive release and several 2009 developments, more companies will need to consider whether to begin including climate change disclosures in their SEC reports. Even those companies already making climate change disclosures will need to consider revising, and in some cases expanding, their disclosures. Some of the most notable developments in 2009 included:

- The U.S. House of Representatives passed the American Clean Energy and Security Act (also know as the Waxman-Markey bill), the first climate change legislation adopted by either house of Congress. Several climate change legislative alternatives are being discussed by various members of the Senate. President Obama's pledge of a provisional target to reduce greenhouse gas emissions by 2020 in the range of 17 percent below 2005 levels—made in advance of the December 2009 Copenhagen conference on climate change and confirmed pursuant to the Copenhagen Accord—should help to assure Senate attention to such legislation in 2010.
- The U.S. Environmental Protection Agency (EPA) initiated a number of significant actions in 2009. Three of the more significant were finalizing rules to require greenhouse gas reporting by large emitters beginning in 2010; proposing rules that would require permits for new facilities (or existing facilities undergoing major modifications) that emit over 25,000 tons of greenhouse gases annually; and the "endangerment finding" on 7 December 2009 under the Clean Air Act that greenhouse gas emissions endanger public health and welfare, which could possibly portend even broader greenhouse gas regulation by the EPA.

- On 27 October 2009, the SEC staff, in a reversal of its prior position, issued a bulletin that is expected to facilitate and encourage shareholder proposals to require that a company provide greater disclosure about its climate change risks. The timing of the staff's bulletin was intended to permit the inclusion of more of these shareholder proposals in proxy statements for the upcoming proxy season.
- Consumer-oriented companies continued their "green" announcements and publicity in 2009. Perhaps the most noteworthy was Walmart's announcement in July 2009 that it was requiring sustainability reports by its suppliers (over 100,000 globally) so that Walmart can begin developing sustainability ratings for its products.
- Significant court decisions were handed down in 2009 regarding greenhouse gas emissions, with the decision of the U.S. Court of Appeals for the Second Circuit in *State of Connecticut v. American Electric Power* receiving the most attention. The Second Circuit's decision, on 21 September 2009, was the first to find that the federal common law of public nuisance applied to claims to abate global warming. The court reinstated common law nuisance claims alleging that the emissions by the five power companies named as defendants had contributed to global warming, thereby injuring the defendants' infrastructure and low-lying properties. Shortly after the Second Circuit's decision was announced, the U.S. Court of Appeals for the Fifth Circuit arrived at a similar result in *Comer v. Murphy Oil USA*. The U.S. District Court for the Northern District of California, however, came to a different result in *Native Village of Kivalina & City of Kivalina v. ExxonMobil Corp. et al*. The District Court's decision was issued after *Connecticut* but before *Comer* and was expected to be appealed to the U.S. Court of Appeals for the Ninth Circuit.

As a result of these developments and in light of the SEC's recent interpretive release, public companies will need to consider how the evolving climate change landscape affects disclosure in their SEC filings. They will need to assess whether climate change and its consequences represent a risk, trend, or uncertainty that may be material to their finances and operations. Given the dynamic nature of this issue, this assessment will likely need to be conducted on a continuing basis. Companies will also need to consider whether they are making other public (but non-SEC) climate change disclosures, as many public companies increasingly are, and ensure that they are not selectively disclosing material climate change information in these other public venues without including such material information in SEC reports.

SEC Disclosure Requirements

The touchstone for determining whether disclosure is required under the SEC rules is materiality: whether or not there is a substantial likelihood that a reasonable investor would consider the information important in making his or her investment or voting decision (*TSC Industries v. Northway* 1976). The materiality of contingent or speculative events, such as proposed climate change legislation, is to be assessed by balancing the probability of an event occurring with its anticipated magnitude to the company (*Basic Inc. v. Levinson* 1988).

Key among the SEC's specific disclosure rules is the requirement that companies describe in their annual reports any known trends, uncertainties, or other factors that are reasonably likely to have a material effect on their business, earnings, or financial condition. This is intended to enable investors to view businesses through the eyes of management and thus increase the overall transparency of their reporting. SEC rules also require companies to disclose, if material, what effect compliance with environmental laws may have on their earnings, capital expenditures, and competitive position. According to SEC rules, companies must also disclose any material pending administrative or judicial proceeding to which they are, or may become, a party. In addition, any such proceeding arising under any federal, state, or local provisions regulating the discharge of materials into the environment must be described if it falls within certain parameters specified in the SEC rules.

Several groups (most prominently Ceres, an investor network) had petitioned the SEC in 2009 and earlier to provide more definitive guidelines regarding climate change disclosure. As noted before, the SEC approved an interpretive release on 27 January 2010 providing such disclosure guidance. In its interpretive release, the SEC highlighted the following areas as examples of where climate change and its consequences, if material to a company's business, may trigger disclosure requirements: the impact of existing and potential laws and regulations; the risks or effects of international accords and treaties relating to climate change; the indirect consequences of legal, technological, political and scientific developments regarding climate change that may create new opportunities or risks (e.g., increased or decreased demand for a company's product due to the greenhouse gas emissions associated with the product); and the actual and potential physical impacts of climate change on the company's business.

Disclosure Considerations

A corporation evaluating whether climate change disclosures are advisable will need to consider several general factors applicable to a broad range of companies, as well as factors more specific to the corporation's particular circumstances. Perhaps foremost among such factors is the increasing call for greater governmental action to counter climate change. This would include international actions that may result from negotiations for a successor to the Kyoto Protocol, as well as actions by individual countries or regions acting independently or in anticipation of, or pursuant to, any international agreements including the Copenhagen Accord.

For public companies that have their operations and sales based primarily in the United States, the prospect of federal legislation and its potential consequences will be a critical consideration in evaluating whether climate change disclosures are necessary. These potential consequences could include the regulation of greenhouse gas emissions; for energy-intensive companies that could mean higher fossil fuel costs. Similarly, such legislation could affect the availability and costs of raw materials. In addition, proposed legislation contains a number of mandates that go well beyond merely regulating greenhouse gas emissions at their sources. Pending legislation provides for building codes and appliance standards and contemplates a "renewable portfolio standard" that requires electric utilities to obtain a percentage of their electricity through renewable sources of energy, such as wind, solar, or biomass. The legislation is expected to have substantial implications for the agriculture sector due to its carbon offset and sequestration entitlements for agriculture and its effects on grain prices and energy and fertilizer costs.

In addition to prospective legislation, companies must consider various regulatory actions, such as those by the EPA. As noted, the EPA has adopted rules mandating the reporting of greenhouse gas emissions by certain companies and has proposed rules that would require construction and operating permits for new facilities (or facilities undergoing major modifications) that emit over 25,000 tons (approximately 22,680 metric tons) of greenhouse gases annually. These permits would require the use of the best available control technologies. Also, the EPA, together with the U.S. Transportation Department and the Obama administration's active involvement, finalized an accelerated increase in the corporate average fuel economy (CAFE) standards and imposed the first-ever greenhouse gas standard on cars and light-duty trucks in 2009.

Companies also will need to consider statutes and regulations in the states in which they operate. Before the aforementioned federal actions on climate change, a number of states (e.g., California, which has been particularly active) had adopted their own climate change measures. For example, six states and one region have adopted enforceable caps on greenhouse gases, twenty-nine states have renewable portfolio standards, and twenty-three states have adopted energy efficiency resource standards requiring that specific levels of energy savings be met by energy efficiency programs. The extent to which state measures may be eclipsed, preempted, or largely unaffected by federal action remains to be determined.

Companies will also need to consider climatic changes predicted for areas in which they operate. This might include the potential for more droughts in the southwestern United States, which would be particularly relevant to companies that rely heavily on water supplies. The threat of rising sea levels in coastal areas may be material depending on where a company's facilities are located and could include higher insurance premiums from areas deemed at high risk from hurricanes.

The nature of a company's industry, of course, is another key factor to be considered. For example, climate change is obviously an issue of critical importance to electric utilities and energy producers and to the insurance industry. Companies in retail industries have also highlighted their concerns about climate change. Recognizing the importance that many consumers give the issue, many companies have increasingly been promoting their "green" efforts. These companies include Walmart, Coca-Cola, Pepsi, Nike, Wells Fargo, HP, Dell, Yahoo, IBM, and Google. In September 2009, Apple announced the carbon footprints for its devices based on their full lifecycle impact, including during their use. Apple's approach was favorably contrasted by some with the more limited method of calculating carbon footprints by many of Apple's competitors, including HP and Dell, which were ranked number one and two, respectively, in *Newsweek*'s inaugural "Green Score" rankings of the 500 largest U.S. companies (McGinn 2009).

Many companies have begun to review the sustainability performance of their supply chains. Walmart announced in July 2009 that each of its more than 100,000 suppliers must provide reports regarding the sustainability of the supplier's products and its supply chain. Walmart plans to use this information to develop sustainability ratings for the products it sells. Their efforts are a continuation of efforts it began in 2007 to monitor the sustainability of its supply chain. Walmart's earlier effort led to the creation by the Carbon Disclosure Project (CDP) of the Supply Chain Leadership Collaboration (SCLC), currently comprised of twenty-eight "blue chip" companies such as Cadbury, Dell, HP, Imperial Tobacco, L'Oréal, Nestle, and PepsiCo.

The survey questions asked by Walmart suggest some of the areas to which its many suppliers, including those that are public companies, will need to give attention (Walmart 2009a). The first four of the fifteen questions are:

1. Have you measured your corporate greenhouse gas emissions?
2. Have you opted to report your greenhouse gas emissions to the Carbon Disclosure Project (CDP)?

3. What is your total annual greenhouse gas emissions reported in the most recent year measured?
4. Have you set publicly available greenhouse gas reduction targets? If yes, what are those targets?

Reporting to the CDP may have important implications for companies that begin such reporting and may also bear on their SEC reporting obligations. The CDP requests detailed information about greenhouse gas emissions and related matters. The CDP's questionnaire asks specific questions about the risks and opportunities to the reporting company that climate change presents. It requests a breakdown of, and the methodology for calculating, a company's Scope 1 emissions (direct emissions), Scope 2 emissions (indirect emissions from the consumption of purchased electricity, heat, or steam), and Scope 3 emissions (other indirect emissions, including those due to employee business travel). The questionnaire asks for greenhouse gas and energy reduction plans and targets and also inquires about greenhouse gas emissions avoided, emission intensity, energy use, and carbon trading. If the company is a supplier it must also provide additional specified information intended to assist its customers in estimating the extent to which the supplier's Scope 1 and 2 emissions are linked with the services and goods it provides to its customers.

In addition, the CDP questionnaire asks that a company describe its "governance practices" for sustainability. Specifically the CDP's questionnaire asks what board or executive committee has overall responsibility for the company's decision making on climate change; whether individual employee efforts are assessed or incented; and how the company communicates its climate change risks/opportunities and sustainability efforts.

In addition, a company reporting to the CDP should be aware of how such reports may potentially reflect on its competitive position. On 24 September 2009, the CDP announced that reporting would be available online and that upgraded reporting software would facilitate comparisons between competitors on sustainability performance. Such comparisons could be relevant in several ways. Exelon, the gas and electric utility, is quoted in CDP's 2009 Supply Chain Report, for example, as stating: "All other things being equal, a greener supplier would be given preference" (CDP 2009d, 4).

Any company reporting to the CDP will have to make sure it is not selectively disclosing material information about climate change and its consequences without disclosing the same information in its SEC reports. This same concern about "selective disclosure" can arise from information on a company's website, in its marketing or press materials, reports to investors and analysts, or participation in surveys. If such public disclosures in non-SEC venues are considered to be material, their omission in the company's SEC filings would highlight defects in these filings and possibly violate regulations prohibiting selective disclosure.

In evaluating disclosure obligations, companies need to consider a number of factors, such as whether climate change and its consequences present opportunities. This would be true for companies involved in "cleantech" ("green" technology), energy efficiency, energy transmission, and sustainable construction. In some instances, superior sustainability performance may provide a competitive advantage.

Outlook

The legislative and regulatory landscape related to climate change is changing and has begun to accelerate at a rapid pace. In addition, an increasing number of climate change initiatives are being undertaken by many organizations and corporations. Public companies in the United States will need to assess climate change disclosures against this backdrop while being mindful of the following:

- remaining compliant with federal and state disclosure laws and regulations
- managing current, and in many cases adopting new, disclosure controls and procedures to ensure they remain well positioned to comply with future disclosure obligations
- addressing the climate change interests and expectations of investors
- managing customer and supplier relationships in regard to climate change matters
- maintaining a corporate image consistent with their business strategies and core values
- ensuring that business opportunities arising from climate change are identified, appropriately communicated, and, to the extent required, adequately disclosed

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See also Accounting; Cap-and-Trade Legislation; Ecosystem Services; Financial Services Industry; Transparency

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Community Capital

Community capital comprises the economic, cultural, and social resources that communities must access to foster their sustainable development. Emerging from nineteenth-century social thought, community capital financial networks such as cooperatives, credit unions, and local alternative currencies benefit both individuals and businesses, while social networks support feelings of well-being and belonging. Corporate social responsibility in community capital extends the corporate sector's focus beyond profit margin toward sustainable and pro-community activities.

Community capital is the sum of the various elements of capital upon which a community relies and from which it benefits. It draws on all the areas underpinning community life: human, social, environmental, economic, and cultural. In addition, community capital includes indigenous resources, regional amenities, and a local skills base; these, combined with corporate and civic forms of philanthropy and volunteerism, are necessary to make a community sustainable in its most extensive aspects.

Community capital comprises the significant forms of capital outlined by the theorist Pierre Bourdieu (1986) in "The Forms of Capital": economic, cultural, and social. At the center of this understanding of community capital, Bourdieu outlined a series of "relationships of mutual acquaintance and recognition." Within this context, community capital can be understood as the kinds of economic, cultural, or social capital that link social groups who provide due concern for the well-being of their counterparts, and who do so without immediate recourse to the usual concerns about profit or other compensation.

Community Capital and Networked Finance

One significant outcome of the global economic downturn that began in late 2007 was the emergence of community capital networks to replenish flows of finance to local businesses. A number of initiatives have extended community capital in local or regional contexts over time. These enterprises have included cooperatives, credit unions, and local alternative currencies. Community capital may also include those assets that can be held in common by a community for their mutual benefit. Such assets may include the provision of labor, technologies, equipment, factory space, or land banks that could be used in commonage. While the reasons for this pooling of resources may vary, ultimately programs that create flows of community capital are devised to have universal benefits for society.

The Cooperative Movement

The cooperative movement emerged during the Industrial Revolution to facilitate the economic plight of workers exposed to the vagaries of nascent capitalism. One of the earliest exponents of the cooperative movement was Robert Owen (1771–1858), who developed the concept of utopian cooperative villages in Britain and the United States. The ethic of pooled labor and resources was common in agrarian societies, and the cooperative movement developed these concepts by establishing a framework for mutual cooperation in a planned community. Throughout the eighteenth and nineteenth centuries, cooperatives, intentional communities, workers' collectives, and religious communes were developed through the promotion of an ethic of community capital. Owen founded the rationalist cooperative in New Harmony, Indiana, in 1825. The

Brook Farm experiment of the 1840s in Massachusetts was frequented by utopians, transcendentalists, and intellectuals such as Nathaniel Hawthorne, Ralph Waldo Emerson, and Henry David Thoreau, under the influence of Charles Fourier (Leonard 2007).

Credit Unions

Credit unions represent another form of community capital. One key idea underpinning the credit union is that ownership remains in the hands of the group membership. In addition, credit unions extend financial services such as loans to their members at reasonable rates without the emphasis on profits that characterize the mainstream banking sector. The role of credit unions in maintaining access to credit and direct finance has been an important aspect of localized responses to the economic challenges that have emerged since the collapse of the corporate banking sector.

In the United States credit unions are classified as nonprofits, while in Canada credit unions are free to return a profit from their enterprise. In the United Kingdom, "mutual friendly societies" were established to extend credit to poorer sectors of society, while "building societies" were created to extend credit for housing to the same sector. Credit-union directors are volunteers and are democratically elected by members without an emphasis on their assets. Credit unions also provide a microfinance service based on the provision of financial services to low-income clients who may not have access to mainstream banks. Corporate credit unions provide a clearinghouse service for the wider corporate sector.

Both cooperatives and credit unions continue to play a significant role in contemporary society. In many countries, cooperatives and credit unions have contributed to alternative economic activity since the onset of the global "credit crunch" and subsequent downturn. Cooperatives continue to play a significant role in rural development, while credit unions are expanding their influence, with new credit unions opening across the world at a rapid rate.

Alternative Currencies

Alternative currency movements are often conceptualized as an object of protest or a tool for constructing alternative communities, economies, and societies. Contemporary alternative-currency networks have attempted to use new forms of money as a tool for building more fair and balanced economies and societies. Traditionally, community capital initiatives have included concepts such as social credit or the paying of a dividend to equalize incomes in free societies. Since the homestead movement of the Great Depression, supporters of alternative currencies have advocated a supply of credit based on principles of bartering or exchanging goods and services (North 2007). In contemporary society, the Local Exchange Trading System (LETS) in North America, or local currencies such as "favours" in the United Kingdom, promote local self-sufficiency. Greens have advocated replacing welfare with a program that would guarantee recipients a basic income and allow them additional earnings, whether in local or traditional currencies, and thereby provide an incentive to work.

The Role of Business

One further area of community capital is witnessed in the moves to engage business with sustainable and pro-community activities. Writers such as Fritjof Capra and Gunter Pauli (1995) have outlined the significant role business plays in creating more sustainable pathways for communities and their environments. The active role played by businesses in developing community capital is best understood though an examination of the concept of corporate social responsibility (CSR). Essentially, corporate social responsibility extends the corporate sector's focus beyond mere concerns with profit margins and allows for recognition of the world beyond the business–customer relationship.

As multinationals increase their presence across the globe, this move toward increased integrity in the relationship between corporations and communities has become more significant. Corporations have also moved toward contributing to communities through increased charitable philanthropy. This process of making donations to help communities develop has been described as "cause marketing." Jocelyne Daw (2006) described the emergence of the cause-marketing phenomenon in international business. Representing a market worth $1.4 billion, Daw outlined the manner in which cause marketing has become a sophisticated contemporary trend that creates deeper links between the corporate sector, communities, and the groups or foundations that enhance the lives of others.

Community Culture

Community culture emerges from a process of socialization whereby inhabitants are indoctrinated with distinct values by social institutions including parents, schools, peers, work colleagues, religious groups, media, and state apparatus. The creation of these bonds of socialization lies at the heart of community capital. For Bourdieu, the local characteristics that underpin socialized community cultures are part of that region's "habitus," or the identity born of shared forms of local experiences and environments. Community capital is then derived from a system of mutual exchange built from what Bourdieu describes as "all the goods, material and symbolic, without distinction, that present themselves as rare and worthy of being sought after in a particular social formation" (Harker, Mahar, and Wilkes 1990, 1).

According to Robert Putnam, author of *Bowling Alone: The Collapse and Revival of American Community* (2000), the social version of capital "refers to the collective value of all *social networks* and the inclinations that arise from these networks to do things for each other." In his study of American community, Putnam set out two main components of social capital: bonding capital and bridging capital. Bonding capital refers to the value attributed to the social networks that exist within homogeneous communities, while bridging capital refers to the social networks that exist between socially heterogeneous groups. Relevant examples are utilized by Putnam to demonstrate the consequences of the existence or nonexistence of community capital. For instance, adolescent gangs may create forms of bonding social capital with negative consequences, while sports groups such as the bowling clubs referred to in Putnam's title may create bridging forms of social capital with positive outcomes. Bridging social capital may be beneficial for society in a number of ways; democratic deficit and social breakdown can be addressed as participatory activity is enhanced in the civic sector. Alternatively, the absence of community capital may lead to the further eroding of civil rights and the loss of public amenities, creating negative consequences for wider society and the environment.

The formation of community capital is dependent on the existence of a "sense of community," which is a shared psychological experience of community rather than its tangible or structural frameworks. Such experiences are multifaceted and interwoven with the experiences of others, and it is within this "imagined community" (Anderson 1983) that community capital emerges in its nascent form. This sense of community engenders shared feelings of belonging that are supported by a mutual respect and sense of commitment. Ultimately this sense of social cohesion can be understood by examining the social relations found within a neighborhood, where socialized forms of influence are crucial to the formation of norms and values. The shared values, both imagined and acted upon, form the social cohesion (or "glue") that binds communities. Internet communities have developed the imagined community further, with the technological capital that has emerged from such innovations central to the contemporary concept of community diffusion.

From a social psychological perspective, David McMillan and David Chavis (1986) set out a theory within the field of community psychology; it argues that a prevailing "sense of community" comprises the following four key elements:

- membership that includes boundaries, emotional safety, a sense of belonging and identification, personal investment, and a common symbol system
- influence that is reciprocal because participants have some influence over the wider group and the group has influence on participants in order to maintain wider cohesion
- integration and fulfillment of needs that occurs when participants attain benefits or rewards for their contribution to the group
- a sense of shared emotional connection that includes shared histories and experiences borne from participation and engagement with the group

Classical Theory and Community Capital

Further understanding of community capital can be gained from the works of classical social theorists. The philosopher, social scientist, and revolutionary Karl Marx (1818–1883) extolled a concept of collectively pooled "species being," or the group-based aggregate of skills passed on within a community from the skilled exponents of communal-based crafts. The social theorist Max Weber (1864–1920) outlined an understanding of "status and association" whereby social networks and mobility could be derived from the groups with which a person associated, with status being bestowed by the community for contributions rather than earnings or profit. Credited by many to be the father of sociology, Émile Durkheim (1858–1917) identified the central role of "organic and social solidarity networks" in the development of society, as different types of social solidarity came to correlate with different types of society. Durkheim divided these into mechanical and organic solidarity in his seminal study *The Division of Labour in Society* (1893). Mechanical solidarity comes from the homogeneity of individuals connected by shared location or common goals and is an attribute of traditional societies. Organic solidarity emanates from the interdependence that arises from specialized activities in modern societies. This interdependence is therefore based on the sum of a community's component elements. In modern societies, social solidarity develops through the interaction stemming from the complexities and interdependence of the industrial age.

The sociologist Ferdinand Tönnies (1855–1936) contrasted social groups formed through personal and social ties—in families, villages, and towns, for instance—that link like-minded individuals sharing values and belief systems (*gemeinschaft*) with the impersonal, formalized, and engaging links, such as economy and industry, that exist across society (*gesellschaft*). The pluralism set out by the French political thinker Alexis de Tocqueville (1805–1859) in *Democracy and America* (2000) depends on the creation of public space for such forms of community capital to exist. Community capital is formed through the tapping of reservoirs of key elements and resources in and around the community by those who comprise the community, and through the value placed on this process. This value is supported by the public-spirited impulse that survives without recourse to preexisting alignments or alliances, avoiding what de Tocqueville described as "the tyranny of the majority." From the work of the historian and philosopher Michel Foucault (1926–1984), community capital can be understood through the nodes of "local governmentality" that emerged from regional forms of power.

Key Indicators

The conditions that point to whether sufficient degrees of community capital exist in a social group include levels of pluralistic activism within participatory democracy and an active civil society with associated nongovernmental organizations (NGOs) and community-foundation groups with access to Internet resources. Economic capital augments community capital in the form of credit unions and cooperative movements, corporate social responsibility movements engaged with cause marketing, and alternative financial networks. Cultural-capital contributions to community capital incorporate "the engaged campus" with enhanced opportunities for volunteerism, knowledge sharing and pooling of existing educational resources, smaller school sizes with literacy programs, and equal access to education for all sectors in society. Particularistic elements within a region such as pedestrian access to commercial, residential, and public structures, as well as the availability of park benches, sports facilities, woodlands, and cycle lanes, play a significant role in the development and retention of levels of community capital. Therefore, spatial planning for public spaces and amenities becomes a crucial part of community-capital projects. Due to the costs involved, public/private partnerships have emerged around community projects, enhancing corporate engagement with the public sector and local municipalities.

Ecological capital is provided through the establishment of sustainable practices such as recycling, community farming, cooperative markets, pooled labor, and alternative or green-living practices. The corrosive results of poor urban planning and neglect were outlined in David Harvey's book *Spaces of Hope* (2000). He presented the significance of good planning practice and the development of the public space as an antidote to the urban breakdown that has become characteristic of major cities such as Baltimore. The development of social ecology and ecological capital is also a significant element of the concept of sustainable development. End-of-pipe solutions are replaced with green processes that incorporate sustainable practices into the chain of production, from the product-planning stage through to recycling of used parts, with integrated forms of management and production being utilized for the benefit of the environment and wider community.

Various forms of mutual engagement create community capital that can be measured through a series of indices to quantify quality of life, happiness, health, longevity, optimism about the future, employment and wealth, civic engagement, and neighborliness. Religious participation and family interaction may also be measured as part of a community-capital index. These indices can be referenced during societal upheavals, such as economic downturns, demographic shifts, increased ethnic diversity, and spatial developments, or in wider events such as climate change, to create better understandings of community-capital reservoirs. The creations of horizontal public networks are at the core of the quest to enhance or retain levels of community capital. Public-spirited concepts such as civic leadership, egalitarian volunteerism, philanthropy, and social responsibility are crucial to this initiative. Once sufficient levels of these civic virtues are attained, the subsequent civic engagement provides an effective bridging function between nonlinear and nonaffiliated networks and the wider population. This connectivity between social networks and community capital has provided a local and interpersonal response to the anomie, or the social instability and personal uncertainty, formed from trends in globalization and accelerated change that is a characteristic of the post-modern condition.

In Chinese culture, the concept of *guānxi* is used to describe the interpersonal networks that exist between two people whereby one person is able to rely on another for assistance, favors, or other forms of community benevolence, regardless of preexisting levels of social status. *Guānxi* can also be used to describe a network of prevailing contacts that can be mobilized within the community. In addition, influence for the common good can be maintained in this way. This form of community capital can become an unspoken norm, part of the manners or etiquettes of what the sociologist Norbert Elias (1897–1990) called *The Civilizing Process (2000)*. Ultimately a key component of sustainability is derived from the sharing of practice and knowledge that emerges from community discourse, as when innovative solutions and best practices evolve from such flows of knowledge.

Recent discussions of community capital have dealt with demographic diversity. Ethnic diversity is on the increase across developed nations. The imparting and learning of new languages and cultures is an important aspect in the development of community capital. Multicultural-based community capital creates opportunities for new forms of economic and development entrepreneurialism. This is the basis for the study *Better Together: Restoring the American Community* (Putnam and Feldstein 2003), which explores social cohesion and civic engagement within the context of shifting demographics and increased migration. Community capital is built as different cultures merge to form new identities based on the exchange of cultural norms and values, and as they develop bonds through institutions and practices such as educational pursuits and volunteerism.

Using Civic Intelligence to Address Issues

Another element in the formation of community capital is civic intelligence, or the pooled expertise devoted to addressing public or civic issues by organizations, public bodies, or individuals. Within the framework of the community, civic intelligence is the understanding that there is a value in the contribution made by all members of the community regarding the decisions affecting the community. According to the sociologist Jared Diamond in his study *Collapse: Why Some Societies Choose to Fail or Succeed* (2005), significant levels of civic intelligence are required for humankind to solve the planet's major problems such as climate change or the energy crisis.

Community capital can be seen in a range of social engagements and interactions, from community-development initiatives to intentional communities, to credit unions, cooperatives, and the social responsibility of the corporate sector. The shared experiences and values formed from community capital create a pool of human and natural resources that can be drawn upon to meet the many challenges facing neighborhoods, societies, and nations on this ever-changing planet.

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See also Corporate Citizenship; CSR and CSR 2.0; Development, Sustainable; Ecological Economics; Municipalities; Public Transportation; Smart Growth; Social Enterprise

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Consumer Behavior

Researchers have found that social, economic, and biological factors contribute to consumer behavior. Consumption of consumer goods has increased since the beginning of the twentieth century, largely because of social factors (desire for social and sexual status, displays of wealth, personal identity, and symbolic meaning). The increase affects sustainable consumption, and policy makers need to examine social contexts when addressing pro-environmental behavioral change.

Understanding mainstream consumer behavior is a prerequisite for understanding how to motivate or encourage pro-environmental consumer behavior. Although the terminology and the context of sustainable consumption were developed during the twentieth century, the debates about consumption, consumer behavior, and consumerism are much older and much deeper.

Consumption, in the words of the social scientist Daniel Miller (1995), has become the "vanguard of history." To question consumption is, at one level, to question history itself. To engage in attempts to change consumption patterns and consumer behaviors is to tinker with fundamental aspects of our social world. To proceed without acknowledging this degree of complexity and sophistication, many thinkers believe, is to invite an inevitable failure.

The wider debates on consumption can be traced back (at least) to classical philosophy. They encompass the critical social theory of the nineteenth and early twentieth centuries, the consumer psychology and "motivation research" of the early postwar years, the "ecological humanism" of the 1960s and 1970s, the anthropology and social philosophy of the 1970s and 1980s, and the sociology of modernity, popularized in the 1990s. Each different avenue of exploration asks slightly different questions about consumption and consumer behavior.

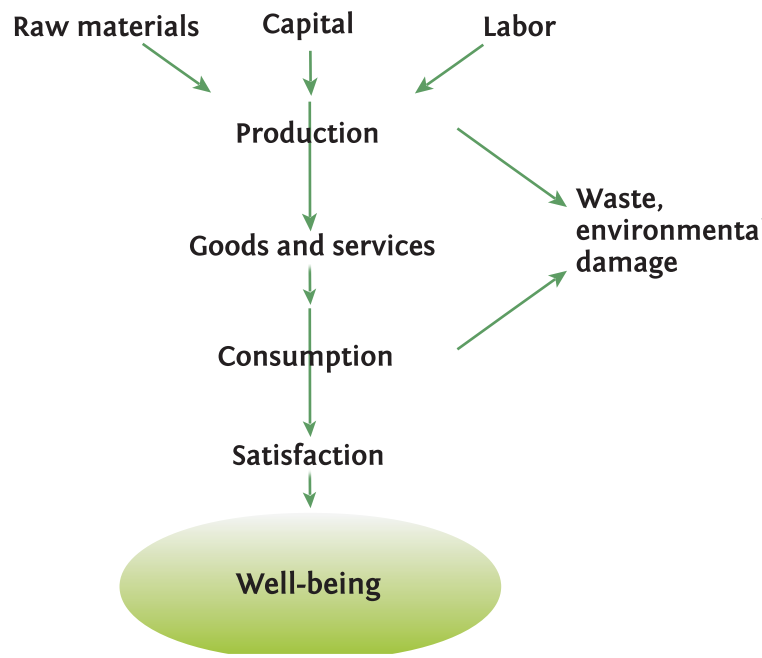
Consumption and Well-Being

Consumption can be viewed as a functional attempt to improve individual and collective well-being by providing the goods and services necessary to meet people's wants and desires. This linear view of consumption is generally the one encoded in conventional economics (Mas-Colell, Whinston, and Green 1995; Begg, Fischer, and Dornbusch 2003). (See figure 1. on page 74.) Stressing the "insatiability" of consumer desire and the "sovereignty" of consumer choice, economics takes a broad, utilitarian approach to evaluating consumer goods and services.

A consumer buys a particular commodity because it offers certain useful functionalities. A new car gets a person from A to B more efficiently, cheaply, and pleasantly than an old car does. A wide-screen plasma TV is easier to see and hear. People are willing to spend more money on these purchases because they value these additional services. But a consumer can never be considered entirely satiated, because new and better products and more and different ways of satisfying appetites and tastes will always be offered.

Though based on the assumption that consumers have a certain set of preferences or tastes, the economic view of consumption does not address the underlying motivations for them. The economic view goes only so far as to "reveal" the ways in which consumers spend their money in the market. Economics makes key assumptions about the rationality of consumers' ability to choose products that offer them utility and thereby contribute to their well-being.

Figure 1. A "Supply Chain" View of Well-Being



The "supply chain" view of consumption illustrates the inherent unsustainability of depending on material things for a feeling of well-being.

Consumption and Needs

Over the years, numerous critics have attacked the conventional economic position on consumption and needs. One of the most telling critiques draws heavily on the concept of human needs. Needs theorists suggest that, in contrast to the "insatiability" of desire, "true" human needs are finite, few, and universal (Max-Neef 1992; Maslow 1954, 1968).

Classifications and typologies of human needs tend to distinguish between material needs (such as subsistence and protection) and social or psychological needs (such as self-esteem, autonomy, and belongingness). They also distinguish between needs themselves and satisfiers, things that produce satisfaction. They suggest, crucially, that not all satisfiers are equally successful at meeting the underlying needs. Food, for example, is a satisfier of the need for subsistence. But not all foods have equal nutritional value, and some are positively bad for us in anything more than very small quantities.

The possibility that some of what we consume does not satisfy our needs provides the basis for a long-standing critique of consumer society (Springborg 1981). Social critics maintain that, far from meeting our needs, commercial interests in modern society have created sets of "false" or "unnatural" needs that have come to alienate consumers from their own well-being, and in the process threaten the environment (Fromm 1976; Illich 1978; Marcuse 1964; Scitovsky 1976). According to this critique, the consumer way of life is deeply flawed. It neither serves our own best interests nor protects the environment. Proponents of this argument call on the so-called life-satisfaction paradox in defense: real consumer expenditure has more than doubled in the last thirty years, but reported life satisfaction has barely changed (Donovan, Halpern, and Sargeant 2002).

The debate about human needs has generated protracted and sometimes fierce disagreements. Cultural theorists and sociologists tend to be skeptical of this discourse on needs, arguing that it is naive, rhetorical, and moralistic. Nonetheless the language of needs has popular appeal, and it links with the discourse of sustainable development. Indeed this needs-based critique of consumer society appears to offer considerable hope for achieving sustainable consumption. If social and psychological needs really are ill served by modern commodities, then it should be possible to live better by consuming less, and in the process reduce our impacts on the environment.

On the other hand, if consumerism fails to satisfy, why do we continue to consume? The social critique of consumer society tends to point to the power of commercial marketers—the "hidden persuaders" in the sociologist Vance Packard's (1956) terminology—to "dupe" consumers into buying things that do not serve their needs. But there are a number of other equally powerful and sometimes more sophisticated responses to the question.

Consumption and Desire

One response to the question of why we continue to consume is that human needs have been overemphasized. Consumers are not driven much by coherent attempts to satisfy well-defined sets of needs and wants, according to this view. Instead many of our tastes and preferences are informed by desire. And desire, it is argued, has a different character from need. Desire is associated with powerful emotional or sexual drives and motivations, rather than with "rational" efforts to match the functional character of goods with specific personal or social requirements.

The idea that consumption is connected to sexual desire is supported by ethnographic research (Belk, Güliz, and Askegaard 2003) and bolsters the wisdom of advertising executives that "sex sells." From cigarettes to chocolate, and from underwear to cars, sexual connotation has been widely employed in advertising, both directly and indirectly, to render goods and services attractive to prospective consumers. But this association of objects with sexual desire is not an arbitrary or artificial device concocted by marketers. If it were, it would be highly unlikely to succeed. What advertising attempts to exploit is a widespread association of material commodities with sexual and social status. Therefore, for well over a century, sociological and psychological discourses on consumption have focused on displays of wealth and income and the status they bring.

This is where accounts of consumer desire sometimes call on evolutionary biology to explain and understand display- and status-oriented consumption (Wright 1994; Ridley 1994). The theory of evolution suggests that animal behaviors are the result of evolutionary adaptation under pressure from the forces of natural selection and sexual selection. (Natural selection is inter- and intraspecies competition for scarce resources, and sexual selection is intraspecies competition for sexual partners). This explanation suggests that consumer behavior is conditioned, at least partly, by social and sexual competition. It also suggests a biological basis for consumption that makes behavioral changes in consumption difficult.

Ordinary and Inconspicuous Consumption

Sociology studies suggest that the conspicuous and status-seeking aspects of consumer behavior have been overemphasized. According to this view, a great deal of consumption takes place inconspicuously as a part of the ordinary, everyday decision making of millions of individual consumers.

Ordinary consumption, argue these studies, is not oriented toward individual display. Rather it is about convenience, habit, practice, and individual responses to social norms and institutional contexts (Gronow and Warde 2001; Shove 2003; Shove and Warde 1997). Instead of acting as willing partners in the process of consumerism, consumers are "locked in" to a process of unsustainable consumption over which they have little individual control (Sanne 2002).

The concept of *inconspicuous consumption* is important to understanding consumer behavior. In particular, it connects with our day-to-day experience of consuming. Shopping for high-fashion goods may explicitly engage our display motivations on selected occasions. Apart from compulsive or addictive shoppers, however, we do not as a rule spend our day-to-day life engaged consciously in this kind of consumption. Much everyday consumption is almost invisible, even to ourselves. The regular payments that leave our bank accounts to cover our mortgages, insurance payments, utility bills, and local taxes do not appear to be associated with display or status. Even when we change electricity or gas suppliers, for example, few of us are motivated to choose a new supplier by any attempt to improve our social standing.

In this analysis, consumers are a long way from being willing actors in the consumption process, capable of exercising either rational or irrational choice in satisfying their own needs and desires. More often they find themselves locked in to unsustainable patterns of consumption, either by social norms that lie beyond individual control or by institutional constraints in which individual choice is negotiated.

Consumption and Identity

There is a broad agreement that, in modern society, consumption is in some sense inextricably linked to personal and collective identity. According to Yiannis Gabriel, a former professor of organizational theory, and Tim Lang, a food-policy professor, identity is the "Rome to which all discussions of modern Western consumption lead, whether undertaken by Marxist critics or advertising executives, deconstructionists or liberal reformers, advocates of multiculturalism or radical feminists" (1995, 81).

Certain sociologists and social philosophers believe that consumer goods are important to processes of identity creation, a belief that forms the basis for a specific view of consumer society. According to this view, the individual consumer is engaged in a continuous process of constructing and reconstructing personal identity in a continuously renegotiated universe of social and cultural symbols.

Authors take different positions on the extent to which this relationship between identity and consumerism is a good or a bad thing. The sociology professor Colin Campbell (1997) argues that an open choice of consumer goods is vital to enabling consumers to be autonomous individuals in modern society. The historian and psychotherapist Phillip Cushman (1990) argues that the "empty self" of the modern consumer, which constantly needs "filling up," is a cultural artifact, or human-made object, generated explicitly by and for the commercialism of modern society. The philosopher Jean Baudrillard (1998) condemns the "social logic" of consumption, in which people consume for status, as a "luxurious and spectacular penury."

Despite these differences, the link between the consumption of material goods and the construction and maintenance of personal identity is one of the most prominent and perhaps most important elements in modern understanding of consumer behavior. Whereas in earlier times we were what we did (or sometimes who we knew), in modern society we are what we consume.

Symbolic Role of Consumer Goods

Embedded within the idea that consumption and identity are linked lies an important insight into our relationship to consumer goods: consumer goods play vital, symbolic roles in our lives. We value goods for what they can do, but also for what they represent to us and to others. Without this belief, it is doubtful that plain "stuff" could serve such a key role in our lives. This insight resonates with popular psychology about our relationship with material possessions (artifacts). A favorite teddy bear, a wedding dress, a favorite set of golf clubs, the souped-up sports car: all these examples suggest that more is at stake in the possession of material artifacts than simple functional value.

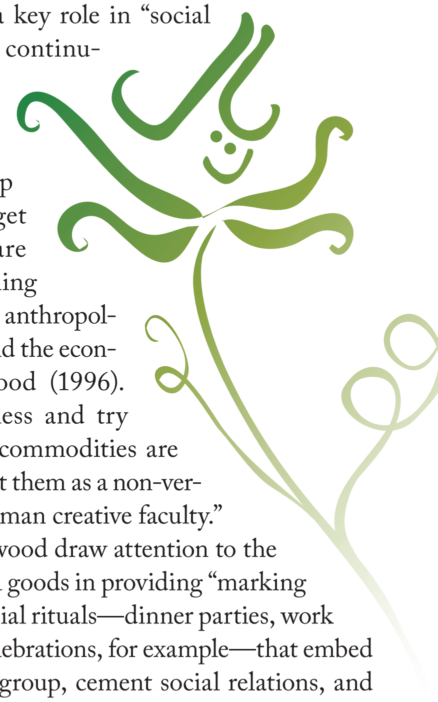
Over the second half of the twentieth century, this popular wisdom was given more credence. The symbolic importance of consumer goods has been underlined by a wide range of intellectual sources; the evidence from anthropology is perhaps the most convincing. Societies throughout the ages have used material commodities (things of value to exchange or sell, such as cattle, for example, in early societies) as symbolic resources to denote a wide variety of different meanings in a wider variety of situations and contexts.

The lesson from the huge body of literature on the symbolic roles of goods is clear: material commodities are important to us, for what they do and for what they signify to others and to ourselves about us and about our lives, loves, desires, relationships, successes, and failings. Material commodities are not just artifacts. Nor do they offer purely functional benefits. They derive their importance, in part at least, from their symbolic role in mediating and communicating personal, social, and cultural meaning.

The symbolic role of material artifacts is not unique to modernity. In the light of the anthropological evidence, we must see the symbolic role as an essential feature of human societies with long roots in antiquity. Any understanding of consumer behavior not built on this insight likely underestimates the social and psychological importance of consumer goods and services.

Consumption as Social Conversation

The symbolic function of consumer goods allows them to play a key role in "social conversations"—the continuing social and cultural dialogues and narratives that keep societies together and help them function. "Forget that commodities are good for eating, clothing and shelter," argue the anthropologist Mary Douglas and the economist Baron Isherwood (1996). "Forget their usefulness and try instead the idea that commodities are good for thinking; treat them as a non-verbal medium for the human creative faculty."



Douglas and Isherwood draw attention to the importance of material goods in providing "marking services." These are social rituals—dinner parties, work functions, or festive celebrations, for example—that embed people in their social group, cement social relations, and help maintain information flows within the social group. These information flows, claim Douglas and Isherwood, go far beyond the "display consumption" mentioned in the above discussion about status- and display-oriented consumption. Information flows are crucial to helping the individual maintain and improve social resilience in the face of cultural shifts and social shocks, and in helping the group maintain its social identity and negotiate intergroup relationships.

Consumption and the Pursuit of Meaning

The ability of consumer goods to operate as a form of social conversation means that they become embedded in a wide variety of different personal, social, and cultural narratives. The anthropologist Grant David McCracken (1990) argues that one of the most pressing problems a culture must deal with is the "gap between the 'real' and the 'ideal' in social life," the distance between our aspirations (for ourselves, for our society, and for human nature) and daily reality. He suggests that consumer goods help overcome this problem. Material artifacts, he says, are "bridges" to displaced meaning (a coping strategy people use to sustain hope). Designer sunglasses, the new car, the wedding outfit, the seaside vacation are more than satisfiers of functional needs. They are bigger than the objects themselves or even than their use value. They are material representations of our expectations for the future, of the status to which we aspire, of the comforts that we deserve, of the rewards that we fervently hope will be showered upon us. They are bridges to our displaced ideals.

The concept of the pursuit of meaning is vital to understanding consumption. No purely functional account of material goods will deliver a robust model for understanding consumer behavior, because functionality is not the point (or not exclusively the point). We consume not just to nourish ourselves or protect ourselves from the elements or maintain a living; we consume in order to identify ourselves with a social group, to position ourselves within that group, to distinguish ourselves with respect to other social groups, and to communicate allegiance to certain ideals. We consume in order to communicate. Through consumption, we communicate not only with each other but with our past, with our ideals, with our fears, and with our aspirations. We consume, partly, in pursuit of meaning.

Implications for Behavioral Change

The psychological, sociological, and anthropological literature on consumption is rich. Its richness has long been recognized in marketing, consumer studies, and motivation research. Business and commercial interests have drawn widely on this depth to design products and devise strategies for persuading people to buy them. Importantly, the same literature is a resource for policy makers attempting to deal with the problem of unsustainable consumption. But the vast literature is dogged with disagreements and intellectual tensions, and its understandings straddle some well-entrenched and rather intractable debates with very long histories. Nonetheless, it is possible to draw out two or three important themes in relation to understanding unsustainable consumption.

The first theme is that we are living in a consumer society. There has been a massive expansion in the availability of consumer goods in developed economies since the mid-twentieth century. These economies have a structural reliance on consumption growth, and previously public goods and services have been extensively commercialized.

Fundamental aspects of our modern cultural identity are different than they were in the nineteenth century. Modern consumer society has its own logic, its own dynamics, its own epistemologies and ethics, its own myths and cosmologies. All of these are different from those of other times and places. Policy makers addressing the large-scale shifts in consumption patterns will be well served to examine the history of consumption.

In certain respects, however, modern consumer society is much like any other society before it. The second theme to be drawn from the consumption literature is that material artifacts have important symbolic roles and, accordingly, can negotiate crucial psychological and social functions in our lives. The main objective of consumption by the individual is, in Mary Douglas's words (1976), "to help create the social world and to find in it a credible place."

The symbolic role of material artifacts appears to be shared by every society for which there is anthropological evidence. But modern society's extensive appropriation of this symbolic role for key social and psychological purposes does appear to be a distinguishing feature of modernity. The social-psychological and cultural complexity associated with this relationship is a main reason for the apparent difficulty in analyzing consumer behavior and consumption patterns.

The third theme is equally important, because the evidence indicates that consumer motivations are often embedded in a variety of ordinary, routine, and habitualized behaviors. The behaviors are heavily influenced by social norms and practices and constrained by institutional contexts. These factors emphasize that consumers are not able to exercise free choice in the selection of goods and services, and they often find themselves locked in to specific consumption patterns by a variety of social, institutional, and cognitive constraints.

These understandings highlight the difficulty and complexity associated with negotiating pro-environmental behavioral change. They also point to the importance of understanding and influencing the social context within which consumer choice is negotiated. Policies that seek to promote pro-environmental behavioral change will need to engage the social context that shapes and constrains social action and the mechanisms of individual choice equally.

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This article is based on chapter two of *Motivating Sustainable Consumption: A Review of Evidence on Consumer Behaviour and Behavioural Change*, a report to the Sustainable Development Research Network (2005) by Tim Jackson. That chapter, in turn, draws from an earlier paper published by the Sustainable Development Commission (Jackson and Michaelis 2003).

See also Development, Sustainable; Green GDP; Marketing; True Cost Economics

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Corporate Citizenship

Multinational corporations have a reputation, often well deserved, of focusing solely on profit at the expense of people and the environment. Their power and influence, however, also render them uniquely qualified to effect positive change regarding such critical twenty-first-century societal challenges as poverty, disease, and environmental degradation.

The success of global society is increasingly influenced, if not defined, by the behavior of multinational corporations. By 2005, more than half of the world's 100-largest economic entities were corporations, not countries. ExxonMobil, for example, with 2005 revenues of over $341 billion and profits of $36 billion, was larger than two-thirds (125) of the 184 countries whose economies were ranked by the World Bank in 2005 (United Nations Conference on Trade and Development 2005). Similarly, Walmart was the nineteenth-largest economy in the world, with sales exceeding $250 billion; its revenue in a single day was larger than the annual gross domestic product (GDP) of thirty-six independent countries (Mau, Leonard, and Institute Without Boundaries 2004, 128).

What global companies such as ExxonMobil and Walmart do, individually and collectively, matters not only to their own customers, employees, and suppliers, but also to the larger global economy and society. (Although the economic downtown that began in late 2007 has affected corporate earnings, causing the 2008 percentage of multinational corporations that were included in the top 100 economic entities to drop, the power corporations wield is still huge, and thus the concepts discussed in this article are more than ever relevant [Forbes.com 2008; World Bank 2009].)

How can companies and society simultaneously benefit from the ways in which multinational firms operate? How might companies operate in the future to increasingly contribute to society's well-being, while simultaneously enhancing their own financial performance? These questions relate to corporate citizenship and corporate success, which the business world must come to terms with.

Questioning the potential for positive outcomes that are created by the private sector is particularly important. The reason is that the behavior of companies such as ExxonMobil and Walmart toward their own employees, other stakeholder groups, and the broader social and physical environment has frequently (and often accurately) been severely criticized in the courts, the popular press, and academic publications. The economists Andreas Georg Scherer and Guido Palazzo point out that prior discussions of the relationship of firms to the social and physical environment presupposed that responsible firms operated within a system of primarily government-defined rules and regulations. With globalization, however, this assumption is no longer valid: "The global framework of rules is fragile and incomplete. Therefore business firms [since about 2000] have an additional political responsibility to contribute to the development and proper working of global governance" (Scherer and Palazzo 2008, 3). Whereas the social, economic, and political influences of multinational corporations (MNCs) are well known, what we know is disproportionately negative and narrowly focused on economic outcomes. Perhaps the most important question facing the business world in the twenty-first century is what can be learned about the positive impacts of multinational business.

During the twentieth century, many business leaders believed that their companies should be detached from society. Reflecting their sentiment, the U.S. economist Milton Friedman (1912–2006) expressed his strongly held opinion that the only "social responsibility of business is to increase its profits" (1970, 122). Going beyond twentieth-century logic, prominent CEOs from all continents are expressing their belief that the relationship between business and society—including business's search for mutually beneficial advances that address the world's most pressing global needs—has become a defining issue for the twenty-first century.

We should question what the implications are for business in a century in which the following situations occur (Adler 2006b):

- Global integration is no longer a choice for most companies.
- Change is often as discontinuous as it previously was reliably predictable.
- Transparency is more likely to be defined by a single photo that exposes previously hidden corporate malfeasance—shown first on an online video community, and then on the evening news—than it is to be defined by any country's legal structure or by the World Trade Organization's entire set of regulations.
- Resource scarcity, as blatantly highlighted in Sudan, exacerbates previously tranquil economic relationships.
- Global environmental crises, human rights abuses, societal violence, and income inequality are more likely to be blamed on the private sector than on government.
- Public opinion is more likely to condemn corporate malfeasance than praise companies' societal contributions.

Transcending Twentieth-Century Assumptions

As we consider the challenges facing the world in the twenty-first century, it is important not to make assumptions based on previous business experience. These assumptions include:

- That which is common is true.
- The environment determines the set of possible behaviors of actors.
- Progress comes from fixing problems rather than from amplifying strengths.
- That which has been, will be.

None of these pervasive assumptions supports business in recognizing—let alone understanding—outstanding, admirable, and effective behavior. Unquestioned, the assumptions certainly do not help business understand why certain MNCs simultaneously succeed financially and act as agents of world benefit successfully, whereas the majority remains oblivious to world betterment. The majority continues, in the name of externalities (unintended societal consequences of a business action), to inflict deleterious effects on the world. To address MNCs' relationship to the array of global societal issues, it is necessary to go beyond the research methodologies that have guided scholarship in the past. It is necessary to consider more-anticipatory approaches.

BHP Billiton and Malaria in Africa

In 1999, former United Nations secretary-general Kofi Annan challenged the business world at the World Economic Forum in Davos, Switzerland: "Let us choose to unite the power of markets with the strength of universal ideals." One multinational corporation, BHP Billiton, an Australia-based international mining company and one of the world's largest aluminum producers, serves as an example of how Annan's challenge may be successfully addressed to the betterment of all.

Besides widespread warfare, one thing that consistently keeps Africa impoverished is malaria, which is estimated to reduce the continent's economic growth by 1.3 percent annually, at a cost of almost $12 billion a year. Every thirty seconds an African child dies of malaria. Whereas malaria has been almost eradicated in most of the world, in Africa it is still out of control, claiming more lives every year.

BHP Billiton came to Mozambique in the 1990s, thus becoming one of the first multinational companies to make a substantial investment ($1.3 billion) in the country following Mozambique's twenty-year civil war (LaFraniere 2006). Known as "Mozal," which is short for Mozambique Aluminum, BHP Billiton's entire Mozambique operation was at risk if it failed to eradicate malaria. In just the first two years of operation, one-third of Mozal's sixty-six hundred employees fell ill from malaria and thirteen died. At any given time, 20 percent of Mozal's employees were absent due to malaria. From a strictly financial perspective, BHP Billiton could not afford the cost of malaria.

For years, international and national public health campaigns to eradicate malaria have been conducted, and they have been failing, in Africa. BHP Billiton quickly realized that it could not protect its Mozambique investment by relying on others or by focusing only on its own employees. So in 1999, the same year that Kofi Annan challenged those in the private sector to become co-creators of society's success, BHP Billiton chose to partner with the governments of Mozambique, Swaziland, and South Africa to create a regional antimalaria campaign covering 4 million residents. For the first time, a large-scale malaria eradication effort succeeded in Africa, and for the first time, it was company led. In just six years, the partnership between Mozal and the three national governments succeeded at a previously unimaginable level. In the entire region, new cases of malaria plummeted from sixty-six to fewer than five cases per one thousand inhabitants. The percentage of infected children fell from more than 90 percent to less than 20 percent in the region of BHP Billiton's smelter.

Malaria-caused absenteeism at Mozal went down from more than 20 percent to less than 1 percent. At the same time, BHP Billiton's Mozambique operations became a financial success. In just three years, it expanded and more than doubled its production in Mozambique. BHP Billiton not only rose to Kofi Annan's challenge, it far exceeded anything the company or the community had ever previously thought possible. Foreign investment went up, profits went up, employment went up, the number of children able to attend school went up, and the number of hospitalized and dying people went down.

Redefining Success

There is no question that scholars of international business can become a primary source for understanding business's role in contributing not only to global companies' financial well-being, but also to the success of the broader society. The field, however, must continue to re-question the fundamental perspectives and assumptions inherent in its conceptualizations and methodologies. Rather than accepting the future as predetermined by historic patterns, the community of international business scholars can offer grounded evidence for informed hope.

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See also Base of the Pyramid; CSR and CSR 2.0; Equator Principles; Health, Public and Environmental; Human Rights; Peace Through Commerce: The Role of the Corporation; Social Enterprise; Stakeholder Theory; United Nations Global Compact

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Cradle to Cradle

"Cradle to cradle" (sometimes abbreviated C2C) is a concept for sustainable waste management and natural resource conservation that aims to utilize 100 percent of all waste produced. This economic concept may be applied to such areas as urban environments, buildings, and manufacturing processes.

In 1987 Walter Stahel and Max Börlin published "Economic Strategies of Durability—Longer Product-Life of Goods as Waste Prevention Strategy." The report demonstrated how companies operating in a loop economy, which focuses on the reuse and recycling of materials over the life a product, could achieve higher profits than competitors whose continued economic growth depended on abundant sources of raw materials and resources. Some experts countered Stahel and Borlin's findings by proposing that a "cradle to grave" concept, in which a product would be responsibly monitored at every stage of its lifecycle from design to disposal, was more compatible with the existing economic model used in industrialized countries. Stahel, an architect by training, insisted that the only sustainable solution was to use durable goods in a "loop" from cradle back to cradle.

Michael Braungart and William McDonough began to promote their own cradle to cradle concept based on research they contributed to *A Technical Framework for Life-Cycle Assessment* (1991), a publication that grew from a Society of Environmental Toxicology and Chemistry (SETAC) workshop with participants of various backgrounds. Braungart and McDonough agreed with Stahel that the rapid depletion of our natural resources makes the cradle to grave approach unsustainable. They also pointed out that the cradle to cradle model can be applied to any system in modern society—urban environments, buildings, and manufacturing processes—and they used many case studies to prove their point.

In their cradle to cradle model, all materials used in manufacturing processes are classified as either technical nutrients or biological nutrients. Technical nutrients are inorganic or synthetic materials manufactured by humans (such as plastic, glass, and metals) that can be used many times in a continuous cycle without any loss in quality. Biological nutrients are organic materials that, after use, can be disposed of in any natural environment to decompose.

How the Model Works

Harmful materials and chemicals continue to be used in the manufacturing (or appear in the ingredient lists) of many products. The cradle to cradle model seeks to remove dangerous technical nutrients, which may cause undesirable health effects or environmental damage, from product lifecycles. This is can be achieved by producing another nontoxic product that has the same function or by replacing hazardous raw materials with a harmless substance.

Nike Considered products are an example of how a cradle to cradle business model can reduce a company's environmental footprint. From the design stage onward Nike measures its Considered lines—both apparel and footwear—according to a company index that evaluates and predicts the sustainability level of a product: a shoe will be "Considered," for example, on the basis of substantially reduced use of solvents and toxic glues during assembly (and in the application of design elements) as well as by the tanning methods used to process leather. Acting on the principle that a product must go back to the cradle at the end of its life, Nike's Reuse a Shoe program collects athletic footwear of any brand—whether discarded, defective, or counterfeit—from a variety of sources. The recycled shoes are then ground with scrap material from prior Nike manufacturing processes and purified; the mix, under the moniker of Nike Grind, becomes a part of a new manufacturing cycle.

C2C Companies

In 1995, McDonough and Braungart founded a consulting firm, McDonough Braungart Design Chemistry (MBDC), now based in Charlottesville, Virginia. MBDC promotes a worldwide cradle to cradle (C2C) certification program so that companies have a means to tangibly and credibly measure their achievements in environmentally friendly design. This proprietary program (i.e., it is privately sponsored and service marked), also helps customers identify and purchase products that meet C2C guidelines. MBDC corporate clients include Nike, Herman Miller (the Aeron chair manufacturer), and the United States Postal Service.

Another organization, the Product-Life Institute, is a nonprofit independent organization. Founded in 1982 in Geneva, Switzerland by Orio Giarini and Walter R. Stahel, the institute conducts contract research as consultants to industrial companies, government authorities, and universities. It develops strategies and policies for projects related to sustainability. These studies include optimization of the product-life of goods and services, improvement of the economic feasibility of goods by extending their useful life through product design, reconditioning and remarketing, selective recycling, and long-life component or product design. The institute's clients include Kodak, DuPont, and Caterpillar.

Criticisms

Some critics have stated that McDonough and Braungart keep the C2C consultancy and certification within its small proprietary circle. They point out that, with only 150 certifications, MBDC's program has so far only achieved limited effectiveness. Critics have also suggested changing the closed and proprietary approach of C2C certification to enhance competition and growth. Efforts in education, public participation, and international cooperation are important to the success of this concept.

Experts in the field of environmental protection have questioned the practicability of the concept. George Tchobanoglous, Hilary Theisen, and Samuel Vigil wrote in their 1993 book *Integrated Solid Waste Management: Engineering Principles and Management Issues* that plastics are the least recycled material in developed nations; unfortunately, there has been little change since then. Recycling and reuse are still labor-intensive processes. Because of the expensive labor costs and influential political lobbying that occurs in developed nations, recycling, reuse, and recovery of the waste have not improved much since the 1990s, especially in the United States. Another hurdle to C2C implementation is the existing technology in recycling. With plastics, for example, thermoplastics such as PETE, PVC, and HDPE are softened when heated and can be recycled and remolded. But other types of plastics, such as thermosetting plastics, are not recyclable due to their properties and the limited research on recycling them. Because of plastics' low cost, their light weight, and their ability to be formed in any shape, their use will increase, but 100 percent recycling of plastics will not be achieved in the near future. C2C is a goal and a process that cannot be reached in a short time and without considerable investment. In the long run, however, the concept of C2C may be achieved through more research in product development, proper material utilization, government regulation, public participation, and waste management.

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See also Design, Industrial; Development, Urban; Energy Efficiency; Lifecycle Assessments (LCAs); Manufacturing Practices; Natural Step Framework, The (TNSF); Remanufacturing; Sporting Goods Industry; Supply Chain Management; True Cost Economics; Zero Waste

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CSR and CSR 2.0

Despite its good intentions, corporate social responsibility (CSR) has largely failed to make a significant positive impact on the world's most serious social, environmental, and ethical challenges over the past fifty years. The CSR 2.0 model presents an evolution of CSR concept and practice that is connected, scalable, and responsive—one that hopes to make a real, measurable difference in how business is conducted.

The concept of corporate social responsibility, or CSR as it is commonly known, has existed in one form or another for more than four thousand years. Several world religions have taught the immorality of usury, or the charging of excessive interest, as well as the morality of caring for those who are less fortunate. The modern concept of CSR can be traced to the last few decades of the 1800s, when industrialists and philanthropists began setting a charitable precedent that is echoed more than a hundred years later in figures such as Bill Gates of Microsoft and Warren Buffett of Berkshire Hathaway.

CSR's Recent History

CSR entered the popular lexicon in the 1950s with the U.S. economist and college president Howard Rothmann Bowen's landmark 1953 book, *Social Responsibilities of the Businessman*. The concept took further shape in the 1960s with the birth of the environmental movement, following the U.S. environmental scientist Rachel Carson's 1962 critique of the chemicals industry (in particular the widely used pesticide DDT) in *Silent Spring*. The consumer movement took shape with the activities of the U.S. consumer advocate (and subsequent presidential candidate) Ralph Nader's social activism, most famously over General Motors's safety record.

The 1970s saw the first widely accepted definition of CSR emerge in the form of the U.S. business and management ethicist Archie Carroll's four-part concept of economic, legal, ethical, and philanthropic responsibilities, later depicted as a CSR pyramid. It also was implemented in the first CSR code, the Sullivan Principles, named for the Reverend Leon H. Sullivan. He successfully challenged U.S. businesses with South African ties to deal more forcefully with apartheid in South Africa. The 1980s brought the application of quality management to occupational health and safety and the introduction of CSR codes like Responsible Care, an initiative of the global chemical industry with the stated aim of improving health, safety, and environmental performance.

In the 1990s, CSR became institutionalized with standards like ISO 14001 (part of the International Organization for Standardization's system of voluntary industry standards for particular products and for environmental management issues) and SA8000 (overseen by Social Accountability International, a nonprofit affiliate of the Council on Economic Priorities). Guidelines like the Global Reporting Initiative (GRI) and corporate governance codes like the Cadbury and King reports (from the United Kingdom and South Africa, respectively) brought attention to the importance of stakeholders (as opposed to shareholders), among other issues.

The twenty-first century has spawned a multitude of CSR guidelines, codes, and standards addressing the industry sector and climate change variations. (*The A to Z of Corporate Social Responsibility* by George Visser et al. [2007], for instance, lists more than a hundred standards.)

An understanding of where CSR has come from is important in seeing where it is headed and what it might become in the twenty-first century. Because the term is used by such a variety of people and organizations there is a risk that it will cease to be meaningful, in the same way that the word "green" loses its luster when seemingly every product under the sun is marketed as being green.

CSR is a dynamic movement that has been evolving over decades, if not centuries, but despite this seemingly impressive progress, some would argue that CSR has failed and that we are witnessing its decline. Those who make this claim say that the concept needs to be reborn and rejuvenated. They make this claim because although CSR has had many positive impacts for communities and for the environment, it should be judged by the total impacts of business on society and the planet. Viewed this way, on every measure of social, ecological, and ethical performance that is available, the negative impacts of business (with a few notable exceptions) have been disastrous. CSR has not averted or even substantially moderated these impacts. The reasons CSR fails are threefold:

1. The incremental approach of CSR has not made any impact on the massive sustainability crises that the world faces, many of which are worsening at a pace that far outstrips any CSR-led attempts at improvement.
2. CSR is usually a peripheral corporate function, even when a company has a CSR manager or a CSR department. Shareholder-driven capitalism is pervasive, and its goal of short-term financial measures of progress contradicts the long-term stakeholder approach to capitalism that is needed for CSR to have any meaningful results. (In shareholder-driven capitalism, a company's primary purpose is to generate profits for its shareholders.)
3. Despite the rhetoric about the "business case for CSR," as practiced at the beginning of the twenty-first century, CSR remains uneconomical. Most of the difficult CSR changes that are needed to reverse the misery of poverty and mass species extinction require strategic change and massive investment. These necessary changes may be lucrative in the long term and economically rational over a generation or two, but the financial markets do not work this way—at least not yet.

A fourth point might be the old adage, "the path to hell is paved with good intentions." Although no one could possibly accuse the original framers of CSR of ill will, the fact remains that numerous corporations have used CSR to highlight their good points—providing jobs to communities or cheap goods to the consumer—in the hopes of playing down their less desirable points: environmental degradation or the promotion of an unsustainable, consumption-based economy. A classic example is Walmart, which has made significant environmental progress recently, but still leaves many questions on labor and social issues unanswered. Another is Exxon, which has strong social programs, but has a poor reputation on environmental and climate change issues. A new model of CSR that will actually work—one that is measurable and grounded in environmental sustainability—is being delineated and developed by those who would like to avoid the mistakes made by the misguided application of CSR.

CSR 2.0

The CSR 2.0 model, first suggested by the business author and CSR expert Wayne Visser in 2008, proposes keeping the acronym CSR but rebalancing the "scales." In this new model, CSR stands for "corporate sustainability and responsibility." This change acknowledges that *sustainability* (with roots in the environmental movement) and *responsibility* (with roots in the social activist movement) are really the two main components that we should care about. A cursory look at companies' nonfinancial reports will rapidly confirm this: they are mostly either corporate sustainability reports (which typically adopt a "triple bottom line" approach of reporting social and environmental impacts along with economic performance) or corporate responsibility reports (which typically reflect a stakeholder approach).

CSR 2.0, however, also proposes a new interpretation on these terms. Like two intertwined strands of DNA, sustainability and responsibility can be thought of as different, yet complementary, elements of CSR. Hence sustainability can be conceived as the destination (challenges, vision, strategy and goals, i.e., what we are aiming for), while responsibility is more about the journey (solutions, responses, management, actions, i.e., how we get there).

If we admit the failure of previous CSR efforts at tackling our most pressing social, environmental, and ethical challenges, then the world may find itself on the cusp of a revolution, in much the same way as the Internet transitioned from the static Web 1.0 technology to the interactive Web 2.0. The emergence of social media networks, user-generated content, and open-source approaches are a fitting metaphor for the changes CSR will have to undergo if it is to redefine its contribution and make a serious impact on the social, environmental, and ethical challenges the world faces.

For example, Web 1.0 moved from a one-way, advertising-push approach to a more collaborative Google–Facebook–Twitter mode. In the same way, CSR 2.0 is starting to move beyond the outmoded approach of CSR as philanthropy or public relations (which has been widely criticized as "greenwashing") to a more interactive, stakeholder-driven model. Similarly, Web 1.0 was dominated by standardized hardware and software, but Web 2.0 encourages co-creation and diversity. So too in CSR, we are beginning to realize the limitations of the generic CSR codes and standards that have proliferated in the past ten years. The similarities between Web 1.0 and CSR 1.0 are illustrated in table 1.

If this is where we have come from, where do we need to go to? The similarities between Web 2.0 and CSR 2.0 are illustrated in table 2.

Embracing the Future

Let us explore in more detail this revolution that will, if successful, change the way CSR is talked about and practiced and, ultimately, the way business is conducted. Five principles make up the "DNA" of CSR 2.0: connectedness to multiple stakeholders; scalability for expanding projects; responsiveness to the beneficiaries' needs; duality for balancing local concerns with larger principles; and circularity for closing the production loop so that there is no waste. Table 3 summarizes some of the shifts in these principles that are occurring between CSR 1.0 and CSR 2.0.

Hence, paternalistic relationships between companies and the community that are based on philanthropy give way to more equal partnerships. Defensive, minimalist responses to social and environmental issues (e.g., implementing carbon reductions only when climate legislation forces this action) are replaced with proactive strategies and investment in growing responsibility markets (e.g., investing in clean technology, as General Electric is doing with its ecomagination program). Image-conscious, public-relations approaches to CSR are no longer credible, and so companies are judged on actual social, environmental, and ethical performance (i.e., are things improving in absolute, cumulative terms?).

Although CSR specialists still have a role to play, each dimension of CSR 2.0 performance is embedded and integrated into the core operations of companies. Standardized approaches remain useful as guides to consensus, but CSR is implemented at the small-scale, local level. CSR solutions, including responsible products and services, go from niche "nice-to-haves" to mass-market "must-haves." And the whole concept of CSR loses its Western conceptual and operational dominance, becoming a more culturally diverse and internationally applied concept.

Table 1. Web 1.0 Compared with CSR 1.0

Web 1.0	**CSR 1.0**
Characterized as a vehicle for companies to connect to customers and use a new medium to present information and advertising	Characterized as a vehicle for companies to establish relationships with communities, channel philanthropic contributions, and manage their images
Saw the rise to prominence of innovators like Netscape, but these were quickly outmuscled by corporate giants like Microsoft, with its Internet Explorer browser	Included as a component of many start-up pioneers like Traidcraft, which is both a trading company and charity, but ultimately turned into a strategy for large multinational corporations like Royal Dutch Shell
Focused largely on the standardized hardware and software of the PC as its delivery platform, rather than on multilevel applications	Followed a "one size fits all" standardization through codes, standards, and guidelines to shape its offering

Table 2. Web 2.0 Compared with CSR 2.0

Web 2.0	**CSR 2.0**
Is being defined by watchwords like *collective intelligence, collaborative networks*, and *user participation*	Is being defined by terms like *global commons, innovative partnerships*, and *stakeholder involvement*
Includes tools such as social media, knowledge syndication, and beta testing	Includes mechanisms such as diverse stakeholder panels, real-time transparent reporting, and new-wave social entrepreneurship
Is as much a state of being as a technical advance—is a new philosophy or a way of seeing the world differently	Is recognizing a shift from centralized to decentralized power; a change in scale from a few large initiatives to many small ones; and a change from single, exclusive applications to multiple, shared ones

Table 3. Shifting CSR Principles

CSR 1.0	**CSR 2.0**
Paternalistic	Collaborative
Risk based	Reward based
Image driven	Performance driven
Specialized	Integrated
Standardized	Diversified
Marginal	Scalable
Western	Global

Table 4. Shifting CSR Practices

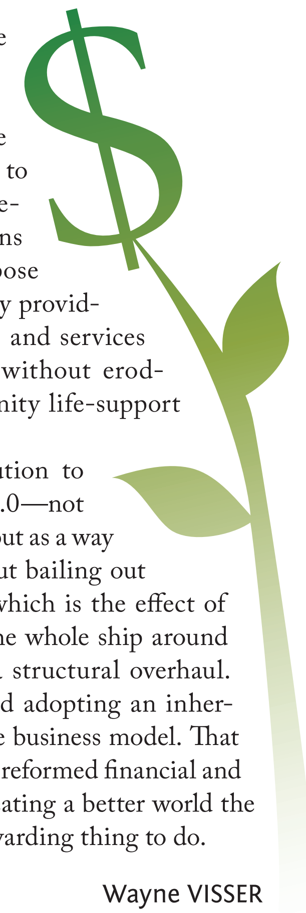
CSR 1.0	**CSR 2.0**
Premium markets	"Base of the Pyramid" (i.e., the poor) markets
Charity projects	Social enterprise
CSR indexes	CSR ratings
CSR departments	CSR incentives
Ethical consumerism	Choice editing
Product liability	Service agreements
CSR reporting cycles	CSR data streams
Stakeholder groups	Social networks
Process standards	Performance standards

How might these shifting principles manifest as CSR practices? Table 4 summarizes some key changes to the way in which CSR would be implemented.

CSR would no longer manifest as luxury products and services (like many green and fair trade options) but as affordable solutions for those who most need quality-of-life improvements. Investment in self-sustaining social enterprises would be favored over donations, or "checkbook charity." CSR indexes, which rank the same large companies over and over (often revealing contradictions between indexes), would make way for CSR rating systems. These systems would turn social, environmental, ethical, and economic performance into corporate scores (A+, B–, etc., similar to credit ratings) that analysts and others could compare and integrate into their decision making.

Reliance on CSR departments would disappear or disperse as responsibility and sustainability are increasingly built into corporate performance appraisal and market-incentive systems. Whether consumers choose, or self-select, ethical products would become irrelevant, as CSR 2.0 companies would begin to "choice edit." In choice editing, companies stop offering implicitly "less ethical" product ranges, thus allowing guilt-free shopping. Liability at the end of products' lifecycles would become obsolete, as the service-lease and take-back economy becomes mainstream. Annual CSR reporting would be replaced by online, real-time CSR performance data flows. Feeding into these live communications would be Web 2.0–connected social networks, instead of periodic meetings of rather cumbersome stakeholder panels. And typical CSR 1.0 management systems standards like ISO 14001 would be less credible than new performance standards that set absolute limits and thresholds, such as those emerging in climate change.

The Purpose of Business



CSR 2.0 comes down to one thing: clarification and reorientation of the purpose of business. It is inaccurate to believe that the purpose of business is to be profitable or to serve shareholders. These are simply means to an end. Ultimately the purpose of business is to serve society by providing safe, high-quality products and services that enhance our well-being without eroding our ecological and community life-support systems.

Making a positive contribution to society is the essence of CSR 2.0—not just as a marginal afterthought, but as a way of doing business. It is not about bailing out the *Titanic* with a teaspoon—which is the effect of CSR 1.0—but about turning the whole ship around and heading back to port for a structural overhaul. CSR 2.0 is about designing and adopting an inherently sustainable and responsible business model. That business model is supported by a reformed financial and economic system that makes creating a better world the easiest and most natural and rewarding thing to do.

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See also Activism–NGOs; Climate Change Disclosure; Fair Trade; Global Reporting Initiative; Greenwashing; Information and Communication Technologies (ICT); Investment, CleanTech; Investment, Socially Responsible (SRI); Stakeholder Theory; United Nations Global Compact

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D

Data Centers

Information technology continues to predominate in the twenty-first century, and the data centers that house the increasing numbers of computers and servers needed to meet demand may strain energy sources. Not only is adequate and continuous power to supply technology an issue, but the growing demand for water to cool equipment may become a concern as well.

If you use Facebook, MySpace, YouTube, iTunes, Google, online banking, online gaming, an online weather service, an email program, or if you read and/or create blogs, all your activities are housed in a data center. Data centers are rooms full of computers (or servers) arranged in rows that run the software and applications that allow you to do everything you do on the Internet. Small data centers have only a few servers, but the ones that support so much of what we do on the Web can house thousands, and in some cases, hundreds of thousands, of servers. For example, some estimates put the number of servers in use by Google at over 400,000.

Imagine a building in which the floor is lined with rows of metal racks. Each rack contains a stack of servers. All of these servers run twenty-four hours a day, seven days a week, and while they run, they constantly create a tremendous amount of heat. (Put your running laptop on your lap for a few minutes and you'll get the idea.) To prevent the room from overheating to a temperature that affects the reliability of the servers, the air must be kept cool. So in addition to rows of servers, data centers require infrastructure, which consists of equipment that supplies the power (uninterruptible power supply) and the cooling equipment that keeps the data center's air from getting too hot.

Data centers also contain networking and storage appliances that hold and transmit information within a company, between companies, or to consumers. Often the rows of servers and appliances are in the middle of a data center, and the infrastructure lines the walls.

Data centers are measured in various ways. Until 2002 (or thereabouts), they were measured in units of area. A 100-square-meter data center can run a small law firm, accounting firm, real estate company, or the like. Today data centers are often described in terms of their power requirements—how many kilowatts they require to power the infrastructure and the information technology (IT) equipment itself.

Types of Data Centers

There are four different types of data centers. The characteristics of each serve the needs of different business models.

Internet Server Farms

Corporations like Amazon, Google, Microsoft, and Yahoo house this type of data center. Because Internet server farms are very large and accommodate great numbers of servers, they must be well planned and built in locations that provide special conditions, including access to a plentiful supply of power and attractive utility rates, availability of lots of water (for cooling), proximity to Internet data lines (called fiber), and safety from the potential for terrorist threats and weather- or geography-related disasters.

Collocation Services (CoLo)

Collocation services are data centers built and run by companies like Savvis, Equinox, and Switch & Data that manage services for several companies in one or more locations. They rent out space, and sometimes equipment as well, in these data centers to other companies who put their applications and data on the rental servers. The CoLo companies take care of running the building and tending to the servers. A collocation service might house data centers for a number of different companies in the same building.

Companies use collocation services for many reasons. Some of the chief incentives are that businesses can:

- save on the cost of owning and operating a data center
- focus on their core enterprise, not the expertise needed to operate data centers in-house
- depend on the high level of security and reliability built into collocation services
- plan for expansion space at comparatively reasonable rates
- add data center capacity quickly

Enterprise Data Centers

An enterprise data center is owned and operated by the corporation that uses it. Typically, enterprise data centers are established in the office building that houses the corporation. Because this space (465–1,900 square meters on average) often preexists the data center, it may be far from optimal for data center use and often must be retrofitted to accommodate it. As the company grows and the demands on the data center expand, the company may have to tackle difficult and costly problems related to supplying extra space, power, and cooling.

Server Closets

Smaller businesses meet their data center needs by using server closets, which are small rooms (and in some cases, literally closets) less than 465 square meters in size. These spaces contain less infrastructure but still must be well-cooled to prevent heat buildup from disabling the servers. All of servers in these rooms may be shut down from time to time for maintenance; this would seldom occur in the large data centers described above.

Data Center Infrastructure

Server farms, collocation data centers, and enterprise data centers contain a complex array of infrastructure. The more reliable the data center—meaning it must continually provide its services without any interruptions—the more infrastructure it requires. Infrastructure consists of the equipment that supplies both power and cooling, the cabling that connects all of the equipment, networking equipment that allows servers to connect to each other and to the Internet, storage equipment (for data storage and retrieval), security equipment, fire prevention equipment, and more.

Over the years the computing power of servers and the number of servers used in data centers have dramatically increased. This has driven up the amount of cooling that data centers require, which in turn has dramatically increased the amount of power that data centers consume. All of this has greatly enlarged their infrastructure requirements.

As an example, provisions have to be made to keep the power flowing to the equipment in data centers that can't allow any interruptions of service, even in the event that the utility company that supplies power goes offline even for a fraction of a minute. So the infrastructure will include generators to supply emergency power, uninterruptible power supply (UPS) devices to make sure that power continues to flow, backup batteries, and the like. All of these items add to the cost and space requirements of data centers. This equipment needs to be installed, cabled, monitored, and maintained, which means dollars must be spent, not only on the IT and infrastructure equipment, but also on the people who install and maintain them as well. Every data center expansion requires more of this equipment to be installed, using up more space and more people-hours.

A direct result of this is that the space requirements of data centers have tripled since 2000. According to Tony Ulichnie, IT consultant and acting director of Site Uptime Network, Uptime Institute, ten years ago a 100-square-meter data center required an additional 30 square meters (approximately) of space to house the electrical and cooling equipment, a space roughly one-third the size of the data center. (This figure is scalable to about a 1,000-square-meter data center.) By the late 1990s, the increased density in that same 100-square-meter data center required an additional 50 square meters of space to house the electrical and cooling equipment. Currently, a 100-square-meter data center requires a room of equal size to house the electrical and cooling equipment (personal communication with author).

Given these infrastructure requirements, it would seem logical for data center managers to maximize the use of every single square meter in the facility and every kilowatt of power. But often, that's not what actually happens.

Energy Crises in Data Centers

There is a surprising underside to data centers:

> Data center power and cooling infrastructure worldwide wastes more than 60,000,000 megawatt-hours per year of electricity that does no useful work powering IT equipment. This represents an enormous financial burden on industry and is a significant public policy environmental issue. (Rasmussen 2008, 2)

(Neil Rasmussen, the Chief Innovation Officer of American Power Conversion [APC], calculated this figure based on APC's estimates of the installed operating megawattage [one megawatt equals one million watts] of global data centers, along with best estimates of how much of the energy used by those data centers was "wasted," meaning that the data center was not performing up to its ability due to issues of equipment positioning, oversizing, and improper settings and adjustments. APC further found that a typical data center was wasting around 20 percent of its total power draw in this way.)

According to analysts at McKinsey & Company, the data center industry will contribute more carbon emissions than the entire airline industry by 2020 (Haskins 2008). A report from the U.S. Environmental Protection Agency (EPA) claims that at the present rate of growth in power consumption by data centers, ten more nuclear or coal-fired power plants will be required to meet this demand in the United States by 2011 (2007, 58).

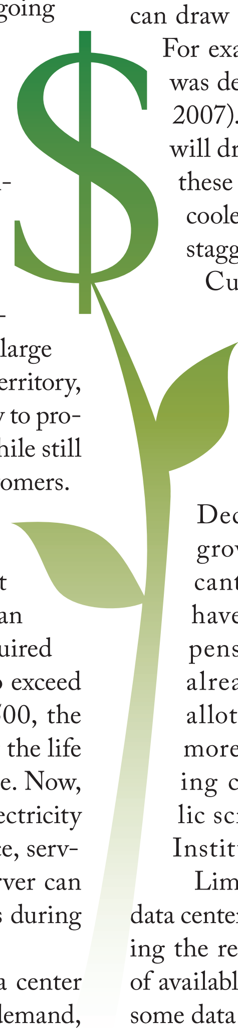
Regrettably, data centers are not models of effective management or energy-efficient processes and technology. In fact, they are contributors in two crises, one ongoing and one soon to be.

Ongoing Crisis: Power

Like most households and businesses, data centers buy power from a utility company. But data centers are very large consumers. The same EPA report cited above states that "data centers can be more than 40 times as energy intensive as conventional office buildings" (EPA 2007, 17). When a large data center operator decides to locate in a utility's territory, the utility may have to act quickly to figure out how to provide the electricity the data center requirements while still providing for the needs of all the other utility customers.

As power demand by data centers increases, the cost of operating the data center skyrockets. IT organizations are accustomed to thinking that servers are cheap; this is because they're used to an earlier time when twenty to thirty years were required for the cost of the electricity powering a server to exceed the cost of the server itself. If a server cost $2,500, the incremental addition of the cost of electricity over the life of the server (three to five years) was like a free ride. Now, it takes less than two years for the cost of the electricity to exceed the cost of the server (Brill 2008). Hence, servers are not a cheap resource at all. A $2,500 server can bring with it as much as $7,500 in electrical costs during its three-year lifetime before it is retired.

This situation has created a crisis for the data center industry for several reasons. At the current rate of demand, the supply of power will be insufficient to meet the needs of the industry as soon as 2011 (Brill 2008). And as the number of servers in use increases, and the costs associated with supplying power to them increase, the ability of data centers to operate profitably is severely challenged.



Coming Crisis: Water

Water is twenty-seven times more effective in dissipating heat than air, and thus it is commonly used in data centers. The water is either circulated through the data center in pipes or piped directly through the racks to the servers. Pipes carry the heat away from the servers to a cooling tank, where the heat evaporates.

According to Dr. Robert Sullivan, a cooling expert and consultant to the Uptime Institute, if a data center operates at an average industry efficiency, approximately 109,000 liters of water per day are required to dissipate the heat that is produced by one megawatt of IT load (the amount of power drawn by the IT equipment) (personal communication with author). To put this in context, large data centers can draw quite a bit more than one megawatt of power. For example, an Air Force data center built in 2007 was designed to draw a load of 50 megawatts (Miller 2007). Microsoft's new data center in Chicago, Illinois, will draw a load of 60 megawatts (Josefsberg 2009). If these data centers were water cooled (rather than air cooled), the amount of water required would be truly staggering (Fonteccio 2008).

Currently, most data center operators take the relatively low price and ready availability of water for granted. But according to a study by the environmental think tank Pacific Institute, "water is becoming scarcer globally and every indication is that it will become even more so in the future. Decreasing availability, declining quality, and growing demand for water are creating significant challenges to businesses and investors who have traditionally taken clean, reliable and inexpensive water for granted. These problems are already causing decreases in companies' water allotments, shifts toward full-cost water pricing, more stringent water quality regulations, growing community opposition, and increased public scrutiny of corporate water practices" (Pacific Institute 2009, 1).

Limitations in the availability of water could hit the data center industry hard. The growing difficulty of securing the required amounts of water, and the higher cost of available water, may threaten the economic viability of some data centers.

Managing Data Centers

One of the hurdles to data center efficiency is that, in an enterprise, data centers are typically managed by two separate organizations: the IT group and the facilities organization.

The IT department, usually under the chief information officer (CIO), is in charge of the servers, the applications that run on them, the networking equipment through which they communicate, and the storage equipment where the data is archived. For this group, availability (uptime) has the highest value. IT wants those servers up and running as much as possible because IT compensation incentives are often based on preventing or minimizing disruption.

The facilities organization, often under a vice president of corporate real estate, is in charge of the physical plant, the cooling apparatus, and all of the equipment involved in supplying power to the data center. Essentially, this group delivers the kilowatts and cooling that IT operations require. Typically, the power bill for the entire data center operation (including the portion used by IT) is paid for by the facilities organization; in fact, most CIOs never see the power bill. Since facilities organizations typically pay the utility bill, they have a financial incentive to try to contain costs, and because CIOs have no stake in the bill, saving energy is not a high priority for them.

Old habits and outdated operational procedures often keep the facilities and IT organizations from working together effectively. Their divergent interests and responsibilities fracture the view of the data center that company executives receive. Lacking an integrated understanding of the entire data center, company executives keep looking for the same things that led to reliability and success in the past (such as redundancy), meanwhile ignoring the reality that power costs are rising steeply, that carbon emissions are growing rapidly, and that both may threaten the cost effectiveness of their data centers if not controlled.

To remedy this situation, Will Forrest, industry analyst and principal at the management consulting firm McKinsey & Co., claims that the cooperation of these two groups is essential. In fact, he recommends that the facilities organization be placed under the control of the CIO so that the power bill and concerns of each group will be integrated (Kaplan, Forrest, and Kindler 2008).

Future of the Data Center

The data center industry is in transition for a variety of reasons. There are both short-term and long-term influences. The more immediate reasons for this transition include:

- the increasing complexity and difficulty of managing data centers
- the uncertainty of infrastructure guidelines from government and advisory organizations
- the prohibitive cost of new data center construction costs and the difficulty of financing them
- the availability of alternatives to owning a data center in the form of collocation facilities that manage the infrastructure
- improving technologies for cooling the data center

The long-term issues pushing data centers into transition include:

- more competition over the availability of water for cooling
- alternatives that are more cost competitive with different data center ownership
- semiconductor chips and operating-systems software coding that are more energy aware and efficient
- government regulation of carbon emissions using cap and trade incentives or regulation

Where are these influences leading the data center industry? Some experts predict that rather than owning data centers, some businesses will elect to buy data center services provided over the Internet. This is known as cloud computing. (Think of how Google provides all its services via the Internet.) It may be that this takes the form of "clouds" owned and operated by a provider such as Google, Amazon, Yahoo, or Microsoft.

Some experts predict a boom in the use of collocation facilities. According to these experts, as data center operations and ownership become more costly and complex, companies will want to focus more on their core business and less on their data center operations. Combined with the need for increased computing power, this makes cost-effective collocation opportunities much more attractive to these companies.

Another trend is also making itself evident. Large organizations like Sun Microsystems and Dell, as well as small startup organizations, are creating modular approaches to data center design. By creating "pods" with built-in cooling and infrastructure, these organizations can deliver much more energy-efficient and secure data centers and can make expansion much less expensive. The pods can be delivered in shipping containers (Microsoft) or in smaller, individually manageable units (Elliptical Mobile Solutions) and can be installed much more quickly than a traditional data center.

The data center industry provides the backbone for business and commerce because it makes possible the rapid transactions that businesses and individuals need to accomplish quickly around the globe. It makes economic sense to send data files instead of FedEx packages.

But the more information we move, the more we must rely on the data centers that make this happen. In fact, the data center industry can be seen as the backbone of the economy as a whole. If it is not efficient and economically viable, it negatively affects the rest of the economy. The challenge that the industry faces then is to supply an ever-greater amount of computing power while consuming a smaller portion of the electrical power and natural resources.

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See also Energy Efficiency; Energy Industries *(assorted articles)*; Facilities Management; Information and Communication Technologies (ICT); Supply Chain Management; Telecommunications Industry; Water Use and Rights

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Design, Industrial

Industrial design incorporates aesthetics and usability into a product's design. Ecodesign, a subset of industrial design, factors the effects of environmental impacts and the product's lifecycle into the product's design. Extended producer responsibility regulations minimize products' environmental impacts at the end of their lifecycles. The legislation varies by country and targets electrical and electronic equipment and chemicals.

The term *industrial design* applies to both the aesthetics and the usability of mass-produced products, especially as those characteristics affect product marketability. According to the Industrial Design Society of America, "industrial design is the professional service of creating and developing concepts and specifications that optimize the function, value and appearance of products and systems for the mutual benefit of both user and manufacturer" (Industrial Designers Society of America 2006). The range of products is itself wide, extending from toothbrushes to turbines.

As the world becomes more environmentally aware, the term *ecodesign* enters the vocabulary. Ecodesign means incorporating new ways of thinking into the product-design process. This design approach means designers consider the environmental impacts of the product during its whole lifecycle, from manufacturing to packaging, transport, use, and finally to disposal. Some examples of environmental impacts are energy and water consumption, emissions of carbon dioxide and other greenhouse gases, consumption of materials and natural resources, waste generation, and the release of hazardous substances. The European Union (EU) estimates that more than 80 percent of all the environmental impacts of a product are determined by its design.

Extended Producer Responsibility

Ecodesign approaches have been mainly driven by the extended producer responsibility (EPR) concept and accompanying legislation. In its true form, EPR extends the responsibility of the producer to the entire lifecycle of the product chain—from production through end-of-life waste management. Therefore, EPR addresses the root cause of the environmental problem and steers the ecodesign of products and product systems. EPR has been implemented in three key forms: regulatory, voluntary, and negotiated.

The end-of-life product stage has become the popular focus for most EPR product regulations. The reason for this focus is that it shifts the responsibility for waste management from government to private industry. EPR regulations generally oblige producers, importers, and/or sellers to internalize waste management costs in their product prices, ensuring the sustainable and safe handling of the remains of their products (Hanisch 2000). The European Union has led the development of EPR product legislation, and other countries have adopted and adapted it.

EPR Regulations

Throughout Europe, North America, and Asia, producers are financially responsible for the take-back and recycling of batteries, packaging, vehicles, and all electrical and electronic consumer products. As of 2009, the product sector most heavily targeted by producer-responsibility product regulations is the electrical and electronics sector. This is due to the scale of the sector itself and the significant environmental problems associated with it. The motor vehicle and packaging industries are also affected by EU directives.

In January 2003, the European Union passed the Directive on Waste Electrical and Electronic Equipment (WEEE) and its partner directive, the Restriction on the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS). The WEEE Directive mandates collection and recycling targets for all historical electronic waste (from electrical and electronic equipment produced before August 2005) and makes producers individually responsible for products put on the market as of 2005. The RoHS Directive mandates the phaseout of certain heavy metals and brominated flame retardants for these new products.

Almost half the states in America have passed or are about to pass take-back legislation for electronic waste as of early 2010. In Canada, many provinces are now passing take-back laws for paints, batteries, tires, packaging, and electronics. Japanese producers are responsible for recycling cars and electronic products (Ministry of Economy, Trade and Industry 2004). It is inevitable that new legislation will be developed to cover all major sectors that cause significant environmental degradation.

European Union Regulations

The European Union's WEEE Directive (Directive 2002/96/EC) is intended to "encourage the design and production of electrical and electronic equipment which take into full account and facilitate their repair, possible upgrading, reuse, disassembly and recycling." The directive's goal is to reduce the "harmfulness to the environment" of the product and its constituent parts and substances. It applies to all electrical and electronic equipment products sold to the European Union for consumer or professional use (EIATRACK and TIA 2009). For historical waste and for "orphan" products (whose producers are no longer on the market), the responsibility is collective. Producers pay a portion of the total costs of collection and recycling according to their current market share (Clean Production Action 2007).

The WEEE Directive promotes individual producer responsibility (IPR) for new electronic products put on the market from August 2005 on. IPR is a policy tool that makes producers financially and/or physically responsible for the end-of-life management of their own products (Clean Production Action 2007).

The RoHS Directive (Directive 2002/95/EC) aims to ensure that after 1 July 2006, "new electrical and electronic equipment put on the market will not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE)." The European Union would prefer a total ban of these materials, but it is not practical with the current technology. This has led to a set of exceptions and conditions for the use of these materials (EIATRACK and TIA 2009).

North American Regulations

Electrical and electronic equipment marketed in North America is subject to an expanding mélange of EPR legislation. In both the United States and Canada, provincial, state, and local governments have passed numerous environmental and safety measures. Many legislators recommend a fee on new products to finance the cost of recycling both historical and future waste (Clean Production Action 2007).

Almost a dozen U.S. states and Canada restrict or ban products that contain lead, cadmium, and polybrominated flame retardants. Over half the U.S. states and the Canadian federal government have done the same for mercury-containing products. California, for example, already prohibits the sale of certain electronic products that are not RoHS compliant, and New Jersey and Minnesota adopted new RoHS-like materials restrictions in 2008. Following the 2007–2008 U.S. legislative session, over twenty state legislatures considered materials restriction bills (EIATRACK and TIA 2009).

Ecodesign and Standards for Energy

The proposed Ecodesign of Energy Using Products Directive (Directive 2005/32/EC) is a response to the increasing number of national regulations in some EU countries that specify environmental standards for end-use equipment (EuE), defined as "equipment which is dependent on energy input (electricity, fossil and renewable fuels) to work as intended and equipment for the generation, transfer and measurement of such energy. It also means parts which are intended to be incorporated into EuE, and which are placed on the market as individual parts for end-users" (European Parliament and Council 2001, 2–3).

As these regulations vary among the member states, the directive's goal is to standardize the environmental requirements for these products throughout the European Union while also encouraging high environmental standards in design. The directive will apply mainly to electrical and electronic equipment, but also to nonelectrical goods such as gas-powered lawn mowers, leaf blowers, and radio-controlled cars; it does, however, exclude

motor vehicles (Clean Production Action 2007). To meet the requirements of the directive, the manufacturer must assess the environmental aspects of the product throughout its lifecycle and evaluate alternative design solutions. The evaluation should aim to reduce the environmental damage caused by the product. When placed for sale, information about the product's environmental aspects should accompany it to allow consumers to make an informed choice.

The United States Department of Energy continues to develop energy-efficiency standards for a number of products and appliances. Energy-efficiency standards, programs to promote improved energy efficiency, tax incentives for energy-efficient products and appliances, and limitations on the sale or manufacture of certain lighting are all proposed measures (EIATRACK and TIA 2009).

Implications

It is important that companies and their designers are aware of the relevant regulations and know how to meet the requirements. But the number of regulations constantly increases, and those relating to EPR apply to a broadening range of products. This means companies should try to reduce the environmental impact of their products even before the regulations are implemented. A growing number of consultancy and advisory services from private businesses and the public sector can help companies respond to this array of regulations.

The key to success is that, from the early stages of planning and design, companies ensure that all the components, materials, and product labeling used to create their products and packaging adheres to the various regulations. These designs must also consider that the regulations vary according to the destination of the product. Thus companies will not only avoid penalties but the bad publicity associated with a failure to comply. Other added incentives are achieving cost savings for the company and the consumer by designing energy-efficient products that are easy to dispose of in a responsible manner.

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See also Biomimicry; Cradle to Cradle; Ecolabeling; Energy Efficiency; Energy Industries *(assorted articles)*; Integrated Product Development (IPD); Lifecycle Assessments (LCAs); Manufacturing Practices; Natural Step Framework, The (TNSF); Product-Service Systems (PSSs); Remanufacturing; Zero Waste

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Design, Landscape

The dual goals of sustainable landscape design are to create functional, livable, and aesthetically pleasing outdoor environments while simultaneously enhancing and protecting the health of the natural environment. Three sectors of the industry—green roofs, lawn alternatives, and native plants—focus on sustainability and demonstrate consistent growth, as do industry initiatives, book publications, conference attendance, and customer requests for sustainable practices from landscape professionals.

Landscape design is the process of shaping the ground and arranging plants, structures, and the spaces between them to create outdoor environments that support various human experiences. Traditional landscape designers generally aim to produce appealing visual effects and/or scenes that are deemed to be beautiful by societal norms also.

Sustainable landscape design is the same process with the added goal of making the natural environment healthier and more capable of supporting both human life and the lives of other creatures in the present and well into the future. Sustainable landscape designers work to improve environmental health by reducing air and water pollution and conserving water; protecting soil quality and minimizing erosion; increasing energy efficiency and using less fuel; managing storm water for maximum absorption and minimum runoff; and enhancing wildlife habitat and biodiversity.

In the practice of sustainable landscape design, the ideal of improving environmental health is considered to be at least as important as creating beauty. Some practitioners place an even higher value on this new goal than on conventional aesthetics. Substantial evidence indicates that the public increasingly agrees with this point of view.

Landscape design is a multifaceted industry that encompasses dozens of specialties, viewpoints, and market niches. Three sectors of the industry—green roofs, lawn alternatives, and native plants—focus explicitly on the goals of sustainability. Although each of these sectors represents a small component of the larger field, all three demonstrate consistent development, and their combined growth confirms that the business of sustainable landscape design is expanding steadily.

Green Roofs

Also called "living roofs," these gardens cover roofs specifically built (or retrofitted) for this purpose. In addition to plants, they consist of a lightweight growing medium (soil mixed with minerals or nonorganic fillers), a drainage layer (a fabric that captures silt), a root barrier (a foil or plastic membrane to keep roots from penetrating the roof), and a waterproof membrane (usually a synthetic material such as rubber or liquid asphalt) to protect the roof.

Green roofs benefit the environment in several ways. Their insulating effect directly reduces the heating and cooling costs of buildings, which saves energy and resources, and reduces the pollution that is associated with energy generation. Because green roofs remain cooler than conventional roofs during the summer, they collectively lessen the urban heat-island effect. Oxygen produced by living plants helps improve air quality. Rain that falls on green roofs is absorbed and used by plants; much of it transpires harmlessly back into the air, an effect that can significantly reduce runoff and lessen the demand placed on urban sewer systems. The plants on green roofs support birds and other wildlife. Finally, green roofs enliven cities and enhance the experience of a building's residents and other users.

While green roofs were popular in Europe for decades, North American demand was slow to develop until early in the twenty-first century. The number of green roofs installed in the United States and Canada rose steadily between 2004 and 2008. According to surveys conducted by the nonprofit organization, Green Roofs for Healthy Cities, 313 projects were installed in 2004 to 2005, 362 more were installed in 2006, and an additional 367 were installed in 2007. In 2008, installations spiked dramatically to 532 total projects, a 45 percent increase from 2007 (Green Roofs for Healthy Cities 2009, 4).

As a further expression of the public's support for green roofs, many cities in the United States and Canada have recently adopted tax policies and other incentives that spurred green-roof installation and technology research. Most notable among these cities were Chicago, New York City, Philadelphia, Portland, Seattle, and Washington, D.C., in the United States and Toronto in Canada. For example, in New York City, effective 1 January 2009 to 15 March 2013, green roofs that encompass at least 50 percent of available roof space are eligible for a one-year tax credit of $4.50 per square foot. Policies such as this one reason the green-roof industry continued to grow despite the economic downturn that began in 2008 (Green Roofs for Healthy Cities 2009).

Lawn Alternatives

Conventional lawns embody many of the environmental problems that sustainable landscape design aims to relieve. Lawn construction can require large amounts of imported soil and amendments, such as fertilizer, lime, and organic supplements, and is a process that consumes energy and natural resources. Lawn upkeep requires water, fertilizers, herbicides, and the frequent attention of gas-guzzling, pollutant-spewing mowers. These environmental costs are made worse by the fact that a vast amount of lawn exists in regions that lack sufficient rainfall to support it.

As an alternative to lawn, wildflower meadows (also called prairies) offer an elegant solution. Neil Diboll (2004), the owner of Prairie Nursery in Westfield, Wisconsin, described the following benefits of prairie meadows in his article "Creating Prairie Meadow Ecosystems as the New American Lawn":

> A properly established and maintained prairie meadow is a self-sustaining plant community that will provide landscape beauty for decades to come. The grasses and flowers create high quality habitat for birds, butterflies, and other wildlife. The deep-rooted plants encourage infiltration of rainwater into the soil, thus reducing stormwater runoff and flooding. Once established, prairies require only annual mowing (or burning).

Meadows and prairies have become a preferred choice in corporate headquarters and the nonused portions of large-scale landscapes, including golf courses. Professional turf managers cannot turn down the dramatic savings that meadows offer over the cost of maintaining vast expanses of mown grass. A growing portion of the general public is also beginning to appreciate wildflower meadows for their beauty, low maintenance, and environmental advantages, especially as more designers find creative ways to incorporate attractive "pocket prairies" into conventional landscapes.

An even more appealing choice with broad popularity across all sectors of the population is "no-mow" or "low-grow" lawn. This sort of lawn consists of deep-rooted grasses that thrive in dry to medium soil without irrigation and need to be mowed just once or twice a year. When established, this lawn of flowing grasses requires neither the chemicals nor the time investment of standard lawn grass. Prairie Nursery owner Neil Diboll reported that the sales of the company's No-Mow Mix had "grown steadily every year since the product was first introduced in 1994" (telephone interview with author 20 August 2009).

Native Plants

Native plants are plants that exist as the result of natural forces such as competition and natural selection. Their form, color, and habit of growth are the product of thousands of years of living, reproducing, and evolving in association with other plants and animals in their region. Generally, "native" also implies not having been manipulated (for example, hybridized or cloned) to satisfy human tastes and desires.

Native plants are the primary—and, in some cases, the only—food source for many million insects and caterpillars (Tallamy 2007, 42–57). These tiny creatures in turn feed the birds and become the butterflies that so many people cherish. Their position in the food chain makes native plants an essential component of wildlife habitat and biodiversity—two pillars of environmental health. When used properly, native plants can also help reduce a landscape's watering and maintenance/energy needs, which satisfies two further goals of sustainable landscape design.

The movement to incorporate native plants in managed and domesticated landscapes has been in existence since the early 1900s. *American Plants for American Gardens*, the first garden-design book to describe native plants according to their ecological associations, was originally published in 1929. (This book's ideas remained so relevant that it was republished in 1996.) In the

1930s and 1940s, the landscape architect Jens Jensen popularized the use of native plants in parks and home landscapes. Another surge in interest grew from the increased environmental awareness of the 1970s, and since then native plants have held a small but steadily expanding place in the landscape industry. The following reports, based on the author's interviews with representatives from a sampling of plant nurseries, illustrate this expansion:

- Van Berkum Nursery in Deerfield, New Hampshire, introduced their Woodlanders series of native plants in 1998. According to co-owner Leslie Van Berkum, the average sales of three sample species in this series (wild ginger, bunchberry dogwood, and foamflower—all native substitutes for common, nonnative, groundcover plants) grew nearly 275 percent in the decade from 1999 to 2009 (17 August 2009).
- Pat Bigelow, president of Bigelow Nurseries in Northborough, Massachusetts, reported, "We've been selling native plants for thirty years, many of them simply because they're good plants, and in recent years the demand for natives has risen exponentially across the board. We now sell tens of thousands of native plants. Landscape professionals are increasingly specifying them for their jobs, so the public sees more of them out in the world and then they want them too. Even better, with this rising demand the palette is expanding and the quality is getting better and better" (27 August 2009).
- At North Creek Nursery in Landenburg, Pennsylvania, native plants represent about 70 percent of the business. Owner Steve Castorani stated: "While conventional plant sales have trended downward during the recession, sales of natives have increased." Company data showed that from 2005 to 2009 the sales of six plants commonly used in wildflower meadows (big bluestem, broomsedge, little bluestem, prairie dropseed, wreath goldenrod, and cutleaf coneflower) increased by an average of 244 percent (25 August 2009).
- Peter Flynn, owner of Bay State Perennial Farm in Whately, Massachusetts, related, "Native plants are an indispensable part of our nursery. Customers not only ask specifically for native plants, they *expect* us to have a well-rounded selection. Sales of native plants have doubled in the last five years" (2 September 2009).

Further Evidence of Growth

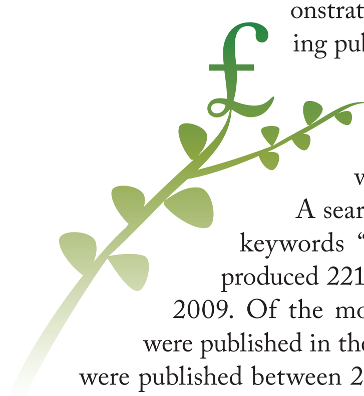
The rising sales of green roofs, lawn alternatives, and native plants are not the only indications that interest in sustainable landscape design is on the rise; focus on sustainability is also evident in industry initiatives, book publications, conference attendance, and customer requests.

Sustainable Sites Initiative

In 2005, the American Society of Landscape Architects teamed up with the Lady Bird Johnson Wildflower Center to begin developing a Sustainable Sites Initiative (SSI). Joined in 2006 by the United States Botanic Garden, this group's goal was to create a set of "national guidelines and performance benchmarks for sustainable land design, construction and maintenance practices" (SSI 2008) The final SSI document—*Sustainable Sites Initiative: Guidelines and Performance Benchmarks*—is based on industry feedback to the first draft and was published in late 2009. An associated reference guide, to be released in 2013, will report on the effectiveness of the guidelines and ranking system in pilot programs across the country.

Books

The increase in the number of new print publications with a focus on sustainable landscapes and native plants demonstrates the existence of growing public interest and demand. The online bookseller Amazon.com tracks its own book sales on a website called TitleZ.com. A search at this website for the keywords "sustainable landscapes" produced 221 book titles as of August 2009. Of the most recent books, eleven were published in the 1990s, and eleven more were published between 2000 and 2004. Between 2005 and 2009, the number of new titles that were published jumped dramatically to twenty-eight (Amazon.com 2009).



At the same website, a search for the keywords "native plants" revealed 1,842 book titles. Of the one hundred top-selling titles, thirty-eight were published in the twenty-five years between 1974 and 1999, while the following single decade (2000 to 2009) saw the publication of sixty-two new titles.

Industry Conferences

Horticultural and trade conferences also reveal the growing status of sustainable landscape design. The Ecological Landscaping Association (ELA), a nonprofit organization that promotes environmentally beneficial landscaping practices, has held an annual conference for professionals and homeowners since 1994. By the 2009 conference, attendance had quadrupled.

ELA's executive director, Penny Lewis, reports: "What is driving this growth is the increasing demand for sustainable design, installation, and maintenance services. As the negative impacts of traditional landscaping practices become more widely known, educated consumers seek out professionals (and products) that are creating healthy, sustainable landscapes" (personal communication with author, 18 August 2009). Even mainstream landscape conferences have begun to focus on issues of sustainability. A typical example is the 2010 Mid-America Horticultural Trade Show (n.d.), which is titled "Sustainability for a Greener Tomorrow."

Customer Requests

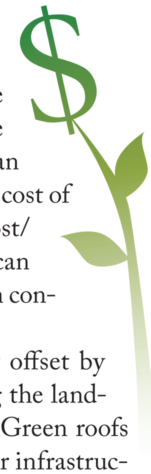
The American Society of Landscape Architects (2007) conducts quarterly surveys of its member firms, which typically comprise 300 to 600 respondents depending on the date of the survey. These surveys track key statistics such as billable hours, hiring trends, and other topics of current interest. Throughout 2008, survey responses indicated a significant client interest in sustainable landscape design:

- In the first quarter of 2008, nearly 72 percent of clients expressed a high degree of interest in sustainability issues. Top issues cited were (in order): bioswales (wide shallow ditches filled with vegetation, compost, or rock that are designed to remove silt and pollution from surface runoff water) and storm water management, energy efficiency, habitat and biodiversity, green roofs, and links to green space and trails.
- Second quarter responses showed that nearly 80 percent of firms reported customer interest in native or drought-resistant plants, and close to half of all firms reported clients who wanted reduced lawns. Nearly 88 percent of firms reported clients with some degree of interest in water-efficient design.
- The third quarter survey revealed that 87 percent of customers agreed they would "use more green yard practices if they knew more about them."

These data demonstrate growing customer awareness of sustainable landscape issues and interest in obtaining services related to sustainable practices from landscape professionals.

Obstacles

Perhaps the biggest obstacle to the public's widespread acceptance of, and demand for, sustainable landscapes is an issue of aesthetics and emotion. Many people desire what is familiar and socially acceptable or, even more compelling, prestigious. At this point in history, the idea that landscapes can and should be environmentally healthy *as well as* aesthetically pleasing has not yet become the norm for the majority of people.



An additional issue is cost, or rather, apparent cost. Green roofs cost more to *install* than conventional roofs. *Creating* a meadow is more expensive than simply seeding a lawn. Some native plants may cost slightly more to *buy* than traditional garden plants. (Like all prices, the cost of native plants is entirely dependent on the cost/ease of producing them. Many native plants can be propagated with the same or less effort than conventional garden plants.)

These initial costs, however, are entirely offset by substantial savings in the long run, assuming the landscapes receive proper construction and care. Green roofs cut electricity bills and the cost of storm-water infrastructure. Mowing a meadow once a year consumes hardly any fuel and produces minimal pollution. When properly selected and planted, established native plants need little care beyond occasional weeding. All three of these sustainable landscape practices save more *over time* than they cost at the start.

Looking Forward

The sustainable landscape design business still occupies a relatively small corner of the landscape industry. Many plant nurseries offer few or no native plants. Plenty of landscape contractors remain entrenched in old familiar practices and have not yet experienced a demand from their customers for anything different.

Despite the challenges inherent in changing traditional practices, sustainable landscape design is both thriving and growing. The increasing demand for green roofs, lawn alternatives, and native plants represent only a part of the whole story. Similar reports could be made about the expanding demand for countless other products and practices that contribute to sustainable landscape design, including:

- bioswales (drainage ways designed to absorb runoff)
- ecosystem gardens
- streambank bioengineering (using vegetation to stabilize eroding watercourses)
- xeriscaping (gardening methods that reduce water demand)
- brownfield reclamation (revitalizing land degraded by pollution or industrial use)
- pervious pavement (allowing stormwater to infiltrate into the soil below)
- gray-water irrigation (reusing wastewater generated by washing and bathing)
- permaculture (landscape design that emphasizes caring for the Earth, replicating natural systems and maximizing productivity)
- recycled paving materials

While sustainable landscape design is still in its early stages, the evidence is clear. Tens of thousands of forward-looking citizens—landscape professionals, gardeners, environmental engineers, city planners, nursery owners, design educators, book and magazine publishers, and everyday homeowners whose lush wildflower meadows sway softly in every breeze—are already demonstrating that their landscapes can and should be designed sustainably.

In the conclusion of her book, *Energy-Wise Landscape Design*, Sue Reed (2010) writes: "It's time for us to dream a new vision for our landscapes, one in which beauty is more than just a familiar picture, a childhood memory, a neighborhood norm, or a societal expectation. In this new vision, beauty is also an expression of our knowledge and values. Now in the 21st century, we know how to shape our landscapes so that in addition to *looking* good, they will also *do* good, for ourselves and for the health of the environment and the larger world."

Sue REED

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See also Agriculture; Building Standards, Green; Facilities Management; Smart Growth

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Development, Rural—Developed World

In developed countries the term rural development *refers to creating and sustaining resources that will provide economic opportunities and services for rural residents. Sustainable examples include agricultural practices such as growing organic crops, and alternative energy projects such as wind farms and producing biofuels. Tourism provides economic benefit to rural areas, but some forms, such as agritourism and nature tourism, are more environmentally friendly than others.*

The term *rural development* refers to the creation and sustenance of resources devoted to improving the economic and social livelihood of people who live in rural communities. Although the concept can sometimes be applied to such residents both in the developed and developing world, the nature of living in a rural community in a developing country is often quite different than that of living in a rural area in the developed world. In developing countries, economic life in a rural community is more likely to revolve around agriculture, whether for subsistence or trade, whereas residents of rural communities in developed countries often lead lives quite similar to that of their urban counterparts. Subsequently, rural development in developing nations is often centered on the creation of such basics as water and electricity, and rural development in developed countries is often about the provision of economic opportunities and community services. In the developed world, rural development is most often concerned with the protection of natural resources such as watersheds and biodiverse ecosystems. As such, in settings where economic resources exist, there is a concern for ensuring clean air and water, species diversity, and the protection of unique systems such as wetlands.

Agriculture

In developed countries, sustainable rural development frequently involves attempts to find forms of agriculture that are more environmentally sensitive and less reliant on modern agro-business technologies that increase productivity and reliability at a high cost to soil, air, and water resources—and perhaps to human health. The goal of sustainable agriculture is to encourage and support farms that are capable of producing food indefinitely without the use of outside agents such as chemical fertilizers and genetically modified strains of plants and animals. Challenges to be addressed include the return of nutrients, such as nitrogen, to soils depleted during the farming cycle, and satisfactory irrigation methods so that water is not depleted over time. Responses to such challenges have included increased reliance on composting to create fertile soils from plant wastes, the use of manure to add nutrients to soil from animal waste, and increased use of renewable energy sources such as windmills. In addition, farmers are encouraged to shift from monoculture practices (growing one crop per field at a time) to polyculture practices (growing more than one crop per field at a time). Polyculture has been shown to decrease the chance for plant disease or blight, and when the proper plant combinations are grown, such as combinations of grasses and legumes, it can improve soil conditions. One combination that has proven useful for maximizing the ratio of nitrogen to carbon is that of cowpea (a legume) and sorghum (a grass) (Treadwell, Creamer, and Baldwin 2009). In the United States and some other industrialized countries, programs that certify foods as organic encourage sustainable agriculture. The organic food industry may provide one way by which farming communities that are relatively close to cities can compete against low-cost producers from other regions.

Tourism

In many developed nations, farmers have turned to agritourism as a way of supplementing their incomes and staying in business. Fueled by increases in general tourism over the past three decades, agritourism involves opening farming or ranching operations for people who are interested in experiencing farm or ranch life, learning about food production, or picking their own food. Agritourism can include relatively small operations, such as farms that maintain fields for strawberry picking or keep horses for riding, or larger operations such as wineries, cider mills, and dude ranches. Agritourism may also include those who deal in craft goods, such as home decoration and wool. As such, agritourism is an umbrella label that includes a variety of practices, not all of which are particularly environmentally sustainable. Nevertheless, agritourism capitalizes on the interests of visitors to learn about food production and consumers' desires to buy food locally. Organizations such as Local Harvest, Inc. maintain websites aimed at connecting interested agritourists with farms that grow and sell products locally, particularly those that feature specialty items such as garlic, fresh fruits, honey, and dairy products.

Tourism has become an increasingly important economic activity in many rural communities. Cultural tourism develops the cultural resources of a region, such as historical sites, museums, and arts communities and facilities. In North America, cultural tourism often displays the history of the frontier, Native American, or immigrant populations, whereas in other parts of the world cultural tourism may focus on indigenous cultures or archaeological sites. By creating a market for knowledge about potentially threatened sites and cultures, cultural tourism is thought to help preserve them. In rural areas, this often includes exhibitions of local folk arts and heritage at museums or through the performing arts.

Like agritourism, cultural tourism is a large umbrella for a variety of tourism practices, some of which are more environmentally friendly than others. Some forms of cultural tourism are relatively positive, such as those that stress the contributions of indigenous cultures and are developed with sustainability in mind. In other cases, the development of tourism in an area can cause an upsurge in the use of automobiles, which leads to increased use of fossil fuels and pollution; tourism can also expand the ecological footprint made by growing crowds, which makes it difficult to preserve a given site. In some cases, indigenous populations and other local residents may feel that their heritage has been "commodified," and thus minimized, as a form of entertainment for tourists. Local residents may also believe that they have "lost control" over such issues as community planning. Because increasing numbers of visitors cause property values to rise, long-time residents and others who work in the tourism industry may find that they are required to travel to less expensive communities in order to find employment and affordable housing.

Rural tourism can also take the form of nature tourism that promotes the region's natural amenities, such as the landscape or wildlife. Nature tourism tends to be sustainable due to the emphasis on preserving the environment on which the tourism depends. Such development can vary from relatively less invasive practices such as hiking, camping, and hunting to more invasive activities such as skiing and water sports. As with cultural tourism, however, some negative effects have been noted, such as increased automobile traffic, commercial development to support the tourism industry, and pollution.

Sustainable Energy

Sustainable energy projects are also part of rural development in developed nations. In the past, such projects included the construction of large dams for electricity production and irrigation, such as the Hoover Dam in Nevada and the system of dams maintained by the Tennessee Valley Authority. While such projects do reduce demand for fossil fuels and limit greenhouse gases, environmental scientists have questioned the dramatic alteration of the natural environment based on the permanently changed ecosystems and the loss of scenic gorges and valleys. In response, small hydroelectric generators called "micro hydro" have been produced in the developing world, but their adoption in the developed world has been slow. For instance, Morehead Valley Hydro Inc. in British Columbia, Canada, produces 110 kilowatts of electricity with a small plant on Morehead Creek (Williams 2009).

The creation of wind farms in the rural United States and other developed countries has accelerated since 1990. Energy produced through wind power doubled between 2005 and 2008, primarily in developed nations. Although wind power accounted for only 1.5 percent of total global energy in 2008, it accounted for 19 percent of energy usage in Denmark, 10 percent in Spain, and 7 percent in Germany. In terms of actual capacity, the United States overtook Germany as the world leader in capacity with over 25,000 megawatts in 2008 (World Wind Energy Association 2009). Wind power does not produce any greenhouse gases or other environmental concerns related to fossil fuels. The major environmental impact of wind power is related to the production of turbines—an impact that typically pays for itself within one to two years. One detrimental effect has been demonstrated in the deaths of migratory bats and birds. Studies vary widely on how detrimental wind farms are to avian life, although the risk to birds is generally agreed to be higher in coastal and migratory areas. One study of wind farms in Flanders, Belgium, found that a given wind turbine killed anywhere between one and forty-four birds per year on average; studies on other regions of Europe yielded similar results (Everaert and Kuijken 2007). In contrast, it is estimated that 57 million birds die in collisions with motor vehicles and 97.5 million in collisions with plate glass (American Wind Energy Association 2009).

A major criticism of wind power is that the height of turbines and their location in rural areas can adversely affect the aesthetics of a community. As many wind farms have multiple turbines spread across a sizable area, complaints about the effects on the viewscape are quite common. Most wind farms do not directly benefit rural communities in terms of power production because they sell energy directly into the power grid.

With the spike in world oil prices during the early 2000s, renewed interest in biofuels has impacted rural communities as well. Although biofuels typically include fuels created from various waste products, in many rural areas the development of farming-related fuels such as ethanol and biodiesel seem to have the greatest potential for sustainable rural development. Plants such as sugarcane in many developing countries, corn in North America, and wheat in Europe are seen as renewable sources of sugar from which fuels can be produced. Criticisms of the production of these fuels include a marginal return on the fuel invested in the production of such plants and the potential for competition between producing plants for energy production and food consumption.

Outlook for the Future

As many rural communities have witnessed their economic foundations, often in manufacturing and agriculture, erode, the rise of the Internet and the increasing importance of tourism have become dominant themes in rural development. The Internet has not only allowed for telecommuting, but it has also allowed businesses once dependent upon an urban environment to relocate to rural communities. Similarly, the increasing importance of recreation and tourism has created incentives for protecting historical and environmentally sensitive and unique environments.

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See also Agriculture; Development, Rural—Developing World; Development, Sustainable; Development, Urban; Energy Industries—Overview of Renewables; Information and Communication Technologies (ICT); Poverty; Travel and Tourism Industry

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Development, Rural—Developing World

In the decades following World War II, top-down approaches to rural development in the developing world often adversely affected the less privileged members of society and the surrounding ecosystem. Since the mid-1990s, several projects that involve rural people in the planning process have resulted in more sustainable development.

In the developing world, rural development in its most ideal form is based on improving economic and social conditions in a way that is sensitive to the needs of the most vulnerable—the underprivileged, poor, and disadvantaged—members of society. The goal is to create more just and sustainable policies and practices that maximize the capabilities of everyone in society (Sen 2001), and not just those in privileged or elite positions. But a number of challenges stand in the way of such policies and practices. Many of these revolve around finding an appropriate balance between how well a particular government is embedded in society—the extent of social ties between bureaucrats and citizens—and how well such governments can remain autonomous enough to avoid becoming co-opted by powerful business interests and individualized aspirations for self-advancement (Evans 1995). In the worst case scenario, a state like Zaire (Congo), for instance, becomes predatory, meaning that collective goals are sacrificed for individual self-advancement among policy makers. While the experiences of each nation are unique, examining past and present development practices will reveal important lessons and ideas for future sustainable development.

Historical Approach

In the era following World War II, a top-down approach was used for rural development in the developing world. This was primarily oriented towards the adoption and diffusion of "green-revolution" agricultural technologies created in the developed world, which at that time were focused on increasing production for export and included high-yield seed varieties, synthetic pesticides and fertilizers, and new irrigation strategies (Humphrey, Lewis, and Buttel 2002). The results of these efforts were mixed. In some countries, the net food productivity increased dramatically, while in other countries productivity declined. More troubling were the unintended negative consequences that included the loss of traditional farming methods, the loss of local ecological knowledge, the decline of subsistence agriculture, a shift to a less-balanced grain-based diet, and the pollution of local waterways. These outcomes are widely viewed by twenty-first-century development practitioners as good examples of how *not* to approach rural development in the developing world.

Current Approach

In response to the problems associated with the historical top-down approach to rural development, rural sociologists and other development specialists have turned to an alternative bottom-up approach. The sociologist and researcher John Gaventa (2009) advocates a participatory action research approach that allows rural people to participate in defining problems as well as in creating, implementing, and maintaining solutions themselves. From 1994 to 2004, the professor of anthropology Robert E. Rhoades and his colleagues used a similar process of research and development in the SANREM (Sustainable Agriculture and Natural Resource Management) project, a multidisciplinary effort to examine issues related to development and the environment in the remote rural landscape of the Andes uplands in Ecuador. Importantly, the focus of this research is on the process of research itself as a participatory activity, involving the locals at every phase. These bottom-up approaches concentrate as much (if not more) on the process of development as on specific outcomes. For instance, the SANREM research shows greater promise than exploitative postwar projects in places like Thailand, where long-developed traditional farming methods were often ignored and replaced with environmentally damaging modern farming methods that relied heavily on the use of chemical pesticides and fertilizers. Many development challenges of the twenty-first century are in large part a direct result of past top-down development projects in developing countries that were in the form of green-revolution agricultural technologies. Because of the failed application of modern farming methods in many parts of the world, local farmers are now much more cautious—if not cynical—about working with outsiders to "develop" new farming approaches.

In the first decade of the twenty-first century, the governments of many less developed countries (LDCs), which are now increasingly referred to as "emerging" countries, continue to promote large-scale, export-oriented commodity agriculture as indicated by policies that subsidize the use of synthetic fertilizers and pesticides, machines, tractors, and irrigation despite the negative consequences that were identified in the section above on historical approach. To understand why LDC governments continue down this path, it is useful to consider the broader global institutional framework and the influence of international funding agencies such as the World Bank and International Monetary Fund (McMichael and Raynolds 1994; McMichael 2008). These institutions wield power through structural adjustment loans that require countries to open their borders to the global economy as a stipulation for receiving much-needed financial aid. Thus when LDC governments accept loans, they essentially have no choice but to continue to promote the policies demanded by these global lending institutions.

Issues for the Twenty-First Century

One of the major downsides of the transition to export-oriented agriculture is that more and more land is devoted to its cause, and less land remains to serve the needs of the most vulnerable rural people who rely on communal lands for small-scale subsistence farming and ranching. Widespread hunger and malnutrition may be the most immediate outcomes. In fact most modern famines happen in countries that are net exporters of food (Sen 2001). The longer-term outcome of losing land is a mass relocation of rural peasants to urban areas where they are forced to find wage labor—a process referred to as proletarianization (see Paige 1997). The massive waves of newcomers place a huge burden on existing urban areas in terms of employment and infrastructure. Rural in-migrants typically overwhelm urban infrastructures, which leads to inadequate safe drinking water and systems of sanitation. In turn these conditions lead to the spread of preventable diseases such as malaria, yellow fever, and diarrhea, which increase infant mortality rates and decrease overall life expectancies.

Changes in the rural countryside also disproportionately affect women. For instance, when India began industrializing and harvesting natural resources, such as wood from forests, women found that they could no longer fulfill traditional roles, such as gathering wood for cooking. This particular crisis ultimately led to the grassroots Chipko movement in the western Himalayas (Humphrey, Lewis, and Buttal 2002), which began in 1973. Women played a decisive part in the protest against the exploitation of government-sanctioned commercial foresters, and their action resulted in a widespread effort to reforest the subcontinent of India. Conversely the main beneficiaries of industrialization have been men who own the land and reap the profits. The state-sponsored development leading up to the Chipko movement demonstrates how rural women must contend with unique challenges as their roles in families and communities change, and they find themselves confronted with new forms of inequality in the family, educational system, and workplace.

Ecotourism and the Ecosystem

As environmental concerns have become a cornerstone of sustainability, development has come to incorporate new ways of protecting local ecosystems. Ecotourism offers some promise for delivering both ecosystem protection and economic growth simultaneously. As with any form of development, however, the process is crucial. One study of local residents in Taiwan revealed a positive attitude towards the notion of ecotourism, but only if local input was taken into consideration (Po-Hsin and Nepal 2006). In the worst case scenario, the protection of local ecosystems can result in a form of oppression. This was the case in the Southern Game Reserve in Kenya, where local Masai people were removed from the land they inhabited for thousands of years when it was set aside for tourists on safari who paid to see rhinos and elephants. The Masai have retaliated by killing more and more of these animals and collaborating with the illegal ivory trade (Peluso 1996).

Organization and Aid

One successful rural development organization that targets these emerging issues is the Grameen Foundation. This organization offers a highly innovative lending tool called microfinancing, which involves the provision of small loans to the rural poor, who are mostly women (Grameen Foundation 2009). People generally use these funds to start small businesses or to finance their education or specialized training in order to find employment or start a business in the future. Muhammad Yunus, the founder of this exemplary program, received the Nobel Peace Prize in 2006.

Demographers with a feminist orientation began noting the beneficial results of promoting programs such as Grameen as well as the broader issue of gender equity as a development strategy. The real turning point was 1994's U.N. International Conference on Population and Development (ICPD) in Cairo, Egypt, where the feminist perspective was first voiced and incorporated. This is particularly relevant to another endemic problem facing rural people across the world: rapid population growth. Population growth historically was framed as a matter of family planning (failure to use contraceptives or to postpone sexual activity). Feminists such as Joni Seager (1993), however, pointed out that family planning amounted to another form of control over women's lives, and that the best strategy to reduce population growth would be to promote gender equity. Along the same lines, the United Nations Population Fund (2009) reported that including and involving women in the development process has been a successful policy in terms of mitigating population growth as well as in increasing the overall social and economic well-being of a given country.

Hence rural development is evolving from a narrow, one-sided, top-down delivery of technologies by experts living in distant wealthy countries to a broad inclusive process that promotes issues of social justice and sustainability. Moreover, rather than fostering a reliance on developed countries and global institutions for technical and financial support, new approaches to rural development in the developing world strive to emphasize local empowerment and greater self-reliance. While significant problems remain—social inequality, hunger, disease, population growth—there is good reason to believe that contemporary approaches to development can offer rural residents in developing countries a much brighter future.

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See also Base of the Pyramid; Development, Sustainable; Development, Rural—Developed World; Development, Urban; Human Rights; Poverty; Social Enterprise; Travel and Tourism Industry; Water Use and Rights

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Development, Sustainable

The concept of "sustainable development" challenges economic development policies—such as globalization, export-led development, and neocolonialism—promoted in the late twentieth century by some Western governments and international financial institutions (the so-called Washington Consensus). Poor communities will be better served if they are empowered to find sustainable ways of providing food, water, energy, shelter, and transportation.

In 1987, the United Nations World Commission on Environment and Development (commonly known as the Brundtland Commission) defined *sustainable development* as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). By this definition, the world desperately needs a new model of development. Many of the world's people are stuck in poverty, and all major ecosystems are in decline—a classic definition of *unsustainability*. A new model could produce a world in which no family is hungry, burns smoky dung, or uses oil lamps for light; where intact ecosystems support growing wealth, not spreading poverty; and in which enhancing human capital becomes the basis of development policy.

Spending more money will not by itself solve the problems. The answer must include a new approach to international development that implements the world's "best practices" in sustainable ways to provide food, water, energy, shelter, transportation, and the like, deployed in ways that promote the creation of real jobs and locally controlled, viable private sectors.

Challenges to Development

In 2000, the member-states of the United Nations endorsed the Millennium Development Goals (MDGs). These set quantifiable targets for eradicating extreme poverty and hunger; achieving universal primary education; promoting gender equality and empowering women; improving maternal health; reducing child mortality; combating HIV/AIDS, malaria, and other diseases; ensuring environmental sustainability; and developing a global partnership for development by 2015 (Millennium Project 2006).

According to the U.N. Millennium Project (2006), which was created to implement the MDGs, some progress has occurred. Between 1990 and 2002, average incomes increased by approximately 21 percent. The number of people in extreme poverty declined by an estimated 130 million. Child mortality rates fell from 103 deaths per 1,000 live births a year to 88. Life expectancy worldwide rose from 63 years to nearly 65 years. An additional 8 percent of the developing world's people received access to water, and a further 15 percent acquired access to improved sanitation services.

Despite such encouraging numbers, many analysts agree that the world will fail to meet its commitments. *The Millennium Development Goals Report 2009* (U.N. 2009) states that less than six years away from the original 2015 deadline, overall progress has been too slow for most of the targets to be met by then. It concludes that successes in the fight against poverty and hunger have begun to slow or even reverse as a result of the global economic and food crises. The Food and Agriculture Organization of the United Nations (FAO) estimates that around 1.02 billion people are now chronically undernourished, and that the number of hungry people in the world increased by 75 million in 2007 and 40 million in 2008, largely due to higher food prices (FAO 2009). The FAO report *The State of Food Insecurity in the World 2002* stated: "In the worst affected countries, a newborn child can look forward to an average of barely 38 years of healthy life (compared to over 70 years of life in 'full health' in 24 wealthy nations)."

In 2005, Jeffrey Sachs, the director of the Millennium Project, described the mission of the project as "ending poverty in our time." He wrote: "Our task is to help people onto the ladder of development, to give them at least a foothold on the bottom rung, from which they can then proceed to climb on their own" (Sachs 2005).

Sachs advocated an approach he called "clinical economics," a concept based on providing clean water, healthy soils, and a functioning health care system with the same level of enthusiasm that development experts use when insisting that poor nations reform their economic systems. He called for supplying the basic necessities of life to the poor around the world as the basis of development. He is correct, but his recipe for achieving it—merely having the world's developed nations live up to their pledges to give more money in aid—will not get the job done. The problem is not a lack of money, but how development dollars are spent and how development is conducted. The developing world cannot lift itself out of poverty in the same inefficient way that the West has done. That would require three or more Earth's worth of resources to meet the needs of the world's consumers.

Peak Everything: Waking Up to the Century of Decline (Heinberg 2007) describes how Chinese and Indian "hunger" for all of the world's resources is leading to an impossible future. The founder of the environmental organization The Earth Policy Institute, Lester Brown, points out that part of the reason world oil prices hit record levels is that China entered the world oil market. If the Chinese used oil at the same rate as Americans, by 2031 it would need 99 million barrels of oil a day. The world currently extracts 85 million barrels per day and may not be able to lift much more. If China's coal burning equaled current levels in the United States (nearly two tons per person per year), China would use 2.8 billion tons annually—more than the 2.5 billion tons the entire world now uses (Brown 2005).

The Climate Change Challenge

One of the most serious challenges to sustainable development is climate change. In January 2005, Dr. Rajendra Pachauri, the chairman of the Intergovernmental Panel on Climate Change (IPCC), told an international conference attended by 114 governments that the impacts of climate change would fall disproportionately on the poor. "Climate change is for real," Pachauri said. "We have just a small window of opportunity and it is closing rather rapidly.... We are risking the ability of the human race to survive" (Lean 2005). Since then, many observers have issued similar or even graver statements, culminating in the IPCC's *Fourth Assessment Report: Climate Change 2007.* IPCC has already begun work on its Fifth Assessment, which is expected to be completed in 2014 (IPCC 2009).

At the same time, however, experts have described how rapidly emerging best-practice methods in sustainable technologies can meet basic human needs around the world in ways that cut carbon emissions and solve most of the environmental problems facing the planet—at a profit (Hargroves and Smith 2005; Hawken, Lovins, and Lovins 1999).

Afghanistan Case Study

In the west central highlands of Afghanistan, a micro-hydro electric power plant has been abandoned since the Soviets stripped the turbines from it decades ago. Rebuilding it could supply a megawatt of power to the city of Bamiyan and to thousands of rural residents who now live without electricity. To date, aid officials have shown no interest in this approach.

The abandoned ditch is a good example of development opportunities and challenges around the world. It could sustainably bring power critical for development to that region of the poorest country in the world outside of Africa. In 2004, however, U.S. president George W. Bush and Afghan president Hamid Karzai made a multimillion dollar deal to build a massive power line from the north to Kabul. Completed in 2008, the line now brings power to the capital city but nowhere else. One early proposal called for spending $2.7 billion (20 percent of the pledged development funds) to build coal plants across the north of the country to feed power to other parts of the country. Another deal proposed constructing a natural gas pipeline from Turkmenistan through Afghanistan to India.

Such plans are flawed on many levels. Given continuing conflict in the region, and the ready availability of ordinance, it is not clear how long such lines will operate. Construction contracts go to Western companies, generating few local jobs and no local ownership. Any generated power goes only to the capital and perhaps a couple other cities. It is not clear whether a proposed gas line would benefit the people of Afghanistan at all, or merely cross their land. Indeed around the world, one-quarter of all development capital goes to building large central power plants that rarely benefit the poor (Lovins 2005, 81).

Even a fraction of this money, diverted to enable local businesses to install efficient lights and power them with solar electricity, would result in more reliable power at roughly the same cost, while building viable local businesses, cleaning the environment, creating jobs, and reducing dependency on such things as charity and humanitarian aid. Numerous efforts by this author and others to have solar energy installed to replace borrowed diesel generators were scuttled by aid experts who preferred to import diesel rather than invest in fuel-free technologies.

Like many areas in the developing world, Afghanistan must rebuild everything: housing, energy supplies, food, water, sanitation, transportation, health care, and security. Official proposals for reconstruction have made little effort to use state-of-the-art sustainability technologies, which tend to work better and are more suited to poor, widely distributed populations.

Big Power vs. Small Solar

In April 2008, the so-called Ultra Mega Power Plant, a 4,000-megawatt coal plant in India, projected to cost at least $4 billion, received assurances of funding from the World Bank, the International Finance Corporation, and the Asian Development Bank. If completed, it will emit 23 million tons of carbon dioxide per year, half a million tons more than the worst carbon emitter in North America (Revkin 2008).

By contrast, concentrating solar power (CSP, a technology that focuses the sun's energy to boil water to generate electricity) would cost about the same—or likely less, given escalating coal prices, and would emit no carbon. Village-scale solar photovoltaics and other technologies would bring far greater development benefits and create ten times as many jobs as the power plant. Because of these advantages, in November 2009, India announced plans to bring on 20 gigawatts of solar photovoltaics by 2022 (Romm 2009). Delivering the power that is essential to the development of renewable technologies is good, but it is essential that it not merely a switch from one form of dependence to another.

Across India, local entrepreneurs are creating ways of delivering renewable energy that also delivers genuine development. SELCO India (the Solar Electric Light Company) sells solar electric panels that provide lighting and electricity to poor villagers at monthly prices comparable to using traditional, less effective sources. Through its network of twenty-five centers across India, SELCO provides infrastructure solutions to underserved households and businesses. It has brought reliable, affordable, and environmentally sustainable electricity to 35,000 homes and businesses since 1995 (World Bank 2009). By offering complete packages of products and services—including solar lighting and electricity, clean water, and wireless communications—SELCO aims to empower its customers to live sustainably. Thanks to solar power, villagers have access to communication technology, clean drinking water, refrigeration, power for clinics, and other development technologies. SELCO shows how, with the ability to light even one bulb, villagers can provide light for silk worms and looms. This provides an income source that enables them to begin to climb the development ladder.

SELCO's system is entirely market based, requiring no government subsidies or massive foreign loans, yet it is lifting thousands of people from poverty more effectively than most of the aid programs around the world. From its founding in 1995 to 2009, SELCO has sold light and electricity to more than 150,000 people and built annual sales to $3 million (World Bank 2009). SELCO offers individual homes and businesses advanced and inexpensive lighting, electricity, water pumping, water heating, communications, computing, and entertainment. Their systems do not require connection to a larger network. SELCO partners with rural banks, leasing companies, and microfinance organizations to provide the necessary credit.

The company's founder and managing director, H. Harish Hande, suggests that development experts rethink their definition of what poor people can afford. He argues that the poor actually spend a great deal of money on kerosene lamps, diesel for generators, and batteries for flashlights. They are capable of paying for a solar installation that would displace the more wasteful options, if institutions will lend at rates that they can repay (Dowerah 2007).

International Development Enterprises (IDE) uses similar sustainable development strategies in Asia, Africa, and Latin America, to help the small farmers that comprise about 70 percent of the world's 2 billion poor people (IDE 2009). IDE designs technology and networks that help those eking out a subsistence living on small farms create income opportunities. To produce higher-value, more marketable crops, IDE offers small farmers irrigation systems, quality seeds, farming techniques, storage, processing, packaging facilities, and marketing strategies, turning them into entrepreneurs. The organization has helped move 19 million people out of poverty since its founding in 1982, enabling them to earn more than $1 billion (IDE 2009).

IDE's model of development starts from the bottom up. It asks how much a farmer has to spend and how a product will help them make a living that can raise them out of poverty. Paul Polak, IDE's founder, asks the world's best designers to focus on the issues of the rural poor but says that is only a quarter of the challenge. The real job, he says, is marketing—actually getting the growing number of appropriate, available technologies to the people who need them in ways that they can afford to implement (personal communication with author, 16 March 2005).

On-the-Ground Development

There are several nongovernmental organizations that achieve success in the most poverty-stricken areas of the planet through their know-how. The Intermediate Technology Development Group has worked for years in "hopeless" situations like the Sudan. It provides irrigation and energy technologies, develops local financing programs, and assists villagers in preserving food ten times longer through evaporative cooling. Engineers Without Borders brings Western engineering students to work with people in individual villages; together students and residents decide which sustainable technologies to implement. They then plan and construct the energy, water, sanitation, school, or bridge projects.

In China, ecological designer John Todd's Eco-Machines (ecologically engineered systems of plants, microorganisms, and other living creatures) are cleaning the water in polluted canals while creating habitats and beautiful community parkways. SEKEM, in Egypt, is using private enterprise to lift thousands of people out of poverty, deliver quality organic food to European markets, and create a university. But such groups are rarely chosen to advise development agencies and rarely receive aid contracts. These deals go to so-called "beltway bandits" (named for Washington, D.C.'s Capital Beltway), who make an industry of applying for government and aid-agency contracts. If aid funding is to become part of the solution there needs to be a merging of the massive funding and institutional capacity of big donor agencies with the on-the-ground capability of the development technology groups.

Afghanistan remains, perhaps, the most urgent case in point. Since the late 1970s, the country has been continuously ravaged by internal and external conflicts. Much of its infrastructure is in ruins or was never completed. In the wake of 9/11, the international community—recognizing the threat to world peace of a devastated Afghanistan—pledged to rebuild the country. This has created a unique but narrow window of opportunity to use the growing body of best-practice sustainable technologies. Success is important not only to the Afghans but to world security; it is urgent that Afghan reconstruction create a robust infrastructure that delivers profitable and stable businesses as it rebuilds the entire economy.

Afghanistan has little money but is rich in wind, sunshine, and flowing water. Technologies using such widely distributed renewable resources are the only approach that makes sense for meeting the needs of dispersed villages. Officials at the Afghanistan Energy Ministry have expressed great interest in renewable energy, but the country lacks the consulting expertise and has few resources with which to pursue a more appropriate energy strategy.

Outlook

Renewable options are not only the best choice for developing countries, they are now the fastest growing form of energy supply around the world and, in many cases, cheaper than conventional supplies. Solar thermal is outpacing all conventional energy supply technology around the world. Modern wind machines come second, delivering over 100 gigawatts of capacity around the world, growing faster than nuclear power did even at the peak of its popularity. The next-fastest growing energy-supply technology is solar electric, even at current prices, and these are falling rapidly (LaMonica 2009).

Collectively the array of sustainability practices—efficient and renewable energy supplies, green building technologies, efficient water treatment and delivery systems, sustainable approaches to providing food and health care—can do a better job of meeting development needs in Afghanistan and other developing countries than the conventional approaches offered by the Western consulting firms with which the U.S. Agency for International Development (USAID) typically contracts.

Sustainable solutions are easier for small local businesses to deliver than the conventional approaches favored by USAID's usual contractors. If some of the money now going to conventional solutions was diverted to financing, training, and supporting local entrepreneurs, developing countries could meet basic human needs while protecting and enhancing their "natural capital" and their social fabric.

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Natural Capital Solutions

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See also Agriculture; Base of the Pyramid; Development, Rural—Developing World; Energy Efficiency; Energy Industries—Solar; Green-Collar Jobs; Investment, CleanTech; Investment, Socially Responsible (SRI);

Natural Capitalism; Poverty; Social Enterprise; United Nations Global Compact

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Development, Urban

Businesses can play a vital role in sustainable urban development by locating near transit within existing urban areas, by constructing green buildings, by protecting and restoring ecological features on their properties, and by practicing transportation-demand management. They can also use renewable sources of energy, reduce energy and resource use, and contribute to the social welfare of communities in which they operate.

The processes of urbanization profoundly affect businesses, and in turn, their actions profoundly affect community sustainability. The connections between businesses, urbanization, and community sustainability can be examined within the context of a wide range of urban development topics such as land use, transportation, energy systems, building regulation, urban design, environmental protection, and human welfare.

Land Use

Development of land is one of the most basic aspects of urbanization, and it has been a main focus of the modern urban-planning field since its origins in Europe and North America in the late nineteenth century. In most countries, planning has historically sought to regulate land use to promote community health, safety, and well-being (for example, by separating pollution-producing industries from homes). In recent decades, other sustainability-related goals have been added to this set of land-use objectives, such as protecting habitat, species, and farmland; reducing motor vehicle use, emissions, and congestion; and making efficient use of public investment for transportation systems and other infrastructure.

Main forms of land regulation in many countries include zoning codes, which establish allowable uses, densities, and building configurations on given parcels of land, and subdivision ordinances, which govern the division of one large parcel of land into many smaller ones. Subdivision procedures also usually require developers of large projects to add streets, parks, schools, and sewer and drainage systems to the land. Changes to these land-use regulations can greatly improve urban sustainability when they require developers to preserve streams and patches of wildlife habitat; to mix commercial, residential, and office development to reduce driving distances for residents; or to make pedestrian travel and public transportation possible.

Construction itself is a major economic sector, and many jobs, investment opportunities, and resource flows are tied to it. Other types of businesses linked to land development include architecture and landscape architecture offices, law firms, engineering and environmental-analysis companies, real-estate enterprises, marketing and sales operations, and banks. Construction and land-development industries, including secondary financial markets, can in turn greatly affect the sustainability of the rest of the economy, as witnessed during the financial crisis that began in late 2007 that was fueled by the collapse of the mortgage-lending market.

Public-sector supervision of land use, often controversial, affects many types of business. Ideally land use is guided by local, regional, and/or national planning documents. In practice, the process is far from perfect, and in communities worldwide, exceptions have been made for politically connected developers. In the United States, local government has almost exclusive control over land use. In other countries including France, Britain, Sweden, Japan, and China, national and state or provincial governments play strong roles in reviewing development decisions and/or establishing overall policy frameworks for land use. For example, the British government has prepared national and regional planning documents to guide local government in land-use decisions since the 1970s. Under the Blair administration, these planning documents were revised to incorporate sustainability concerns in the mid-1990s. In China, national decisions about ownership and land-use rights have led to radically different patterns of land development at different historical times. Reforms to allow private ownership of land in or near cities, for example, helped spur rapid urbanization in China in the 1990s and 2000s.

In many countries, land development during the past century has taken increasingly unsustainable forms as the resulting communities consume large quantities of farmland or open space and require high levels of motor vehicle use. The term *suburban sprawl* refers to development that has several of the following characteristics: low-density land use, homogeneous development (single-use districts such as residential, industrial, or commercial areas that result in the wide separation of homes, workplaces, and shopping), poorly connecting street patterns, "leapfrog" development that skips over available land adjacent to existing urban areas and occurs on less expensive land farther away, and high levels of motor vehicle dependency. Excessive driving within sprawled locations produces secondary impacts including increased local air pollution, fossil fuel depletion, and greenhouse gas emissions. Sprawling land-use patterns also tend to erode the sense of place-based human community by reducing pedestrian-oriented public spaces in the built landscape and making walking and public transit use difficult.

Although often viewed as a North American or Australian phenomenon, suburban sprawl occurs worldwide. A 2006 European Environment Agency study found that the land area of European cities had grown 78 percent since the 1950s, while population had only grown 33 percent. Areas such as the coast of southern Spain have seen particularly rapid sprawl, in part due to second-home construction. In Asia, many recently developed Chinese cities, built using ten- to twelve-story buildings with high population densities, have some sprawl characteristics in that they typically use a "superblock" model with poor street connections and a need for motorized vehicles to get around. The superblock, used also with poor results in American urban renewal of the 1950s and 1960s, typically creates very large urban blocks with mid- to high-rise buildings and green spaces at the center of the block. The problem is one of scale and connection; distances around each block are very long, pedestrian travel options are limited, and the city loses the fine-grained diversity of traditional urban places.

Revised models of land development hold promise of greater sustainability. Since the mid-1990s, a movement for "smart growth" has sought to limit urban sprawl by focusing on "infill" development within existing urban areas. Smart growth usually refers to compact, higher-density, mixed-use development that makes efficient use of public infrastructure. Infill often occurs on vacant or underutilized land, or through cleanup of contaminated industrial sites. "Transit-oriented development" clusters growth around public-transit stations or in the transit-accessible centers of cities and suburbs and creates walkable mixed-use places. "New urbanism" began in the late 1980s and emphasizes pedestrian- and community-oriented design of places within suburban and urban locations. Elements of this philosophy include attractive sidewalk environments, street-level retail within commercial buildings, porches on the front of homes with garages at the back, the creation of neighborhood centers for suburbs that do not have them, the addition of small parks and public spaces within neighborhoods, and the creation of connecting street networks that can diffuse traffic.

Business location decisions play a very important role in sustainable land use. For the past fifty years or more, businesses have been leaving downtown locations in favor of sites along arterial strips or business parks at the suburban fringe, but sustainability advocates are trying to attract firms back to more central and transit-accessible locations. Appropriate site location has become a main criterion within green-development rating systems, described further in the section "Building Design and Regulation." Using land efficiently (for example, by utilizing multistory buildings and reducing the size of surface parking lots) is also an important consideration for sustainable development. If businesses develop a site, they can seek to preserve existing habitat and wetlands on the site (the latter is often required by law), or they can go further to restore green spaces for their habitat or amenity value.

Transportation

The creation of transportation systems is another main element of urbanization, and rising motor-vehicle use, with its resulting pollution, greenhouse gas emissions, and dependency on petroleum, is a leading sustainability concern. Public officials generally seek to reduce driving in three main ways: by providing alternative transportation options such as public transit and bike and pedestrian infrastructure; by raising gas, toll, and parking prices as well as offering other incentives such as reduced-price transit passes to entice people to drive less; and by changing land use so that jobs, housing, shopping, and other destinations are closer together.

Businesses have an important role to play in reducing motor-vehicle use. As mentioned in the section "Land Use," location decisions are very important. Firms can reduce employee driving by choosing central locations close to public transit and housing. The field of "transportation demand management" (TDM) makes use of multiple strategies to reduce single-occupant-vehicle commuting, such as vanpool programs, ride-matching services, free or reduced-price transit passes, higher parking charges, and financial incentives for employees who forgo parking privileges. Providing safe, covered bike parking for employees and even showers for those who bike long distances to work can also help encourage workers not to drive. In metropolitan areas with serious air pollution problems, regional air-quality management agencies have required large employers to institute TDM programs with designated internal coordinators. Beginning in the 1990s, TDM programs in regions such as the San Francisco Bay Area; Los Angeles; Toronto; and Perth, Australia, have reduced motor vehicle travel in targeted areas by 10–30 percent.

Another strategy to reduce employee commuting is to adopt first-source hiring policies in which local residents are hired first in preference to those living further away. Some local governments in the United States have required their contractors to do this. Portland, Oregon, for example, instituted a policy in 1978 that linked economic development incentives to preferential hiring of local residents and resulted in the annual hiring of more than 700 local workers. This strategy is often pursued to benefit nearby lower-income communities, but it can have substantial benefits in terms of reducing long-distance commuting. Another approach used by some large companies is to build appropriately priced housing for workers near the job site. "Company towns," such as Pullman, Illinois (originally owned by the Pullman Sleeping Car Company) and Gary, Indiana (originally built by U.S. Steel), have sometimes been criticized for having an overly controlled and homogenous character. But creating smaller amounts of affordable housing near a work site may make sense, especially for businesses with low-paid workers that operate in areas with otherwise expensive housing. This can be a way to cut long-distance commuting by employees and its resulting increases in traffic congestion, resource consumption, and emissions.

Companies also make green choices when they buy their own fleet of vehicles—in particular when they purchase highly fuel-efficient cars and trucks, or vehicles that use compressed natural gas or clean-diesel technology. Reducing total mileage driven through more efficient operations is also important. Lastly, use of local suppliers can help reduce air pollution and greenhouse gas emissions related to long-distance freight shipping, especially transport by air since it produces high levels of greenhouse gases.

Energy Systems

To become more sustainable, communities and utilities are developing a wide variety of programs to reduce energy use and substitute renewable sources of energy for fossil fuels. Some of these programs directly target businesses. For example, Pacific Gas & Electric's "Express Efficiency" programs in California in the 1990s and 2000s have offered rebates to businesses for installing energy-efficient lighting, refrigeration, air conditioning, agricultural, and gas technologies. The early 2000s version of the program was credited with saving 300,000 megawatt-hours of electricity annually. On their own, businesses can pursue sustainable energy strategies to reduce costs and improve their environmental performance.

Although public attention is often focused on technologies such as photovoltaics (the use of solar cells to produce energy) and wind energy, efficiency improvements usually represent the cheapest and quickest way to reduce energy use. Strategies include selecting highly efficient appliances, vehicles, and industrial machines; weatherizing buildings; reducing unnecessary travel; using materials with lower embodied energy; and installing more efficient systems for heating, ventilation, cooling, and industrial processes. One particularly promising strategy is cogeneration, through which waste steam from industrial processes or heating plants is used to generate electricity. District heating systems, in which a centralized plant provides heating for an entire district or neighborhood, also can provide highly efficient energy use. Simple steps such as retrofitting roofs with highly reflective, light-colored materials, or installing a "green roof" with soil and vegetation, can reduce building energy consumption and improve efficiency.

Use of renewable energy systems to actively produce energy is another strategy. Wind power generally performs best in large installations in windy locations far from urban buildings, but solar-photovoltaic and hot-water systems are well suited to rooftops. Depending on geographic location and materials cost, biomass boilers that burn plant matter and heat water that is used in central heating and hot water systems may also be useful.

As well as benefiting firms individually, energy efficiency and renewable energy hold many business opportunities. Installing or financing photovoltaic (PV) solar applications is one growth area. Renewable Funding LLC is a new business that has contracted with cities such as Berkeley, California, to use municipal bond money to install PV panels on residential homes. Property owners pay the expenses back over time through incremental additions to property-tax bills and avoid having to foot the cost of the solar system up front.

Building Design and Regulation

Green buildings are a major focus of design activity worldwide. Building codes administered by local governments require a basic level of energy efficiency, and codes in recent decades have been modified to emphasize more efficient use of energy and water. Since the 1990s, organizations in many countries have developed more specific green-development rating systems, such as LEED (Leadership in Energy and Environmental Design) Green Building Rating System in the United States, BREEAM (Building Research Establishment Environmental Assessment Method) in Britain and Europe, and the Green Globes system in Canada. These systems typically award credits for a variety of green building elements, including location and site design, energy efficiency, water efficiency, use of environmentally appropriate building materials, and indoor environmental quality. Buildings are certified at a variety of levels depending on how well they perform according to set criteria for these elements. For example, the LEED Green Building Rating System offers a basic certification level plus silver, gold, and platinum levels.

Construction or use of a green building offers many advantages to businesses, including reduced energy and water costs as well as a degree of insulation from future energy price increases. A more pleasant, attractive, and healthy working environment can also benefit employees (for example, natural lighting of work spaces during daylight hours, user-operable windows and climate controls, and paints and carpets that do not release volatile organic compounds into the air). A positive public image is another potential benefit, especially for buildings that are officially certified as green.

Urban Design

Many local governments, businesses, and developers have come to realize the importance of designing streets, public spaces, and entire neighborhoods to be environmentally healthy and socially vibrant. Instead of the often sterile, empty, or traffic-filled spaces of mid-twentieth-century cities, landscape architects and urban designers are adding an array of pedestrian amenities, plants and trees, public art, public spaces, storefronts, restaurants, and even housing to business districts. In some cases, these elements overtly seek to improve environmental sustainability, such as the use of vegetated swales (low places) to absorb runoff from streets or on-site parking lots. In other cases, urban design strategies help to create a richer civic life that in turn has advantages for social and economic dimensions of sustainability.

Business-location choices can support or undermine the urban-design and community-development goals of local governments. Choosing a location in a district that the city or town is trying to revitalize can help create more thriving neighborhoods and a more sustainable community. Conversely, relocating from existing communities to far-flung urban-fringe locations saps the vitality and sustainability of communities by removing the tax base and jobs, among other impacts.

On their own properties, businesses have opportunities to enhance community sustainability and character through environmentally friendly urban design and green architecture. Placing buildings along streets, with parking behind or underneath, helps create a more interesting, pedestrian-oriented street environment than current suburban landscapes filled with large parking lots. Adding small parks, plazas, art works, or plantings in front of buildings likewise adds benefit to the community. By consulting neighbors and working with them, businesses and developers can develop site designs that respond to neighborhood needs (for example, by stepping down building heights where they adjoin residential development, by preserving heritage trees or historical architectural details, or by including street-level retail space).

Environmental Protection and Restoration

A main focus of sustainable community efforts is cleanup of dirty water, polluted air, and contaminated sites. Cities and towns also focus on protection and restoration of landscape features such as shorelines, wetlands, and areas of wildlife habitat. Such civic initiatives can be a source of pride for the entire community, and they can dovetail with new economic development strategies. Vancouver, British Columbia, has undertaken a multidecade restoration of contaminated industrial lands in its False Creek area, creating a series of new neighborhoods, business districts, and greenways around this large inlet. Chattanooga, Tennessee, and Pittsburg, Pennsylvania, have also both made names for themselves by cleaning up industrial pollution and creating civic amenities along formerly polluted waterways.

Businesses can take a lead in initiating or supporting environmental programs. For example, the Co-operative Group, a 1.7-million-member consumer cooperative based in Manchester, United Kingdom, runs a Green Energy for Schools program, through which it has installed solar panels at more than one hundred schools throughout the United Kingdom at no cost to the schools. The company has also won awards as the United Kingdom's greenest grocer for supplying sustainably produced food to dozens of local communities. As part of its overall corporate commitment to sustainability, HSBC Bank makes contributions to local environmental and social organizations in the eighty-six countries in which it operates. In 2005, it was the world's first bank to become carbon neutral, which meant that its global operations contributed zero net carbon dioxide into the atmosphere.

Human Welfare and Equity

Social equity and human well-being are essential elements of sustainable development, and businesses have important roles to play in helping communities achieve these goals. Although human welfare and social equity are not necessarily part of their business mission, such efforts often benefit businesses as well. Historically, many local and regional firms played important community roles by supporting local philanthropies, providing civic leadership, conducting youth training programs, and encouraging volunteer efforts by their employees. In the current era of globalized business, there are often fewer incentives for such local engagement, but active involvement in community welfare is no less important. The Target Corporation (formerly the Dayton-Hudson Corporation) has a hundred-year history of civic leadership and philanthropy in its home base of Minneapolis, Minnesota, and in other communities in which it operates. Target's bylaws require it to give away 5 percent of its pretax income, and it has donated more than $150 million to schools in the United States.

Living wages, health care, and affordable housing represent particular social sustainability concerns in many communities, and businesses can contribute in each of these areas. Although only required to pay minimum wages set by government, businesses can make ethical choices and create a wage structure that allows employees to live decently in their local communities. In countries such as the United States without nationalized health care, businesses can also make sure that their employees receive health insurance. They can provide services such as child care and on-site recreation for workers. They can also ensure that employees have adequate retirement packages in countries that lack a strong social-security network for the elderly.

Future Outlook

If sustainable urban development is to happen, businesses must play an integral role. In the coming years, sustainability challenges such as climate change will make action increasingly urgent. The need to reduce greenhouse gases will not just affect selected industries, but location, travel, and operations decisions by all types of business. The peaking and decline of petroleum production will also impact a wide range of economic decisions. Businesses can contribute to more sustainable urbanization through site selection, transportation demand management, construction of green buildings, protection and restoration of ecological features on their properties, provision of public amenities and services to enhance social environments, and contributions toward the social welfare of communities in which they operate.

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See also Building Standards, Green; Community Capital; Development, Sustainable; Facilities Management; Local Living Economies; Municipalities; Property and Construction Industry; Public–Private Partnerships; Public Transportation; Smart Growth

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Ecolabeling

Beginning in 1978, various countries started voluntary national product ecolabeling programs based on environmental-impact assessment criteria. To increase uniformity in European countries, the European Union authorized a voluntary ecolabeling scheme for "environmental excellence" in the 1990s. In order to provide global standards for environmental labeling procedures, the International Organization for Standardization defined the ISO 14020 series of environmental labels and declarations.

Ecolabeling is both a benchmarking tool for assessing enterprise sustainability performance and a fundamental guide to consumer choice in terms of the eco-efficiency of a process, product, or service. Besides being an acknowledged communication tool for promoting management strategies on an environmental and social scale, ecolabeling is also a marketing tool.

The complexity and rapid diffusion of socioenvironmental issues has created new challenges in production and consumption sectors in terms of adequate strategies for promoting ecological and social product compatibility and encouraging more purchase-conscious models. This approach has resulted in the proliferation of tools at international, national, and European levels that contribute to sustainability initiatives from an economic, environmental, and ethical perspective (i.e., the triple bottom line approach coined by John Elkington in 1994).

Background

The first relevant initiatives in the field of nonmandatory ecolabeling developed in Europe in the early 1980s, initially as self-declared claims by companies that attested to vague "ecological" characteristics of their products; certifications by private-sector bodies that proclaimed specific characteristics of a product (for example, chlorofluorocarbons free); or dubious declarations concerning the environmental compatibility of some types of goods (for example, green detergents, recycled paper). This kind of ecolabeling was utilized as a marketing tool, and it was often not based on valid scientific criteria. Consequently, contrary effects and market misinformation were the result.

To curb the diffusion of unofficial labels listing vague claims, many countries started voluntary national ecolabeling programs based on strict environmental-impact assessment criteria associated with production processes and accountability tools. The initiative guaranteed the diffusion of accurate information, but above all, it represented a significant instrument for firms to measure the eco-efficiency of process improvement and/or product performance.

Gradually, different environmental labeling systems were established at the national level including Blauer Engel (Blue Angel) in Germany (1978), considered by many to be the precursor of subsequent programs; EcoLogo in Canada (1988); Eco Mark in Japan (1989); White Swan in Scandinavia (1989); NF—Environnement in France (1991); Green Seal in the United States (1992); Green Label in Israel (1993); Green Label: Thailand (1994); Green Label in Hong Kong (2000); and Environmental Choice Australia (2001).

In the 1990s, the European Union (EU) authorized a voluntary ecological labeling program with Regulation EEC 880/92 (Ecolabel I), later modified by Regulation EC 1980/2000 (Ecolabel II), known as the EU "flower." The program resolved difficulties arising from the many different national nonmandatory ecolabeling systems available in Europe by creating an EU brand of "environmental excellence" for products that respected the strict requirements set out by the European Community based on the methodology of lifecycle assessment (LCA).

LCA is characterized by its holistic approach "from cradle to grave" and applies lifecycle thinking in quantitative terms to the environmental-overview analysis of activities related to processes or products (goods and services). In LCA, the use of resources, raw materials, energy sources, and electricity is identified as input, while emissions to air, water, and land as well as waste and by-products are recorded as outputs. The LCA procedure consists of four interrelated phases: goal and scope, lifecycle inventory analysis, impact assessment, and interpretation of results.

State of the Art

Delineating the specifics of particular categories of current environmental labels is quite complex. Each system is characterized by specific programs and varies in terms of ecological criteria and standards on which product and process conformity is assessed. In addition, the ecolabeling process is still evolving in many product and service sectors. Consequently, identifying adequate systematic indicators for the evaluation of a product's true environmental impact is not always easy.

Nevertheless, within the context of the various types of ecolabeling available, systems that require certification of conformity awarded by an independent body are distinguished from those that merely portray a firm's self-certification, and nonmandatory programs are differentiated from mandatory programs such as those that require energy labeling. Taking into account the different certification and label-issuing procedures, an alternate classification can be made of the various systems on the basis of the public or private nature of the certifying body. Ecolabeling systems can be classified at international, community, and national levels.

On an international scale, many systems of nonmandatory ecolabeling are available. In order to standardize procedures in these systems, the International Organization for Standardization (ISO) has defined a set of standards regulated by the ISO 14020 series (environmental labels and declaration). As of 2009, ISO has defined three different labeling categories in this series: ISO 14024 for environmental excellence brands (type I); ISO 14021 for self-declared environmental claims (type II); and ISO 14025 for Environmental Product Declaration (EPD) (type III).

Type I Labeling

In the different type I environmental labeling systems, the EU flower—the Ecolabel logo—represents "excellence." The product groups benefiting from this label have to represent a wide sector of the market, demonstrate significant positive environmental impact at a global and/or regional level, favor research for competitive advantage among manufacturers, and satisfy real consumer expectations. Nowadays the EU Ecolabel covers a wide range of products and services that include cleaning products, appliances, paper products, textile and home and garden products, and lubricants, as well as services such as tourist accommodations and campsites.

Although the EU Ecolabel scheme has developed positively in recent years, it is clear that more can be done to streamline its procedures. The July 2008 proposal for the revision of the EU Ecolabel regulation introduced significant changes, including a simplified assessment procedure, a broader range of product groups, the reduction of annual fees, and the introduction of measures to encourage uniformity and synergies with other national ecolabeling schemes.

Type II Labeling

The type II environmental labeling programs, based on the ISO 14021 standard, include self-declared environmental claims. The personal integrity of the producer (or the importer, distributor, and/or any subject that can benefit) is the only guarantee for this type of ecolabeling, in addition to the assumption that a series of requisites guarantee the validity of the declaration. In order to avoid excessive differences in personal declarations, which can generate confusion and consumer disorientation, the ISO 14021 standard sets out specific requisites and terms for the description, defines assessment procedures to be followed, and sets out specific guidelines that confirm the validity of the declarations on the part of the manufacturer. The requisites for self-declarations include accountability, precision, validation, detail, and clarity of reference, as well as the use of concise, straightforward language. Self-declared environmental claims range from "reduced energy (or water) consumption" to "recyclable" or "designed for recycling" to "compostable" to "recovered energy" and "reduced resource use."

Type III Labeling

The Environmental Product Declaration (EPD), known as type III environmental labeling and standardized by ISO 14025, establishes principles and specifies procedures for product development. The EPD is a document that accompanies a product and outlines the characteristics associated with environmental impact, quantified in LCA methodology, and validated by an independent body. The information is objective, quantified, verifiable, comparable, and credible, and it is primarily intended for use in business-to-business communication. Moreover, the

EPD is a tool that does not refer to predefined indicators to communicate the environmental performance of a product or service.

Implications

Ecolabeling programs can become an effective driving force in the transition process towards ecosustainability when current critical elements are eliminated. The main critical factor is undoubtedly consumer disorientation that results from the vast range of environmental labeling systems available on the market. This factor, unfortunately, affects numerous sectors including tourism, which in recent years has seen the eruption of ecolabeling certification programs and procedures characterized by very different content and impact in many areas of the world.

Moreover, this negative element is accentuated if it is taken into account that the consumer is not always capable of fully understanding the information on the label, which often requires specific competence. The reason for this is that criteria used in the different programs are not uniform and frequently far too complex or too superficial.

The combination of these elements together with the price factor, which is generally upgraded, limits the diffusion of ecocompatible products and services, especially as consumers are not always willing to pay a higher price for the purchase of goods of low environmental impact.

Another element to consider is the difficulty of assessing the "real" effects generated by using ecolabeling programs. As of 2009, there is no official published data that supplies information on volumes of sales and market shares, nor are there qualitative and quantitative indicators that refer to the reduction of environmental impact. No doubt standardization of the methodologies used by ecolabeling programs would help in implementing more efficient standards and practices. Then information on environmental protection could be streamlined with feedback from relevant data on results obtained.

A strong commitment is needed on the part of many of the participants involved to coordinate the different initiatives in order to establish a multilevel framework—based on distinct levels of sustainability—that favors rating activities within the international ecolabeling scenario.

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See also Consumer Behavior; Global Reporting Initiative (GRI); Greenwashing; Lifecycle Assessments (LCAs); Marketing; Performance Metrics

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Ecological Economics

An ecological economics model factors in "natural capital" and "social capital" (that is, the resource assets of our ecosystem and the value of trust in relationships among individuals) in addition to financial capital as measured by gross domestic product (GDP). It proposes we measure progress in terms that acknowledge human well-being and social fairness, ecological sustainability, and real economic efficiency.

An ideology of free-market capitalism and unlimited economic growth is based on certain assumptions about the real state of the world. The financial world serves as a set of indicators for goods, services, and risks in the real world. But when such indicators are allowed to deviate too far from reality, "adjustments" must ultimately be made; crisis and panic may ensue. Ecological economics attempts to reconnect these indicators with reality by raising two crucial questions: what are our real assets, and how valuable are they? The answers lie in acquiring a new vision of what the economy is and what it is for—the proper and comprehensive accounting of real assets—and establishing new institutions that use the market in its proper role of servant rather than master.

Present Economic Model

Our mainstream vision of the economy is based on a number of assumptions that were created during the so-called frontier period when the world was still relatively empty of humans and their built infrastructure. In this "empty-world" context, built capital was the limiting factor to economic development, while natural capital and social capital were abundant. ("Built capital" comprises the infrastructure—machines, factories, buildings, and roads, for instance—that supports a society's economy; "natural capital" refers to the land and its stock of natural resources, including ecosystems; and "social capital" refers to the value in networks of trust among individuals, as facilitated by institutions, rules, and cultural norms.) It made sense, in that context, not to worry too much about environmental and social factors of the economy since those could be assumed to be relatively unproblematic and ultimately solvable. It made sense to focus on the growth of the market economy, measured by gross domestic product (GDP), as a primary means to improve human welfare. And it followed, therefore, to think of the economy as only marketed goods and services, and to think that increasing the amount of goods and services produced and consumed was the ultimate goal.

But the world, now relatively full of humans and their built-capital infrastructure, has changed dramatically. In this new context, many believe that the goal of the economy is to sustainably improve human well-being and quality of life—and that material consumption and GDP are merely means to that end, not ends in themselves. Indeed, ancient wisdom and new psychological research reveal that material consumption exceeding real need can actually reduce well-being. Adhering to this view requires examining what it really is that contributes to sustainable human well-being; it calls for recognizing the substantial contributions of natural and social capital, which are now the limiting factors in many countries. It asks us to distinguish between poverty assessed by a low quality of life and poverty defined merely by low monetary income. To build a sustainable economy according to these principles, we must create a new model of development, one that acknowledges the new "full-world" context and vision. This new model of development would use measures of progress that clearly acknowledge the goal of sustainable human well-being and the importance of ecological sustainability, social fairness, and real economic efficiency.

A New Economic Model

Ecological sustainability implies recognizing that built capital and human capital (knowledge and physical labor) cannot infinitely substitute for natural and social capital, and that real biophysical limits exist to the expansion of the market economy.

The concept of social fairness implies that we recognize the distribution of wealth as an important determinant of social capital and quality of life. The conventional model has brought to this concept the assumption that the best way to improve well-being is through growth in marketed consumption as measured by GDP. This focus on growth has not improved overall welfare of society, and explicit attention to distribution issues is sorely needed. As Robert Frank argued in his 2007 book, *Falling Behind: How Rising Inequality Harms the Middle Class*, economic growth beyond a certain point sets up a "positional arms race" that changes the consumption context and forces everyone to overconsume positional goods (like houses and cars) that deplete the nonmarketed, nonpositional goods and services of natural and social capital. For example, the drive to consume more positional goods led many people to reach beyond their means to purchase ever larger and more expensive houses, a situation that fueled the burst of the housing bubble in 2007. Such overarching concepts of economic growth also fuel increasing inequality of income, which actually reduces overall societal well-being, not just for the poor but across the income spectrum.

Real economic efficiency implies including all resources that affect sustainable human well-being in the allocation system, not just marketed goods and services. Our current market allocation system excludes most nonmarketed natural and social capital assets and services that are critical contributors to human well-being. A new, sustainable ecological economic model would take such factors into consideration and measure and include the contributions of natural and social capital and would thus better approximate real economic efficiency the current model lacks.

The new model would also address a complex range of property rights regimes necessary to manage adequately the full range of resources that contribute to human well-being. For example, most natural and social capital assets are public goods. Making them private property does not work well. On the other hand, neither does leaving them as open access resources (with no property rights). What is needed is a third way to "propertize" these resources without privatizing them. Several new (and old) common property rights systems have been proposed to achieve this goal, including various forms of common property trusts.

The role of government in regulating and policing the private market economy would also need to be reinvented to establish ecological economics. Government has a significant role to play in expanding the "commons sector" that can propertize and manage nonmarketed natural and social capital assets. Government is important in facilitating a developing vision of what a sustainable and desirable future for a society would look like. As Tom Prugh, Robert Costanza, and Herman Daly argued in *The Local Politics of Global Sustainability*, strong democracy, based on developing a shared vision, is an essential prerequisite to building a sustainable and desirable future.

Proposed Solution

The long-term solution to the financial crisis, as ecological economists see it, is therefore to move beyond the "growth at all costs" economic model to a model that recognizes the real costs and benefits of growth. The current addiction to fossil fuels and overconsumption supported by our current economic model must be broken; a more sustainable and desirable future that focuses on quality of life rather than quantity of consumption must be created. It will not be easy; it will require new vision, new measures, and new institutions. It will require a redesign of the entire society. But breaking this addiction does not amount to sacrificing "quality of life." Ecological economists believe quite the contrary: not breaking the addiction is the real sacrifice.

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See also Development, Sustainable; Ecosystem Services; Financial Services Industry; Green GDP; Natural Capitalism; Social Enterprise; Sustainable Value Creation; True Cost Economics

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Ecosystem Services

Ecosystem services are the critical functions of the natural environment upon which human life depends, from carbon storage and waste decomposition to pollination, seed dispersal, and recreation. To date, these benefits and services generally have been free or undervalued, but new financial mechanisms are emerging to protect them.

In 2005, after four years of work across ninety-five countries, 1,300 contributing scientists published the Millennium Ecosystem Assessment, the most comprehensive survey ever taken of the state of the world's ecosystem services, the critical functions performed by the environment—such as flood control, climate regulation, and water purification—upon which society depends. The report concluded that 60 to 70 percent of these functions are being degraded faster than they can recover (Millennium Ecosystem Assessment 2005, 6). Unlike ecological "goods" such as food and fuel, which have traditionally been assigned value in the marketplace, ecosystem services seemingly have been provided to society free of charge. Yet many would be prohibitively expensive—or in some instances, impossible—to replicate through technology.

Market Mechanisms and the Environment

The idea of applying market mechanisms to environmental systems began in the United States in the early 1990s. (Market mechanisms regulate supply, demand, and prices in fluctuating markets.) A cap-and-trade system was set up under the U.S. Clean Air Act; it provided for trading pollutant allowances of sulfur dioxide, one of the gases responsible for acid rain. Under the Acid Rain Program, the largest utilities in the United States reduced their sulfur dioxide emissions more than 50 percent from 1980 levels. The real breakthrough was that the trading generated a jump in reductions and was responsible for the most cost-effective reductions. Resources for the Future, a non-profit, nonpartisan research organization, calculated that allowance trading saved $700 to $800 million per year, compared to uniform emission rate standards (Burtraw 1998, 5–6).

In this case, government and market mechanisms worked in synchrony. The government maintained property rights and set clear limits on emissions, while the market determined the lowest price at which these limits could be achieved. Sulfur dioxide levels in the atmosphere fell by roughly50 percent in two decades, and signs of recovery were evident in previously acidified lakes and streams throughout southern California (EPA 2004).

This early model demonstrated how markets have the advantage of creating value for improvements, even at the margin. Compare this with traditional command-and-control regulation, which creates value for getting to a certain point (e.g., 20 percent reduction in emissions) but no incentives for going beyond that point. When designed appropriately, markets will reward actions with continuously better results that extend beyond compliance.

Market-based policy mechanisms tend to lead to cheaper regulatory compliance for business than technology-focused or other prescriptive regulations. Management practices that are developed to comply with such regulations ensure their certainty; there is little risk that these practices will be overlooked in future regulatory targets or actions.

Business relies on ecosystem services for the most fundamental aspects of its operations, including protection from severe storms and disease, predictable flows of clean water, pest control, and long-term storage of carbon dioxide, known as carbon sequestration. Ecosystem services make up the natural infrastructure upon which business relies. Yet to date, much of the focus of corporate environmental management has relied on a simple input/output model. Companies track their material and energy inputs and their waste and emissions outputs. How business operations affect, or are affected by, the functioning of ecosystem services is rarely, if ever, considered.

If the trends depicted in the Millennium Ecosystem Assessment continue, ecosystems that had previously provided "free" services to business will soon require significant investment for restoration and conservation. Evidence of this can be seen in the rising prices of basic raw materials due to failing natural systems, such as the decline in pollinator bees in the United States, or in sudden and severe economic losses, such as the impact of the December 2006 tsunami in Malaysia and Thailand, which was exacerbated by the degradation of coastal wetlands that once acted as storm protection in Southeast Asia.

The private sector could also be affected by societal responses to ecological degradation in the form of rising insurance rates, shifting regulatory frameworks, increased shareholder expectations, or narrowed access to natural resources or cheap capital. Those living in regions bumping up against ecological limits have tended to blame business, guilty or not, for overtaxing their natural systems (a familiar example being the allegations in 2003 against Coca-Cola in Kerala, India, for misusing local water resources).

Some of these costs will need to be internalized by individual corporations, but others will be passed on through the value chain, possibly reaching the final consumer. Companies with geographically dispersed supply chains, or those selling to unstable regions in southern Asia, Africa, and the Middle East, will likely see disproportionate impacts from increased conflict over environmental assets, leading to corporate concerns around access, cost, and political risk. The emergence of market mechanisms to protect ecosystem services promises new business approaches to these multifaceted issues.

Transactions in Ecosystem Services

An array of policy tools has been developed to harness the power of markets and the global economy toward the conservation of ecosystem services. Payments for ecosystem services (PES) is an umbrella term for the entire range of economic incentive schemes for conservation, from global markets trading in interchangeable commodities, such as carbon credits, to highly localized efforts to conserve a native species, such as the ivory-billed woodpecker of the southern United States. To better understand the divergent types of PES schemes, it is useful to break them into the three broad groups: public payment schemes, self-organized deals, and open trading schemes.

Public Payment Schemes

Many environmental markets, including the carbon markets, have been launched using public purses to generate initial demand and help a market reach a level of liquidity sufficient for private actors to get involved.

Government payments to property owners who agree to adopt land management practices associated with the production of ecosystem services are the most widespread form of direct environmental service payment in the world. For example, the Conservation Reserve Program in the United States pays farmers each year to plant vegetative cover on croplands particularly vulnerable to erosion. Government tax breaks to provide incentives for the conservation of ecosystem services are also common. For example, tax credits for so-called conservation easements (the selling off of the rights to develop a piece of property in a certain way) are designed to protect certain ecological functions.

Philanthropic conservation programs have been set up around the world according to a direct PES model. The Nature Conservancy, the world's largest environmental organization, often pays landowners for the development rights to their land in order to protect the ecosystem services associated with undeveloped habitat.

Self-Organized Deals

Self-organized deals, in which individual beneficiaries of ecosystem services contract directly with providers of these services, are becoming increasingly common. This type of transaction between two or more private actors, such as a nongovernment organization (NGO) or business, is likely to increase as ecosystem services degrade, grow scarce, and begin to impact the supply chains of business. These schemes provide mutual benefits to all parties without the need for an extensive market structure.

One study of self-organized deals in forest biodiversity protection services across thirty-three countries found that the main buyers were (in order of prevalence) private corporations, international NGOs and research institutes, donors, governments, and private individuals. The most prevalent sellers were communities, public agencies, and private individuals (Landell-Mills and Porras 2002, 216).

Open Trading Schemes

Open trading schemes are also beginning to emerge around the world. These PES schemes, which are the logical extension of self-organized deals, require the normal attributes of functional markets, including sufficient liquidity and transferability, low transaction costs, and good access to information. There are two kinds of open trading schemes: voluntary markets and compliance markets.

Voluntary Markets

Voluntary markets for ecosystem services are often driven by philanthropic or public relations motivations, but they benefit business by identifying inefficiencies, reaping early mover advantage, and anticipating regulation. Voluntary transactions are useful to business because they can provide first-mover advantage (the benefits gained by being the first significant company involved in a market), especially where large technological investments in asset-intensive industries are concerned. Voluntary transactions often have lower bureaucratic costs, thus making credits cheaper to produce. Numerous businesses are engaging in voluntary transactions in the hope of gaining a seat at the public policy table or being rewarded by future regulation for their actions. The Acid Rain Program in the 1990s did not recognize early action, but there are signs that regulators now consider this a mistake.

Voluntary transactions and credits may be hard to guarantee, however, because of the fragmented and expensive nature of verification in nonregulated systems. Such high transaction costs have prevented numerous voluntary ecosystem services deals and have represented a serious impediment to carbon trading. This is illustrated by the fact that the 330 million tons of carbon dioxide equivalent (CO_2e) traded on voluntary markets in 2007 represented only 0.5 percent of that traded on compliance markets (New Carbon Finance and Ecosystem Marketplace 2008, 6). As the verification systems for voluntary markets mature and various standards are consolidated, these transaction costs should diminish and fundamentally alter the calculus.

While voluntary markets enable the financing of innovative new projects and provide customized products to niche buyers, however, they have never reached the scale concomitant with the scale of the ecological degradation. For that, they are generally accompanied by a compliance market.

Compliance Markets

Compliance markets for ecosystem services are driven by regulatory requirements that often take the form of a cap on environmental degradation. The European Union Emissions Trading Scheme is an example of a compliance-based market in carbon sequestration services. In the United States, stipulations under the Endangered Species Act have enabled conservation banking agreements with credit prices ranging from $3,000 to $125,000 per acre (Fox and Nino-Murcia 2005).

Like any other market, markets in ecosystem services require repeated transactions among sufficient numbers of buyers and sellers, timely and credible information, fair competition, and trust. For the emerging markets to come to scale, oversight and regulation will be important early elements to ensure credibility in the market and to prevent unintended consequences. Unique to these markets, biological and economic sciences must provide the fundamental building blocks of any given transaction. Multiple tools that incorporate biodynamic modeling to enable potential market players to identify ecosystem services on a given plot of land, assess their reliance on the health of those services, and then place a monetary value on them to enable trading are now under development.

Ecosystem Services: Agriculture

The agriculture industry relies on and affects numerous ecosystem services, including water provision and filtration, biodiversity (beneficial insects and pollinators, germplasms), soil renewal, carbon sequestration, and climate regulation.

The industry faces a number of ecosystem service–related challenges, including competition with ecosystem services for water. Every diversion of rainfall, surface water, or groundwater from ecosystems to rain-fed or irrigated agriculture represents a trade-off between other ecosystem services and food or livelihood benefits. Water scarcity is therefore leading to higher input and infrastructure costs. In addition, intensive systems of production and the overuse of marginal and fragile ecosystems have already led to the degradation of soil quality and productivity. Increasing demand for available land, especially due to urbanization and sprawl, is leading to higher costs of land and transportation. Pollution of surface water and land is contaminating crops and can affect public health. Management practices are strongly influenced by external drivers, such as land tenure, production subsidies, market and consumer preferences, and access to technologies, inputs, and credit.

A range of possible ecosystem services–based solutions is emerging. With the help of valuation experts, agricultural firms can now weigh the benefits of the ecosystem services provided by their land. They can then use this information to demonstrate to insurers that good soil and water stewardship leads to consistent yields and should therefore be rewarded with lower insurance rates. Agricultural businesses, similar to Timber Investment Management Organizations (TIMOs), may choose to retain land holdings once the ecosystem services that the land provides are turned into cash, since it would then provide new revenue streams.

Enhancing ecosystem services may also have cascading benefits of efficiency (water and energy), drought and salinity tolerance, pest and disease resistance, reduction of waste, higher yields, and more nutritious food. As consumer concerns increase regarding runoff and pesticide residues on products, considering an ecosystem-services approach may also reap reputation and brand benefits.

Ecosystem Services: Energy and Extractives

The energy and extractives industry (oil, gas, mining) depends on and/or affects carbon sequestration, water provision and filtration, climate regulation, and biodiversity. The industry is responsible for generating some of the most carbon-intensive products in the world, which contribute to climate change throughout their lifecycle. Production requires intensive freshwater use at a rate of thousands of tons per day at most facilities. Production typically contributes to the degradation of the local water supply, so the industry is increasingly seeing its rights to water access challenged, which drives up costs. Three-quarters of active mines and exploratory sites overlap with areas of high conservation value, from desert to rainforest, tundra to oceans. Unfortunately, many energy and extractives businesses lease the land they develop and have little incentive to protect it over the long term.

Ecosystem services–based solutions are emerging in the energy industry as well. Project managers in energy and extractives can incorporate ecosystem services frameworks into preexisting environmental impact assessments. Corporate government-affairs departments can use ecosystem services as an impetus for clarifying underground property rights and the parties accountable for terrestrial systems aboveground. Natural-lands managers can use ecosystem-services audits to establish a record of comprehensive environmental stewardship that may offer various benefits in an industry tarnished by its environmental history.

Ecosystem Services: Utilities

The utility industry depends on and impacts slow and consistent water flow (e.g., from mountain snow packs, agriculture, and streambeds); water storage and flood avoidance; carbon cycling, both locally and globally to assimilate emissions; upstream land management to prevent sedimentation and protect water quality; and wetlands storm water and wastewater treatment.

Electricity generation requires access to large amounts of clean water for cooling or driving turbines. Wastewater disposal is becoming an increasing challenge, especially because of growing populations and sprawl, which limits the land available for spraying sludge. Energy costs of transporting water are high and increasing. Poor hillside management and deforestation are leading to sedimentation of dams.

The ecosystem services–based solutions emerging in the utility industry offer broad possibilities for improving the environment. Corporate real estate developers can use constructed wetlands for storm water and wastewater management and treatment, thus avoiding traditional infrastructure costs. Utilities could provide carbon storage on company property through reforestation or forest maintenance. A nongovernmental partner could measure and monitor the carbon stored by company land. Companies could also "stack" ecosystem-services offerings by opening land to local agencies for recreational use. Landscaping contractors could be instructed to optimize wildlife protection through right-of-way lands, buffer zones, and migratory corridors.

Ecosystem Services: Pharmaceuticals

Water filtration, especially in developing countries; waste assimilation, particularly as it pertains to bioactive waste; and biodiversity are important considerations in the pharmaceutical industry. Active pharmaceutical ingredients in medicines can be released into the environment from patient and livestock excretion and make their way into sewage treatment plants or septic systems; from there they can penetrate soils through seepage or sludge application. The majority of medical compounds originate from natural products, often in high-biodiversity regions of the world, but maintaining access to these regions is becoming increasingly difficult, especially because of accusations of "biopiracy" from developing countries.

Possible solutions to ecosystem-service challenges could include companies that partner with local land and resource owners to avoid access restrictions and to gain knowledge of indigenous flora and fauna with potential medical benefits. Those selling to developing countries could view ecosystem services as a "bottom of the pyramid" strategy for alleviating poverty among potential customers. The breakdown in ecosystem services is closely coupled with poverty.

Future Trends and Challenges

All the markets mentioned here—agriculture, energy and extractives, utilities, and pharmaceuticals—represent new opportunities for both sellers and buyers of ecosystem services. The most efficient users are able to sell surplus services to buyers in need of high levels of the same services to operate their businesses.

As tangible value is assigned to ecosystem services, business will benefit by exploring potential investments, as well as the exposures associated with them. It is likely that in the foreseeable future, attention to these services will become similar to the attention businesses give to other corporate assets, such as infrastructure. In this case, the infrastructure is the ecosystem services upon which the company relies.

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See also Agriculture; Cap-and-Trade Legislation; Ecological Economics; Energy Efficiency; Energy Industries (*assorted articles*); Green GDP; Investment, CleanTech; Mining; Pharmaceutical Industry; Sustainable Value Creation; True Cost Economics; Water Use and Rights

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Education, Business

In order to meet the shortage of trained managers with competence in sustainable management, business schools must design and implement programs that will prepare students to deal with the environmental and social issues they will face as managers in the twenty-first century. Business schools and associated organizations and institutions are demonstrating an increasing focus on sustainability in their courses, programs, conferences, and action plans.

Business schools were questioned and implicated during the financial crisis and global economic downturn that began in late 2007. While it has long been argued that business schools are centers of academic freedom, scholars such as Henry Mintzberg (2004) and Rakesh Khurana (2007) have pointed out how the exclusive pursuit of profit and shareholder value as the primary model of capitalism has corrupted the purpose of business. Meanwhile other scholars such as Anthony Cortese (2003) and Andrew Hoffman (2009) have highlighted the lack of connection between business school priorities, such as scientific and theoretical research, and critical, real-world issues facing managers, including an increasingly interdependent set of social and environmental issues. In the context of such critique, it is important to question the purpose of management education and examine the role of sustainability in business schools.

Sustainable Management Education

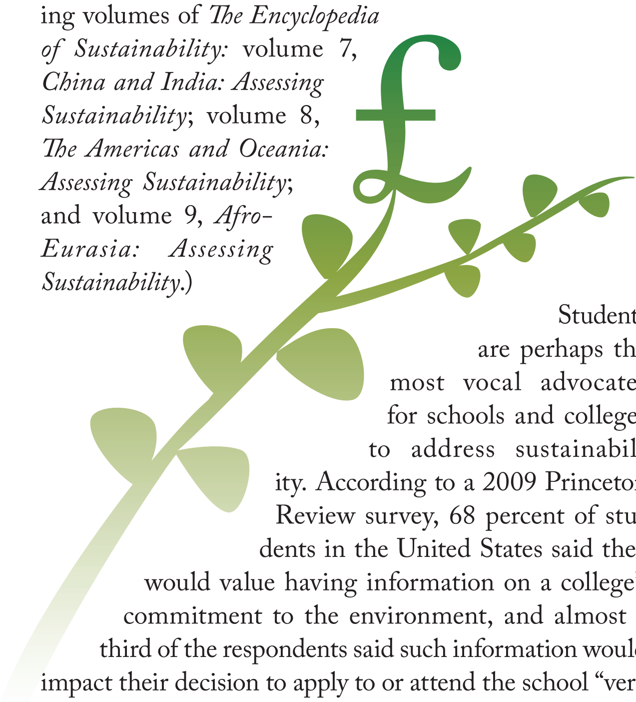
Sustainable management education is about more than changing lightbulbs or switching to recycled paper on campus. It is about rethinking what is taught and how it is taught, and reassessing the connections between what is learned in the classroom and the impact of managers' actions in the world. It is the combination of educational context, learning processes, and content designed to prepare business students to engage in the imperative—and interconnected—management issues of the twenty-first century. Sustainable management education expands the existing paradigm of "capitalism" to include the elements, principles, and values of "natural capitalism," a concept coined by the environmentalists Paul Hawken, Amory Lovins, and L. Hunter Lovins (1999). It is ultimately about imparting the knowledge, teaching the skills, and developing the competencies and courage of managers, entrepreneurs, and leaders to create a future that is ecologically sound, socially just, and economically viable for future generations.

Responses to Sustainability Issues

More and more companies in the twenty-first century are increasingly concerned about social and environmental issues and see that there is a compelling business case for action. Many are moving rapidly to try to incorporate sustainable management theory into practice. According to the world's largest directory of company-issued sustainability reports, CorporateRegister.com (2009), more than 22,700 reports citing environmentally and socially responsible practices were registered from over 5,600 companies as of September 2009.

While this momentum is impressive, one of the fundamental barriers to effective implementation of sustainable management practices is the lack of human resources—people with the skill sets to help redesign business processes and standards, rethink systems, retrain employees, communicate with customers, and/or reevaluate finance and capital management. Simply stated, there is a shortage of trained and talented managers with knowledge of, and competence in, sustainable management. According to a McKinsey & Company survey of executives, chief executive officers (CEOs) ranked the inadequate education system and the resulting lack of talent, as well as operating in new emerging markets, at the top of future constraints in meeting the challenges of environmental and social issues (Oppenheim et al. 2007).

Higher education has lagged behind the business sector on issues of sustainability, but there has been a noticeable shift since the 1990s. Once considered a novelty in management research and teaching, one indicator of change is the number of schools that are including sustainability in courses and programs. In 1998, the World Resources Institute produced a report called *Grey Pinstripes with Green Ties* that examined the inclusion of environmental topics in thirty-seven masters of business administration (MBA) schools. Later taken over by the Business and Society Program of the Aspen Institute Center for Business Education and rebranded *Beyond Grey Pinstripes*, the benchmarking report was expanded to include teaching that was related to social-impact management. The Aspen Institute's 2008 report provided information on over 130 global MBA programs. (Although the primary focus of this article is business schools in the United States, the editors, with the guidance of the author, have commissioned articles on business education worldwide for forthcoming volumes of *The Encyclopedia of Sustainability:* volume 7, *China and India: Assessing Sustainability*; volume 8, *The Americas and Oceania: Assessing Sustainability*; and volume 9, *Afro-Eurasia: Assessing Sustainability*.)



Students are perhaps the most vocal advocates for schools and colleges to address sustainability. According to a 2009 Princeton Review survey, 68 percent of students in the United States said they would value having information on a college's commitment to the environment, and almost a third of the respondents said such information would impact their decision to apply to or attend the school "very much." This is a significant change from almost fifteen years ago when a small group of MBA students created an organization called Net Impact with a mission to educate and equip individuals to use the power of business to create a more socially and environmentally sustainable world. Today the organization has fifteen thousand members in two hundred chapters that span six continents, making it perhaps the most influential sustainability-focused network of business students, graduates, and professionals. In 2008, the members created a guide to graduate programs called *Business as Unusual* to inform prospective students who were searching for sustainable business programs. The guide has become the de facto benchmarking list and featured eighty-seven schools from around the world in its 2009 report (Net Impact 2009).

Beyond pressure from students and the corporate sector, a broader network of organizations and institutions has been instrumental in moving the case for sustainable management education forward. The Academy of Management, with almost twenty thousand members, is the oldest and largest scholarly association in the world, and it plays an important role in facilitating and disseminating knowledge about management and organizations. In 1991, a small group of faculty members created the Organizations and the Natural Environment (ONE) special interest group within the academy to facilitate and legitimize management research related to environmental issues. Today ONE is recognized as a formal division, and in 2009, the annual academy conference focused on the theme "Green Management Matters." Similarly members of the Social Issues in Management (SIM) division, which was created in the 1980s, have had an important impact on stakeholder theory, corporate citizenship, and the social dimension of sustainability. The divisions and interest groups within the academy have provided an important channel for individual faculty to share research, run specialized sessions, and build support for integrating sustainability teaching into courses and research.

Faculty and administrators have also formed networks outside of the academy. The Association for the Advancement of Sustainability in Higher Education (AASHE) works to empower schools and colleges to lead sustainability initiatives by providing resources, professional development, and support to operations, education, and research divisions. In 1990, the Association of University Leaders for a Sustainable Future (ULSF) created the Talloires Declaration, a ten-point action plan that commits institutions to sustainability and environmental literacy in teaching and practice. As of 2009, over four hundred college and university presidents and chancellors worldwide had signed the declaration. The United Nations also convened a group of scholars and leading academic organizations to articulate a set of principles for responsible management education at a summit in July 2007. By September 2009, 244 institutions had adopted the resulting six Principles for Responsible Management Education (PRME 2009).

Another hopeful sign is the recent interest in sustainability among accrediting institutions, which exist to ensure that schools adhere to high-quality standards for education. (In addition to the requirement to continuously demonstrate improvement, the U.S. Department of Education requires accreditation in order for institutions to qualify for federal and state financial aid.) The most prestigious of the business school–focused bodies is the Association to Advance Collegiate Schools of Business (AACSB). In 2008, AACSB renamed their annual conference the Sustainability Conference. Over two hundred deans, associate deans, faculty, and administrators attend this annual event. Similarly the Western Association of Schools and Colleges (WASC), the regional accrediting body, will convene its first dialogue on sustainability at the 2010 Academic Resource Conference, which is dedicated to the topic. Both AACSB and WASC are critical players in the higher education system because they can have a profound impact on the priorities and practices of schools and colleges. Although the extent to which accrediting agencies will actually require schools to demonstrate commitment to sustainability remains to be seen, this issue is clearly on the agenda of many educators and administrators.

Other organizations that are working to create dialogue about sustainability within the university system include the following:

- Second Nature, aimed at serving and supporting college and university leaders
- Higher Education Associations Sustainability Consortium, an informal network whose Fellows Program support the work of individuals aimed at accelerating sustainability projects nationwide
- American College & University Presidents' Climate Commitment, focused on reducing greenhouse gas emissions
- U.S. Partnership on Education for Sustainable Development, focused on developing national sustainability standards
- Disciplinary Associations Network for Sustainability, which provides resources for professional development, education, and cross-disciplinary projects, as well as access to legislative briefings about higher education and sustainability-related policies

The drivers behind these efforts are clearly diverse; however, it is evident that the stakeholders of the business school system—students, faculty, graduates, funders, vendors, utilities, government agencies, recruiters, and accrediting bodies—are increasingly looking to see if schools "get it" with regard to the issue of sustainability.

Emerging Innovations

The depth to which sustainability is integrated into business schools is varied and inconsistent. A careful look at the *Beyond Grey Pinstripes* and *Net Impact* rankings reveals a range of approaches. MBA programs utilize five distinct approaches.

Beyond the traditional MBA, the first approach involves adding courses in sustainability as electives. The number of sustainability electives offered in MBA programs increased from 13 in 2001 to 154 in 2007 (Wankel and Stoner 2009, 345). While this is an important advancement, the optional nature of electives limits the exposure of management students to sustainability concepts.

Beyond offering electives, some programs, such as the one at the Leeds School of Business at the University of Colorado, have begun to require a course related to sustainability as part of the core MBA curriculum. The Leeds School of Business takes the same approach with respect to the issues of ethics and globalization.

The next level of curriculum design is a concentration or minor that supplements the core MBA degree with a sequence of courses in subjects related to sustainability. There are a number of progressive programs in this realm, such as those offered by Duke University, the University of Oregon, and Columbia University. A related option is to offer a dual degree. The University of Michigan is a showcase example of this strategy, where students complete a master's degree in business administration in the Ross Business School and a master's degree in science in the School of Natural Resources.

A number of schools have begun experimenting with a similar model to the dual-degree category—a certificate to complement the core degree. This option is more concentrated and less formally structured than the duel-degree option. Some recent programs in this category are offered by Arizona State University, York University, and Portland State University.

Although the first three approaches are important advancements, sustainability teaching remains at the periphery of core disciplines such as operations, finance, capital management, marketing, and strategy. How can sustainability be integrated into management education? What would a model curriculum look like? How could core disciplines prepare students to create and manage wealth while contributing to an environmentally healthy and equitable society?

A handful of institutions are experimenting with answers to these questions and providing models for sustainable management curricula. Two MBA programs blazed the trail: Bainbridge Graduate Institute launched an MBA in Sustainable Business in 2002, and Presidio Graduate School followed with an MBA in Sustainable Management in 2003. Both schools share a similar educational philosophy that is rooted in the integration of sustainability across all courses. They also share a commitment to highly relevant, practical teaching that focuses on solving real-world problems. Both schools have been recognized in the *Net Impact* and *Beyond Grey Pinstripes* reports. What is important about these examples is that they are no longer interesting experiments at the margins of higher education. In 2009, there were at least twelve similar sustainability-focused MBA programs, as well as new undergraduate and doctorate programs emerging across the United States in small, large, public, and private institutions.

Barriers to Change

It is evident that a shift is occurring in management education. While the business sector and students are the primary drivers of change, individuals, organizations, and networks are increasingly working to redefine management education and its alignment with human and natural systems. Fundamental structural issues remain for business-school educators and administrators. Perhaps the most profound is the tension between the traditional approach of management education, which focuses on rigorous research and theoretical inquiry, and the movement toward more practical, issue-based teaching, which is oriented toward meeting the challenges faced by practicing managers, including sustainability and social responsibility.

Another emerging tension is the state of the economy itself. The extent to which budget cuts to public funding in education in the United States will stall progress on sustainability remains the subject of debate in 2009. Many schools and administrators recognize that making a commitment to sustainability—if only in operations and infrastructure—is a smart thing to do. As demonstrated by the business sector, taking action on climate change reduces energy and utility costs, which could become a powerful driver for sustainability initiatives within a higher education system that faces significant budget cuts.

Outlook

While the business schools noted above deserve credit for blazing a trail and bringing change to traditional education models, the next frontier of innovation remains to be seen. In order to truly transform the economy and society, what is needed is a business school system that produces graduates who are systems thinkers and solutions-oriented problem solvers. The tipping point will be the creation of a fully integrated management education system in which the content, process, and context of learning are connected and sustainable. This vision includes:

- schools that are redesigned to function as sustainable systems; take action on issues like climate change; embody responsible consumption of energy, water, and material flow; and support sustainable development in the respective local community and region
- an approach to teaching that focuses on highly relevant, experiential, practical learning and solving real-world problems, and that creates an environment that captures and nurtures best practices that can be evaluated and replicated
- schools that function as a bridge between theory and practice by engaging business managers and leaders in dynamic learning laboratories that have real value and impact
- curriculum that goes beyond the integration of sustainability within disciplines and courses to its integration within the overarching, strategic program-level competencies—that is, management programs that are designed around, and academic excellence that is measured by, the skills, knowledge, and attributes—that management students need to have a meaningful, systems-shifting impact in the business world

Business schools have been slow to respond to the need for sustainable management education; however, the tide has begun to turn. The landscape of sustainability in business schools is best understood within a systems context, and while progress has been made with a range of innovative developments, some fundamental tensions within the larger system must be noted. Notwithstanding these tensions and the current economic outlook, the field of sustainable management continues to build momentum. Sustainability *is* the next frontier in management education where business schools will reclaim the purpose of education and produce graduates who have the courage and competence to create markets that restore ecological systems and nurture social structures.

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Note: Information in this article regarding business school curricula and programs is current as of 2009.

See also Corporate Citizenship; Education, Higher; Financial Services Industry; Leadership; Natural Capitalism; Stakeholder Theory

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Education, Higher

As business leaders increasingly recognize the importance of sustainable development to their companies' futures, the greatest barrier they encounter is the shortage of a workforce with knowledge and training in sustainability. Higher education has a critical role to play by providing the programs and curriculum content that graduates need to help align the goals and actions of business with the values and practices of sustainability.

As the business sector increasingly embarks on the challenge of seeking a more sustainable future, corporate chief executive officers (CEOs) are coming to recognize that "we have met the enemy and he is us." Barriers to moving forward sustainably are more often than not internal barriers rather than external barriers. While corporate leadership may grasp the value and fundamentals of sustainability, it is middle management and line staff who are charged with finding solutions and executing new policy—and too often they simply do not have the knowledge base and training in sustainability to be able to change the way they do business.

In short, business leaders seeking to move their companies toward sustainability have a huge workforce problem. A recent Arthur D. Little study of Fortune 500 CEOs reported that, while 90 percent agreed that "sustainable development is important to their company's future," only 30 percent say they have the "skills, information, and personnel to meet the challenge" (Weeks 2009).

Business leaders increasingly believe that a "sustainability-literate" workforce is critical to their long-term success and profitability, with better sustainability practices and improved efficiencies impacting positively on the bottom line while helping to better position and prepare their companies for the future. Charles O. Holliday Jr. (2006), chairman and CEO of DuPont, spoke for a growing number of his peers when he wrote in a 2006 letter to Senator Edward M. Kennedy that "an environmentally sustainable business is just good business, given the growing concern for environmental problems across America. A key component of an environmentally sustainable business is a highly educated workforce, particularly involving environmental principles." The Association for Career and Technical Education (ACTE 2008) identified the same challenge in 2008 when it reported that "the need for human capital is proving to be a barrier to the continued growth and expansion in energy efficiency and sustainability. . . . There must be a greater focus by policymakers and business and industry leaders on providing the training and retraining necessary to help shape this new workforce and ensure the continued pipeline of skilled workers."

As the primary source of learning for both management and the vast majority of business employees, higher education has a critical role to play in helping business enterprises become more sustainable. Each year higher education in the United States sends 3 million graduates out into the workforce armed with the attitudes, skills, and knowledge that will either advance sustainability or continue "business as usual." And the impact, good or bad, of each of these 3 million individuals will last a lifetime. Workers, managers, and professionals at all levels and in all sectors must understand the foundations of a green economy in order for this transition to be successful. As the old adage goes, higher education is either part of the solution or part of the problem. (Although the focus of this article is higher education in the United States, the editors, with the guidance of the author, have commissioned articles on education worldwide for forthcoming volumes of *The Encyclopedia of Sustainability:* volume 7, *China and India: Assessing Sustainability*; volume 8, *The Americas and Oceania: Assessing Sustainability*; and volume 9, *Afro-Eurasia: Assessing Sustainability*.)

It must be clear that the challenge is not about preparing students for the growing number of "green" jobs. The United States has existing systems and processes for developing new career-training programs that are generally effective in dealing with labor shortages (though one can legitimately argue that both business and government need to help higher education accelerate the development of green-job training programs). The number of truly new green jobs such as solar- and wind-power installers, while growing rapidly, will always be a small percentage of the total job market.

The challenge instead is to prepare this next generation for what promises to become a labor market where every job is "green." Sustainability is much more than solar panels and wind turbines; it is a new way of understanding business and its relationship to the environment and society that ultimately needs to be shared by all members of the workforce.

Sustainability in Higher Education

The following indicators demonstrated the growing interest in sustainability on U.S. campuses as of August 2009:

- Over 650 college and university presidents had signed the American College and University Presidents' Climate Commitment (ACUPCC 2009) and pledged to make their campus climate neutral within a fixed period of time.
- Several dozen mainstream higher education associations included advancement of sustainability as a part of their agenda and core programs.
- When the four-year-old Association for the Advancement of Sustainability in Higher Education (AASHE) held its 2008 conference, 1,700 participants attended.
- Over 300 campuses had conducted campus sustainability assessments and hired sustainability coordinators/directors (most since 2004), and hundreds more were planning to conduct sustainability assessments.
- Over 500 schools had institution-wide sustainability or environmental committees.
- According to the Sustainable Endowment Institute's 2010 College Sustainability Report Card (2009), of the 300 colleges and universities with the largest endowments, 83 percent bought at least some food from local farms; 44 percent had high-performance green-building projects; 58 percent were committed to carbon reduction; 77 percent were using at least some hybrid or electric vehicles in transportation fleets; 40 percent purchased renewable energy or renewable-energy credits; and 45 percent generated their own renewable energy to some degree.
- Since 2006, several dozen larger universities attracted multimillion-dollar contributions for their sustainability efforts; several universities received gifts exceeding $20 million to establish sustainability centers or institutes.
- In March 2009, 12,000 students traveled from across the United States to participate in the three-day PowerShift 2009 Conference outside Washington, D.C., to learn about global warming and to lobby the U.S. Congress.
- In January 2008, Focus the Nation, a U.S. nonprofit organization, organized the biggest national teach-in in history and engaged about a half-million students at over 1,900 institutions in a day-long teach-in about global warming.

The U.S. federal government has also begun to recognize that they face a similar problem. Transforming the nation's economic, energy, and environmental systems to move toward a clean, green economy, as called for by President Barack Obama's administration, will require a level of expertise, innovation, and cooperative effort unseen since the 1940s war effort. Top-down and regulatory approaches such as cap-and-trade climate bills are simply not enough. Architects, engineers, planners, scientists, business managers, financial experts, lawyers, entrepreneurs, political leaders, resource managers, and workers are all needed—not to mention environmentally literate consumers—to drive the green economy.

As a result, the U.S. federal government is beginning to support sustainability in higher education. For example, the Higher Education Opportunity Act of 2008 authorized a University Sustainability Program at the Department of Education to offer competitive grants to institutions and associations of higher education to develop, implement, and evaluate sustainability curricula, practices, and academic programs. The Energy Independence and Security Act of 2007 authorized $250 million annually in grants and another $500 million in direct loans for renewable-energy and energy-efficiency projects at higher education institutions, public schools, and local municipalities. President Obama's FY2011 budget proposed two additional programs. Science, Engineering, and Education for Sustainability (SEES) is a new $765 million National Science Foundation (NSF) initiative that intends to integrate NSF's work in climate and energy science and engineering to generate the discoveries and tools needed to "inform societal actions that lead to environmental and economic sustainability" (NSF 2010, 29). The RE-ENERGYSE (Regaining our Energy Science and Engineering Edge) program is a comprehensive $75 million federal education initiative focused on educating for the clean energy sector at universities, community and technical colleges, and K–12 schools (NSF 2010, 25).

The greatest sustainability gains on U.S. campuses to date have occurred in campus operations, particularly in energy conservation and renewable energy, sustainable building design, water conservation, purchasing, transportation, and chemicals and waste management. Driving many of these changes is the exploding number of schools making aggressive carbon-reduction commitments, representing over one-third of the nation's entire student body (ACUPCC 2009).

Considering that there are about 4,200 institutes of higher education in the Unites States, progress in teaching and learning about sustainability is slower. In 2008, at least twelve new graduate-degree programs, twenty undergraduate programs, and twenty-four continuing-education and technical-training programs were launched. At least thirteen sustainability-themed research centers opened in 2008, and plans for thirty-three more were announced, with new centers focused on such topics as socially responsible business, cellulosic ethanol, social entrepreneurship, green materials, and green auto technology. An additional ten sustainability-themed research centers opened in 2007, seven of which focused on the development of renewable energy (AASHE 2008).

During 2007 and 2008, corporations funded new centers at the following universities and colleges in the United States (AASHE 2008):

- BP committed $500 million to the University of California, Berkeley, and its partners; the University of Illinois, Champaign-Urbana; and the Lawrence Berkeley National Laboratory for a joint research program to explore how bioscience can be used to increase energy production and reduce the impact of energy consumption on the environment.
- Rochester Institute of Technology Golisano Institute for Sustainability received a $2 million donation from Xerox Corporation to further the research of new sustainable technologies.
- University of California, Berkeley, College of Chemistry received $2 million from the William and Flora Hewlett Foundation and the Dow Chemical Company Foundation to establish the Dow Chair of Sustainable Chemistry to research chemistry for environmental causes.
- Vale provided a $1.5 million grant to Columbia University to create the Center on Sustainable International Investment, which promotes learning, teaching, policy-oriented research, and practical work within the foreign direct investment (FDI) area, and pays special attention to the sustainable-development dimension of investments.
- Ithaca College received a $500,000 grant from HSBC Bank USA to support sustainability education on campus.
- University of Arkansas Applied Sustainability Center received a $1.5 million donation from Walmart to fund advanced research on greenhouse-gas emissions, agriculture, and environmental education.
- ConocoPhillips donated $1 million to support Duke University's Climate Change Policy Partnership (CCPP), an industry–university collaboration working to develop policies that address global climate change.

This corporate funding seems encouraging, but again it must be considered in the context of the approximately 4,200 institutes of higher education in the United States. Such investments in individual institutions, laudable as they are, do not constitute systemic change. While individual corporations have occasionally taken steps to advance sustainability on individual campuses, businesses have yet to join forces to collectively urge—and assist—higher education as a whole to address the increasing need for a growing workforce by businesses seeking to become more sustainable.

Business programs provide an example. According to a 2007–2008 survey of 113 business schools in the United States by the Aspen Institute Center for Business Education (2008), experimentation with elective courses on sustainability is on the rise. In addition, 30 percent of schools offered a special concentration or major that allowed students in masters of business administration (MBA) programs to focus on social and environmental issues. The percentage of schools surveyed that required students to take a course dedicated to business and society issues had increased dramatically to 63 percent.

Yet the proportion of schools in the United States requiring content in core courses on the ways in which mainstream business can confront social or environmental challenges, which is the key factor in determining how many business students become sustainability literate, remained dismally low. As a partial result, three new schools were founded to offer a more integrated approach to sustainable business education: Presidio World College (San Francisco, founded in 1993), Bainbridge Island Graduate Institute (Washington State, founded in 2002), and Dominican University of California's Green MBA program (San Rafael, California, created in 1999). All offer MBAs in sustainable business, each with unique areas of expertise, but all integrate sustainability into the core business curriculum.

As is the case in many liberal arts schools, students have been the greatest drivers of change in business schools because they understand how the dangerously narrow focus on shareholder value has played havoc with people, the environment—and often with corporate profits. For example, in a recent study of students in twelve international business schools, "half of the students surveyed acknowledge that the priorities communicated during the MBA program may have been a contributing factor in corporate misconduct" (Aspen Institute Business and Society Program 2003, 4).

Next Steps

Certainly business is one of the biggest external influences on higher education. For example, corporate contributions (not including research contracts, which significantly increase this percentage) made up about 15 to 20 percent of all campus donations since the late 1990s (Jaschik 2008). At varying points in history, business leaders have called on higher education to change (with varying degrees of success), most recently to strengthen science, technology, engineering, and math (STEM) education.

Business has a growing community of increasingly visible and influential sustainability proponents, including many members of the Fortune 100. And the leaders of these companies are increasingly realizing that one of their biggest barriers to becoming more sustainable is their own workforce, which is largely illiterate regarding sustainability. It would seem to be relatively easy to engage this group in advancing their own self-interest by joining together to collectively help tip higher education towards sustainability.

Business has yet to be organized to help push or support the sustainability movement in higher education. A promising exception—and possible model—is the new Sustainability Consortium organized by Walmart, Arizona State University, and the University of Arkansas to engage leading academic researchers and companies in working collaboratively to design and develop a sustainable index for consumer products.

One possibility would be to create a "Business Alliance for Sustainability in Higher Education," perhaps modeled on—or even in conjunction with—the Business Roundtable or the Business–Higher Education Forum, both of which are organizations made up of CEOs from prominent U.S. firms. Such a group committed to sustainability could undertake a number of initiatives, such as a focused advertising / public relations campaign that would call for sustainability-literate graduates and highlight model schools, and make an effort to establish what constitutes sustainability literacy in different sectors and fields.

Another possibility might be an initiative to advance a "green hiring pledge" to be signed by CEOs who promise to employ sustainability-literate employees and commit to certain steps to do so. This would complete a triad of sequential, complementary pledges that include the "green graduation pledge" (graduating seniors pledge to take a firm's environmental performance into consideration when accepting a job) and the ACUPCC (presidents who commit to making their college and university campuses become climate neutral).

Regardless of the tactics chosen, business is unlikely to get the labor force it needs until it organizes itself and collectively identifies and activates those leverage points that will help tip the higher education system as a whole towards sustainability.

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See also Corporate Citizenship; Education, Business; Green-Collar Jobs; Energy Efficiency; Energy Industries—Overview of Renewables; Investment, CleanTech; Leadership; Zero Waste

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Energy Efficiency

Energy efficiency consists of technologies that consume less energy and produce less greenhouse gas emissions while performing the same functions as less efficient technologies. Energy efficiency is considered to be the most cost-effective way to mitigate climate change; buildings and transportation are key areas for efficiency improvements. Improving efficiency requires investment by consumers, businesses, and governments.

The importance of energy efficiency is often overlooked. A report by McKinsey & Company (2009, i, iii) predicted that a comprehensive energy-efficiency program in the United States would, by 2020, reduce the country's projected energy consumption by 23 percent, reduce annual greenhouse gas emissions by 997 million metric tons, and save Americans $130 billion per year in energy costs. The study also identified significant barriers to energy efficiency, including the initial investment costs and the fragmentation of savings potential across millions of buildings and "billions of devices" (McKinsey & Company 2009, 10). Worldwide, twenty-first-century energy-efficiency technology has the potential to reduce energy consumption by 18–26 percent and reduce carbon dioxide emissions by 1.8 billion to 2.5 billion metric tons (International Energy Agency 2008b)—without any changes in consumption habits.

Technologies that allow end users to consume less energy while achieving the same results are considered energy efficient. For example, turning down the thermostat, moving closer to work, and using dimmer lightbulbs all conserve energy, but they are not considered to be energy efficient per se. On the other hand, installing better insulation, keeping a vehicle's engine tuned, and using compact fluorescent lighting are energy-efficient measures. Because energy-efficient technologies reduce consumption (and hence, lower energy costs) without decreasing individuals' standards of living or businesses' productivity, they are one of the most attractive ways to address the world's energy deficit.

Partial Solution to Climate Change

Energy use creates more than 66 percent of global greenhouse gas emissions, which in turn affect climate change (World Resources Institute 2005). Energy efficiency is broadly viewed as the most cost-effective way to mitigate climate change because it can yield positive returns on investment in the long term. But energy efficiency alone cannot reduce energy-related greenhouse gas emissions to 50 percent of their current levels—which is the target set by the Intergovernmental Panel on Climate Change and endorsed by world leaders at the 2008 G8 summit in Hokkaido, Japan (Houser 2009, 2). (The Copenhagen Accord of 2009, on the other hand, asks for limiting warming to 2°C but doesn't mention specific targets.) In the carbon abatement plan set forth by the International Energy Agency (2008a), better efficiency of end-use fuel and electricity accounts for about 36 percent of greenhouse gas reductions. ("End-use" refers to the energy content of a fuel at the time it is consumed and doesn't reflect energy losses that occur during processing.) To become an effective strategy for the abatement of greenhouse gas production, energy-efficiency measures must be taken by millions of individuals and businesses.

Current Energy-Efficiency Programs

Energy-efficiency programs exist in industrialized countries around the world, including the United States, the European Union, Japan, Canada, and Australia. These programs have been moderately successful, although there is room for improvement. In the United States, energy conservation programs such as Energy Star have reduced energy consumption per unit of floor space by 11 percent in residences and by 21 percent in commercial buildings (McKinsey & Company 2009, 11). In 2006, the European Commission adopted a plan for reducing energy consumption by 20 percent of projected values by 2020. When the plan's progress was evaluated in 2008, however, it had reduced consumption by only 11 percent (ECDGET 2009, 5). In 2009 the European Commission requested feedback for revising the plan through a survey of businesses, public officials, nongovernmental organizations, and citizens; the majority supported better efficiency education for architects and engineers, greater focus on improving building efficiency, greater up-front funding, and greater cooperation with local public officials (ECDGET 2009, 5).

Better Buildings

Key among efficiency measures should be a plan to increase the energy efficiency of buildings. Buildings consume 40 percent of the world's energy, according to the World Business Council for Sustainable Development (WBCSD 2009b) and are responsible for 33 percent of the world's greenhouse gas emissions (Houser 2009). Yet it is wholly feasible to reduce that energy use by 50 percent by 2050, as the Peterson Institute for International Economics says in a study based on the WBCSD's Energy Efficiency in Buildings project (Houser 2009, 1). The Peterson Institute's study estimates that a worldwide investment of $1 trillion annually is needed to reach this goal, but it predicts that 83 percent of the costs will be recovered over the next twenty years (Houser 2009, 7).

According to the United States Department of Energy (2009), heating accounts for 23 percent of the average building's energy consumption, while cooling requires 16 percent and water heating another 11 percent. Lighting takes up 16 percent of energy costs. Higher-efficiency heating, ventilation, and air-conditioning (HVAC) systems and better insulation are only two important steps toward reducing a building's energy load. Another step—more-efficient lighting—goes beyond better lights. Intelligent controls, which can be easily upgraded as technology progresses, can ensure that buildings operate at the optimal energy level. For example, a system using motion detectors can reduce heating, cooling, or lighting in unoccupied areas. Energy-efficient windows—which allow more light and solar energy to enter and less heat to escape—can reduce lighting and HVAC costs by as much as 50 percent in residential buildings and up to 40 percent in commercial structures. Solar energy can be used to heat water, and geothermal heat pumps can be used to reduce heating and cooling loads. The remainder of building energy usage comes mainly from devices that offer higher energy efficiency. For example, buildings equipped with photovoltaic (solar) cells can be designed to consume "negative" or "zero" energy, meaning the surplus electricity can be sold to the local electrical grid, turning a cost into a revenue generator.

Improved Transportation

Transportation by ground, air, and water is responsible for one-quarter of the world's energy consumption and the same portion of carbon dioxide emissions (International Energy Agency 2008b, 17). Personal vehicles consume 60 percent of the energy used for transportation in the United States (USEIA n.d.), and the use of personal vehicles is expected to grow in developing countries. Thus improving the average fuel efficiency of cars and light trucks is central to increasing the energy efficiency of the transportation sector. Hybrid technology is only one means among many of improving fuel economy: others are direct fuel injection, variable valve timing, integrated starter systems (which shut off the engine while the vehicle is stopped), continuously variable transmissions, turbochargers, and superchargers (USDOE and USEPA 2010b).

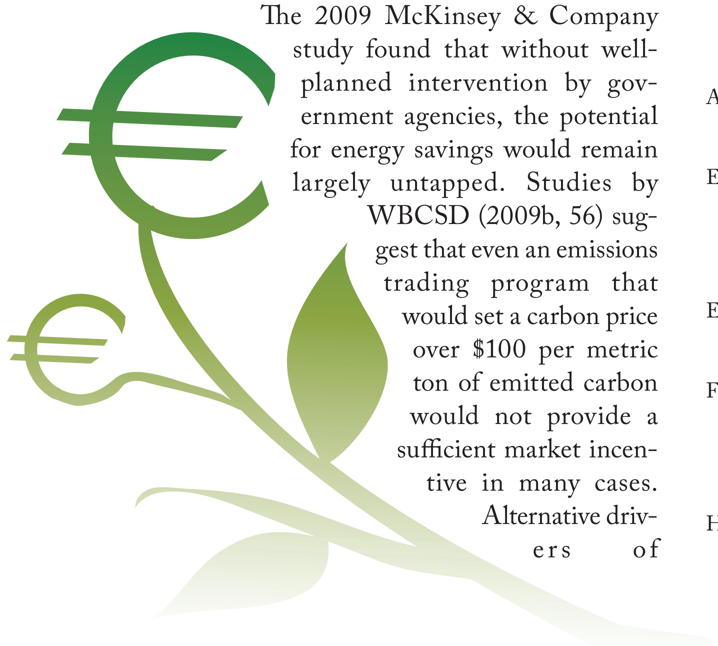
Trains move freight more efficiently than trucks; a study by the Federal Railway Administration (FRA) found that trains were approximately two to five-and-a-half times more efficient per ton of freight than trucks on identical routes (FRA 2009, 8). According to the Air Transport Association of America (ATA 2010), the single greatest increase in the fuel efficiency of air transport for the United States will come from a reform of the nation's outdated air traffic control system and procedures. Other opportunities for improvement include modernizing fleets, planning flight routes for better efficiency, and using winglets to reduce drag (ATA 2010). Abundant opportunities to improve the efficiency of transportation exist, but they require significant investments by consumers, businesses, and government.

Challenges to Improved Energy Efficiency

Even though energy-efficient technology is widely available and offers potential savings in energy costs to consumers, it has not been fully utilized in the majority of homes and businesses. The failure to take advantage of energy-efficient technology is often due to its higher initial cost, relative to less-efficient devices and processes. For example, a 14-watt compact fluorescent lightbulb uses up to 75 percent less electricity than the equivalent 60-watt incandescent bulb and lasts up to ten times as long, which results in a savings of $30 over the lifecycle of the bulb (USDOE and USEPA 2010a). But a compact fluorescent bulb costs more than triple the price of an incandescent bulb; many consumers are either unaware of the potential savings or unwilling to pay the higher up-front cost. Better product labeling and stricter standards are needed if consumers are to buy products that are cheaper over their lifetimes once energy consumption is factored in. Similarly, businesses may not be able to justify the outlay of capital required to invest in energy-efficient measures, especially when the savings are difficult to measure and are spread over several years (McKinsey & Company 2009, 12).

Up-front costs and lack of awareness are not the only barriers to energy efficiency. In many cases, the savings that would be realized by such measures are difficult to predict. Unlike fluorescent bulbs, some energy-saving measures are not widely available, and the actual up-front cost can be difficult to assess. In other cases the savings might not be realized by the party making the investment. For example, the landlord of an apartment building has little incentive to purchase a more-efficient hot water heater when the utility costs are divided among tenants. Even when the monetary cost of energy-saving measures is low, the savings may not be large enough to induce consumers to make a change. Programs that address these barriers could lead to dramatic improvements in energy efficiency.

Overcoming Barriers



The 2009 McKinsey & Company study found that without well-planned intervention by government agencies, the potential for energy savings would remain largely untapped. Studies by WBCSD (2009b, 56) suggest that even an emissions trading program that would set a carbon price over $100 per metric ton of emitted carbon would not provide a sufficient market incentive in many cases. Alternative drivers of change are needed. In the case of buildings, the change could be in the form of national regulations and codes. Such change requires concerted action across local and national governments and would not rely on a global agreement for incentives.

It is important for businesses to have input in the decision-making and policy-making processes for implementing energy-efficiency technologies because they will be the major investors in and owners of them. The financial burden of developing and deploying new and existing technologies may be too great for any one company to bear by itself; businesses and governments will need to work together. Public–private partnerships of an unprecedented scale will be needed for success. The WBCSD study (2009b, 56–62) recommends the wider use of subsidies or tax breaks to implement energy efficiency, promote energy-awareness programs among professionals and citizens, support the research of energy-efficient technologies, and change energy consumption structures. Ultimately, large-scale improvements in energy efficiency are possible, but they will require participation from government, businesses, and individuals.

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See also Airline Industry; Automobile Industry; Building Codes, Green; Consumer Behavior; Energy Industries—Overview of Renewables; Energy Industries (*assorted articles*); Facilities Management; Information and Communication Technologies (ICT); Investment, CleanTech; Municipalities; Property and Construction Industry; Public Transportation; Public–Private Partnerships; Supply Chain Management

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Energy Industries—Overview of Renewables

The term renewable energy *refers to any energy source that is naturally occurring and abundant—for example, solar, wind, hydro, biomass, tidal, and geothermal. Although appealing because many forms of renewable energy are widely available and they do not rely on fossil fuels (and therefore are considered "cleaner"), they are still more expensive for producers and consumers. Putting a price on carbon emissions, however, may level the field between renewables and fossil fuels.*

The case for rapid growth in renewable energy is clear. Catastrophic climate change, as well as many other environmental, economic, and social factors, necessitates a transformation of the $5 trillion per year fossil fuel–based energy sector (Stuebi 2009).

Part of that transformation will involve cleaner ways of using fossil fuels. Another part entails making everything that uses energy more efficient. A third part comes under the broad heading of behavioral change and aims to decrease demand or limit demand increases. Fourth are far-reaching approaches to changing entire systems like transport, the way we commute, and travel. The fifth, and likely most significant, is renewable energy, producing much-needed energy in cleaner ways.

This chapter focuses on the policy question of how to bring about change in the electricity sector. The answer is twofold: price plays one important role, and the other is an approach to regulation that seeks to encourage wholesale change in how electricity is produced, delivered, and used.

Fast Growth

Many renewable energy technologies have been growing at double-digit rates for years and are expected to continue to grow at similar (or even faster) rates well into the future.

Individual chapters in this section describe the development of each renewable sector and its future prospects. Figure 1 on page 146 summarizes growth trends for wind, solar, and biomass through 2020, all of which are projected to continue to grow rapidly at least through then.

Rapidly Declining Costs

An important element in the growth of renewable energy technologies is their cost relative to traditional fuels. It is often more expensive to install wind, solar, biomass, or hydro plants than a coal or gas plant producing the same amount of electricity. Once installed, however, renewable plants provide virtually free power, but average electricity prices from coal are still cheaper than most of the cleaner alternatives. Nonetheless, costs for the latter have been coming down quickly.

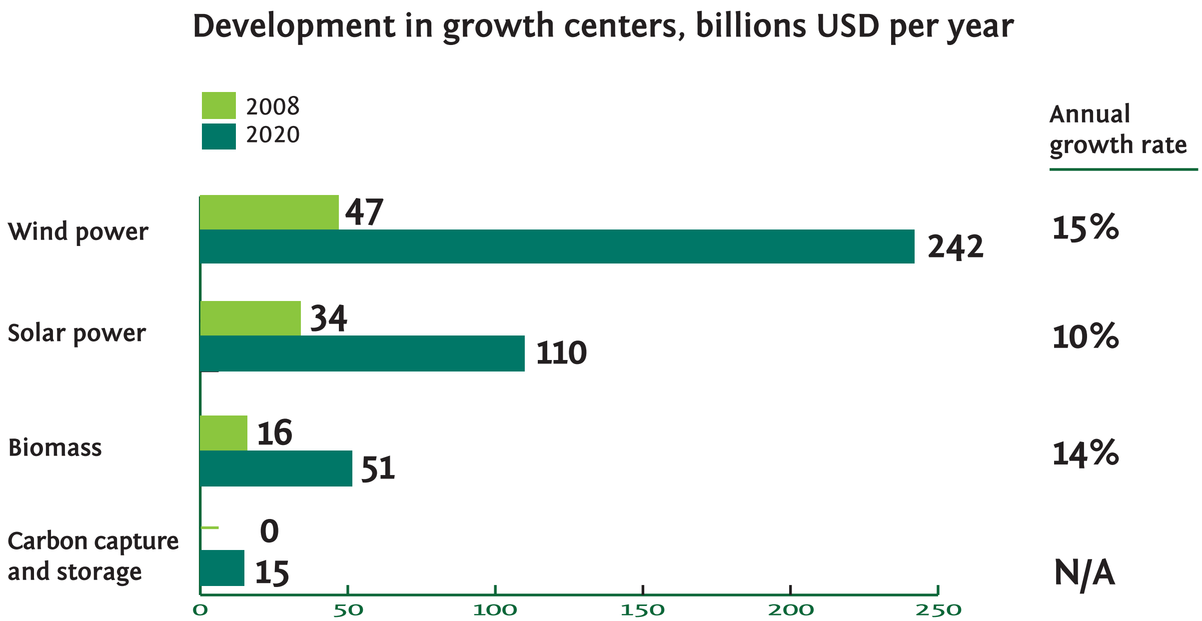
The holy grail is "grid parity"—the point at which renewables find themselves on equal footing with coal and gas. Some forms of onshore wind power have achieved this already. Others are fast approaching this point.

Shape of Things to Come

History demonstrates that the introduction of new technologies is often explosive rather than linear. Growth in technologies usually follows an S-shaped curve: slow start, rapid acceleration, and then tailing off at the end as the former innovations become ubiquitous. When successful, the market usually spreads these new technologies more widely and cheaply than had been predicted.

Renewable energy in general will clearly follow this pattern. One sign is the increase of patents for clean technology in Europe at a rate of roughly 10 percent annually between 1997 and 2007. The United States and Australia,

Figure 1. Growth Potential of Renewable Energy Technologies



Source: McKinsey & Company (2009a, 41).

Note: Numbers represent billions per year in C (€).

The market for low emission energy technologies is expected to grow by 13 percent per year through 2020; wind power expenditures are expected to see the greatest increase, growing to €165 billion (approximately US$225 million) by 2020.

which have not implemented strong climate policies as of early 2010, have experienced no such increase. To be sure, low-carbon innovations have begun in the United States, spurred by some state-level emission caps and the prospect of national-level controls. But only when the long-term economic signals are in place and innovation clearly pays will entrepreneurs and investors move into high gear.

Regulating Change

A key aspect of bringing about change in the power sector is by ensuring that the price of electricity includes the social costs of carbon pollution. Without proper regulation, emitting global-warming pollution is free—or even supported through fossil fuel subsidies. Putting a price on carbon would make renewable technologies more attractive vis-à-vis traditional fuels and hasten the transition to a low-carbon economy.

A market for carbon is the obvious way to bring this about, but creating one requires a limit on carbon emissions—a cap. And while it would be prohibitively complex and expensive to impose individual carbon limits for every business, it is relatively simple and cheap to turn the obligation to reduce carbon emissions into an opportunity. The fundamental task is to reward emissions reductions in the most flexible way.

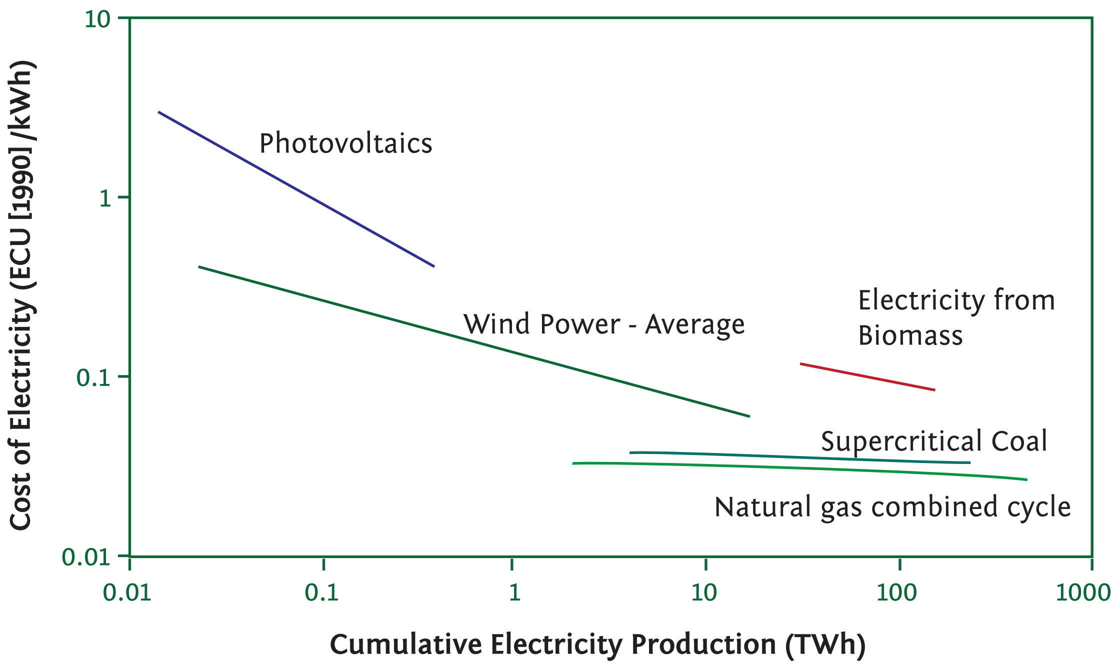
The method for doing this is called, somewhat prosaically, "cap-and-trade." It should really be called "rewards for innovation." Cap-and-trade is an enormous, publicly structured Robin Hood program to take money from the inefficient and unimaginative and pay the efficient and innovative, without deciding beforehand who is in which group. It is the definition of "doing good by doing well" and will be a fundamental driver of change in the energy sector.

Rate Decoupling and Full Unbundling

Another important regulatory mechanism is the decoupling of electricity sales from a utility's profits. Traditional utilities, like all other industries, benefit when they sell more product. Their product is electricity. Hence they have little economic incentive to distribute it more efficiently or to motivate customers to conserve.

One way to cause utilities to change is to set renewable electricity standards or energy efficiency mandates. Sometimes these measures are justified, but as with any economic standard, this is an inefficient way to go about doing business. Utilities will act to meet the regulation but no more. Standards cap innovation and adaptation. They do not cap carbon emissions or any other form of pollution.

Figure 2. Electricity Generation Technology Learning Curves for the European Union, 1980–1995



Source: Tam & Gielen (2007, 6).

From 1980 to 1995 the cost of generating electricity from renewable sources fell, while production from these sources increased. By 1995 the cost of wind power was less than 0.1 ECU (European Currency Unit) per kWh, and the European Union had produced more than 10 terawatt-hours of wind power (the ECU was replaced by the euro in 1999, at a value of 1 to 1).

Instead, utility profits ought to be decoupled from their sales. Breaking the profit-revenue link ensures that it is in the interest of the utility to motivate customers to use less of its product. As California showed when it adopted decoupling in the 1980s, breaking this link also enables another kind of decoupling that is ultimately most important—that between economic growth and emissions (Sudarshan and Sweeney 2008).

Decoupling is often only an intermediary step to an even better outcome: fully unbundled rates. Everyone gets paid for the exact services they are providing, and all services are clearly listed on the bill. Transmission is no longer part of the usage charge but is listed separately, and additional services and maintenance are assessed when needed instead of being lumped into the electricity rate.

That changes the equation for grid parity quite significantly. Individual solar panels suddenly become much more cost-effective, as they avoid the costs of using transmission through the grid. Full unbundling puts the costs of traditional energy in plain sight and makes distributed generation all the more attractive.

Distributed generation makes households not only consumers but also suppliers of energy—selling electricity back to the grid if they produce more than they use. Decoupling and full unbundling will help facilitate the large-scale deployment of renewable energy technologies like solar panels on rooftops or small geothermal facilities. Power in this kind of distributed system will frequently be used close to where it is produced. This will save much of the 10 percent of electricity that is currently lost during transmission, often across hundreds of miles of high-voltage cables, from plant to end user (USDOE 2009).

Smart Grids

A price on carbon, even with rate decoupling or full unbundling, is not enough to cause sustainable, systemic change in how power is produced. The complexities in the way we produce, distribute, store, and deliver energy demand a more holistic approach.

In many ways, the most exciting changes in the power sector will not come from technological breakthroughs in solar, wind, biomass, hydro, and others—as important as they may be—but through transformation of the entire system. The grid itself, the so-called smart grid of the near

What's the Difference Between a Gigawatt and a Gigawatt-Hour?

These terms often appear together, and they may seem similar. But understanding the distinction can help illuminate discussions about generation and consumption of electricity. Hearing that a new nuclear power plant has a 4 gigawatt capacity, for instance, is meaningless without something to compare the figure to.

The first thing to know is that *energy* is defined as the ability to do work, while *power* is energy consumed per unit of time. No matter if you drive a gas guzzler or a moped, the gasoline used has the same energy per liter or gallon of gasoline. A sports car, however, uses much more power than a more efficient vehicle, which allows it to go from point A to point B at a much faster rate.

What is a gigawatt?

A watt is a measure of power, the rate at which energy is converted to electricity. A 100 watt incandescent lightbulb uses 100 watts to light a room, while a compact fluorescent light or lamp (CFL) uses only 25 watts to provide a similar amount of light. One billion watts equals 1 gigawatt (GW); in 2006 this was enough to power 780,000 average U.S. homes at average power in a given instant. (This calculation is based on data reported by the United States Energy Information Administration [EIA].)

How much power does it represent?

A gigawatt is enough to power in a given instant:

- 10 million 100-watt lightbulbs
- 561,000 average households in the relatively warm state of Tennessee
- 1,257,000 average Vermont households (mostly due to the relative lack of air conditioning used in the cold northeastern state)
- 1,967,000 average households in the United Kingdom
- 3,290,000 average Beijing households (or 7.2 million average low-income homes in Beijing)
- over 50,000,000 homes in areas of rural western China

Why the variation?

The local climate, the physical size of a household, the appliances (number, type, and efficiency), and the extent to which electricity is used for heating, cooling, heating water, and cooking (i.e., consumer behavior) can all influence the demand of a household. Estimates are calculated from average monthly or annual electricity consumption for each household type. Power consumption in a three-bedroom U.S. household might vary from 0.5 kilowatts (at night) to 4 kilowatts or more (during peak hours); taken in aggregate, this can lead to large fluctuations in demand. In the province of Ontario, Canada, for example, demand on 4 March 2010 varied from about 1.4 GW at 3 a.m. to over 1.9 GW at 8 p.m. The province's record peak of 27 GW occurred during the summer of 2006—approximately fifteen times the average of the aforementioned day in March 2010 (IESO 2010).

Because power companies need to build enough capacity to cover peak demand (capacity that goes unused a majority of the time) or purchase power at a premium from other companies, these fluctuations mean greater cost to the consumer. Smart meters (meters that track consumption over time) allow producers to charge higher prices for peak consumption, as well as allowing consumers to keep track of how much energy they're using. Conventional meters—which are still widely used—only track total consumption, which means that producers must average peak power costs into the base price and consumers have no idea how much energy they're consuming at any given time. By reducing electricity usage during peak hours (for instance by doing laundry at night), consumers can help lower the costs of generating power.

What is a gigawatt-hour?

A gigawatt-hour (GWh), meanwhile, is a measure of *energy* equal to one gigawatt generated for one hour. Gigawatt-hours (as well as megawatt-hours and kilowatt-hours) are used because, generally speaking, it is not practical to measure how much

(Continued)

energy is used in a given second. As stated above, a gigawatt-hour is enough to power 561,000 Tennessee households for one hour.

The following are equivalent to 1 GWh; in the case of fuels (such as gasoline and liquid propane in the list below), 100 percent conversion to energy is assumed. (When a fuel is burned, the heat energy produced by combustion must be converted into electricity using a turbine, steam, or other means. Heat transfer and friction make perfect conversion impossible; a conversion rate of 38 percent of available heat energy to electricity is typical of modern fuel-powered generation systems [USEIA 2010a, 54].)

One gigawatt-hour is equivalent to:

- 1,000 megawatt-hours (MWh)
- 1 million kilowatt-hours (kWh)
- 3.41 billion British thermal units (Btu)
- 3.6 trillion joules (J)
- 860.4 billion calories (Cal)
- 86 tonnes of oil equivalent (toe)
- 123 tonnes of coal equivalent (tce)
- 141 cubic meters of liquid propane
- 97,124 cubic meters natural gas
- 103,866 liters gasoline
- 30,000 cubic meters hydrogen

Therefore if you consume an extraordinarily large hamburger (with condiments) containing 860 billion calories (about 1.5 billion times the size of a typical hamburger), you would then need to burn off a gigawatt-hour's worth of energy—a lot of time at the gym. Assuming you could jump rope at seventy or so skips per minute, this would take approximately 170,000 years.

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future, will become an engine for innovation and ingenuity in the entire electricity sector.

The term *smart grid* subsumes many different aspects of electricity distribution and consumption. It can range from the mundane—like real-time electricity meters—to the truly revolutionary—like remote controls of air conditioners and other appliances that could allow utilities to steer customer demand via the grid.

Electricity use is not even throughout the year. Depending on climate, electricity use either peaks during the summer because of air conditioning or the winter because of heating, or both. Daily usage also varies. In homes, it generally peaks in the morning and evening, then declines at night. Utilities, however, must install enough capacity to meet peak demand, and much of that capacity goes unused most the time. (See the sidebar "What's the difference between a gigawatt and a gigawatt-hour?" on pages 148–149 for a further explanation of this often misunderstood topic.) Smart grid technology and a comprehensive view of the entire energy system can ensure that customers use electricity efficiently and that utilities need not overbuild to meet peak demand. The key is to keep the system as flexible and open as possible, while maintaining crucial oversight and central, long-term planning functions.

Regulators will need to help plan, fund, and even build smart grids. In the end, the regulatory task here is similar to that of pricing. Policy makers, rather than attempting to design the new grids and pick the winning technologies, should create a set of conditions and incentives that will motivate businesses and entrepreneurs to find innovative solutions to problems previously deemed intractable.

The Future

Renewable power is the energy of the future. It will move us from the high-carbon, low-efficiency world of today to a new world of low-carbon, high-efficiency economic development. Smart regulation can hasten this transition by capping global-warming pollution and creating a carbon market that provides incentives to build a new power system. The key to realizing this vision is for regulators to leave it to the market to pick and choose winning technologies and to maintain flexibility. The subsequent entries in this section provide a menu of possible options.

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See also Cap-and-Trade Legislation; Energy Efficiency; Energy Industries (*assorted articles*); Investment, CleanTech; Sustainable Value Creation; True Cost Economics

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Energy Industries—Bioenergy

Derived from natural resources, bioenergy is a prominent renewable energy source throughout the world. Most simplistically, it is wood used for cooking and heating; more complex examples include thermochemical conversions that produce biofuels. Although relevant technologies exist (and continue to be developed), many are not yet cost-effective, and questions remain about the industry's long-term environmental impact.

Bioenergy is any energy, or fuel used to produce energy, that is derived from either biomass or plant matter. According to the U.S. Energy Information Administration (2009), the United States consumed more bioenergy in 2008 than wind, solar, and geothermal energies combined. Despite its widespread use around the world, the term is often mistakenly equated with liquid biofuels such as ethanol and biodiesel. Biofuels—solid, liquid, or gaseous—are virtually the only liquid fuel alternative to oil for transportation purposes; they can be used not only for fueling vehicles but also for heating, cooling, and electrical power generation.

In many parts of the world, bioenergy remains the dominant energy source for heating and cooking, but bioenergy is much more than wood used in the home or liquid biofuels like ethanol. Bioenergy production includes biogas and electricity generation from such sources as food-processing wastes and the anaerobic digestion of cow manure. (Anaerobic bacteria digest matter in the absence of oxygen, yielding a biogas rich in methane and carbon dioxide.) Bioenergy is being used in district heating systems; for example in St. Paul, Minnesota, water heated from waste wood heats the central business district of the city.

Interest in bioenergy is growing for several reasons. Economic developers and rural communities see it as a growth industry that can create jobs and revive local economies. Proponents of agriculture and forestry see it as a tool to protect productive working landscapes and provide new markets for these volatile industries. Environmentalists see bioenergy as a means to reduce greenhouse gas emissions associated with fossil fuel use. Against this backdrop, policy makers are looking for ways to guarantee that rural communities capture the full benefits of sustainable bioenergy production (Radloff and Turnquist 2009).

Bioenergy as a Renewable Resource

Energy derived from biomass is considered renewable because bioenergy is simply stored solar energy from the sun. It can be produced from a wide range of biomass types including plants, animals, and animal wastes. Biomass includes conventional crops such as corn and soybeans, vegetable oils, agricultural residues like corn stover and rice straw, wood and forest residues, and mill residues. Other types of biomass, also referred to as feedstock, include construction waste, perennial grasses like switch grass, and short rotation woody crops (including willow and hybrid poplar). Animal renderings and animal manures are additional examples of biomass (Biomass Research and Development Board 2008).

Because bioenergy is not classified in a consistent manner, this article identifies three broad "types" of bioenergy based on *how* the energy derived from biomass is used: bioheating/biocooling, biopower, and biofuels.

Bioheating/Biocooling

Bioheating/biocooling is the most prevalent use of biomass worldwide, especially in parts of the developing world where it is the primary energy source for cooking. In countries like Nepal, Sudan, and Tanzania, about 80–90 percent of all energy comes from biomass (Rosillo-Calle et al. 2007). In the United States, the residential home heating market is the largest user of wood fuel. Other bioheating/biocooling examples include schools and commercial buildings that heat and cool with wood, as well as district heating systems that provide heating and cooling to multiple buildings through a system of connected pipes carrying hot water or steam.

Biopower

Biopower is electricity produced from biomass, and it is often generated through cofiring of biomass with coal. Heat from the combustion process drives a steam turbine that generates power. Alternative methods of generating biopower include gasification, a technology that converts biomass under high temperatures into a gas called "syngas." The syngas can then be converted to electricity using a more efficient technology than a conventional steam turbine. Several additional biopower technologies exist. Combined heat and power (CHP) technology increases energy efficiency by generating electricity and capturing and using any excess heat produced in the process.

Biofuels

The third category of bioenergy is biofuels, which include liquids as well as solid. Conventional liquid biofuels (like ethanol) come from existing food crops. More advanced liquid biofuels may come from cellulosic sources such as wood and perennial grasses. Solid biofuels (including wood pellets) are currently derived from wood waste and mill residues. As the demand for bioenergy grows, more solid biofuels may be manufactured from additional sources including perennial grasses, construction waste, and other waste streams.

Bioenergy is unlike other renewable energy resources in two key aspects. First, bioenergy is not an intermittent source of energy. Unlike wind and solar, which depend on windy and sunny days respectively to generate power, bioenergy is an on-demand source of renewable energy that can be dispatched where needed. As long as the feedstock supply is adequate, bioenergy represents a dependable, constant source of energy that can be generated at any time of the day as needed—independent of daily weather patterns.

Second, biomass as an energy source is a complex system of interdependent components. According to the U.S. Environmental Protection Agency (US EPA 2007), economically and technically feasible bioenergy projects require an adequate feedstock supply, effective conversion technologies, dependable markets, and viable distribution systems. The challenge of ensuring an adequate feedstock supply is particularly challenging.

Converting biomass into energy may be a complex process, but it can be broken down into three major phases: growing and transporting feedstocks, converting feedstocks into bioenergy, and marketing bioenergy.

The Biomass Supply Chain

Growing and transporting feedstocks is known as the biomass supply chain. The first step in the process is the growing and/or harvesting of available biomass and nonagricultural waste. Biomass feedstocks can be lumped into three general categories: conventional feedstocks, dedicated feedstocks, and waste or underutilized feedstocks.

Conventional feedstocks include wood waste, grains, and other common forms of biomass. These types are easy to convert to bioenergy because systems are in place to grow them, harvest them, and process them using existing technologies. Examples include corn grain (for ethanol) and trees (for making pellets or for combusting directly).

Dedicated feedstocks are crops grown specifically for bioenergy production, including short-rotation woody trees (such as hybrid poplar), several types of perennial grasses (including miscanthus and switch grass), and algae and jatropha. Dedicated feedstocks are capable of producing large volumes of biomass per acre.

Waste or underutilized feedstocks refers to those types of biomass commonly thought of as waste products like food-processing waste, brush, tree tops and trimmings, construction and demolition debris, leaves and yard waste, animal renderings, and manure. As some of these feedstocks become increasingly valuable, it's clear they are not really "wastes" at all; rather they are historically underutilized waste products that in many cases make good bioenergy feedstocks. The second step in the biomass supply chain is to process the available biomass into a feedstock. For example, slash from a recent timber harvest may need to be bundled prior to transport. The feedstock is then aggregated and delivered to some type of biorefinery for processing.

Converting Biomass Feedstocks into Energy

The next step in the process of bioenergy production is the conversion of the feedstock into intermediate products such as combustible gases, carbon dioxide, oils, tars, and liquids. These intermediate products are then converted into final, usable energy products such as electricity, heat, and solid and liquid fuels using one of five basic conversion technologies, ranging from simple to more complex.

1. **Physical conversion.** This is the simplest way to convert biomass into a usable energy form. Making wood pellets is one example, and straight vegetable oil (SVO) production is another. With SVO production, oil is simply extracted through a seed-pressing process. Pressed vegetable oil can be used as a transportation fuel in tractors and in diesel engines. In both the wood pellet and vegetable oil examples, the biomass feedstock is physically altered through force, producing a fuel that can be used for transportation or converted into another energy product through one of the other conversion technologies discussed below.
2. **Combustion.** Combustion technologies convert biomass into hot air, hot water, and steam. They range from smaller household technologies like wood stoves to large commercial and industrial technologies including fixed bed combustion and fluidized bed combustion systems. Larger commercial and industrial combustion systems rely on wood chips, corn stover, bark, and other less processed feedstock, while smaller household-size technologies require higher quality fuels.
3. **Chemical conversion.** Through chemical conversion, feedstocks are decomposed into liquid biofuels (US EPA 2007). An example of chemical conversion is transesterification, the process used to make biodiesel in which oils, fats, used cooking greases, and other fatty wastes are combined with a catalyst such as methanol. The final products are biodiesel and glycerin, which is often used in soaps.
4. **Biochemical conversion.** Through biochemical conversion, enzymes and bacteria break down feedstocks like cow manure and perennial grasses into intermediate products such as biogas. Biogas is similar to natural gas and contains impurities including sulfur, carbon dioxide, nitrogen, and hydrogen, but biogas can be cleaned up and used in a similar fashion as natural gas. It can be combusted to generate electricity or compressed for other uses, including transportation. Examples of biochemical conversion technologies include simple composting, bioreactors at landfills, and anaerobic digesters on farms and at wastewater treatment facilities.
5. **Thermochemical conversion.** The thermochemical conversion method is similar to the biochemical conversion method in that it produces intermediate products that are then further refined into useful end products. With thermochemical conversion, however, the biomass feedstock is decomposed through the use of heat instead of with enzymes and bacteria. Intermediate products resulting from thermochemical conversion of biomass include combustible gases, liquids, tars, and charcoal. These products can be further refined into many different final products: ethanol, diesel, gasoline, hydrogen, and bio-oil. Examples of thermochemical technologies include gasification and pyrolysis (the chemical decomposition of organic matter using heat).

Bioenergy Opportunities

Making bioenergy is relatively easy; making a profitable business out of bioenergy production is not. In order for the bioenergy industry to thrive, it needs a reliable market. Bioenergy can either be used on-site, in the local community, or exported to another region. Using bioenergy on-site is an attractive option for many energy producers, because on-site use can directly substitute for off-site energy purchased at retail prices. Selling bioenergy locally is another attractive option because it cuts down on transportation costs.

There are several social, economic, environmental, and technical opportunities associated with greater bioenergy use. In rural communities, increased use of bioenergy may stimulate the economy and create cooperative and local ownership opportunities related to the growing, transporting, refining, and marketing of biomass. Enhanced bioenergy use could also make biomass-rich communities more energy independent and less susceptible to fluctuating energy prices. While expanding social and economic opportunities, bioenergy could also help the environment. Bioenergy can be produced from feedstocks such as perennial grasses, which sequester carbon underground through their vast root networks. It can also be produced using animal manures that otherwise have the potential to negatively impact water resources. In order to maximize the benefits of increased bioenergy use, there are several technical opportunities which must be taken advantage of as well.

Cellulosic Ethanol

Substantially increasing liquid biofuel production to meet transportation needs will require technical advancements in cellulosic ethanol, which is produced from nonedible plant parts such as leaves and stalks. Cellulosic ethanol currently requires too much heat, enzymes, and bacteria to be cost-effective. In the meantime, if conventional ethanol is to expand, new technologies or combinations of technologies will need to be put in place to make the process more efficient. Besides ethanol, there are significant opportunities to expand liquid biofuel production with advances in technologies like pyrolysis, direct catalytic conversion, and advanced gasification. Besides improving conversion technologies, advances must also occur in the area of feedstock development.

Algae

Algae are often touted as a potential feedstock for biodiesel production. As with cellulosic ethanol, it is possible to generate biofuels in this manner, but it is not yet cost-effective. In order to successfully develop algae as a biofuel feedstock, research and development need to occur. There are thousands of types of algae, for example, and some of them are better suited for biofuel production than others.

Bioenergy Challenges and the Future

The potential advantages of increased bioenergy use are numerous, but there are several hurdles to expanding bioenergy production and consumption as well. The biggest challenge facing expanded use of bioenergy is the question of sustainability. Despite being one of the largest renewable energy resources in the world, there is little good data on supply and demand of biomass in many countries. This lack of good baseline data makes it very difficult to derive sustainable bioenergy policies to guide the industry (Rosillo-Calle et al. 2007). Effective policies will need to be crafted at many levels in order to ensure the sustainability of biomass resources over the long haul. These policies will need to address soil and water health, air emissions, and the sustainability of the biomass sources themselves. Concerns about the net energy balance and greenhouse gas emissions of various types of bioenergy, especially liquid biofuels, will also need to be addressed.

Transporting and storing biomass is another very significant challenge facing the industry. Biomass has a relatively low energy density and often a high moisture content. These characteristics make moving and storing biomass a challenge—both from a technical and economical standpoint. Because of this, many observers believe that bioenergy production will happen on a distributed basis, with many small biorefineries generating energy and other bio-products across the rural landscape. This scenario presents the land use challenge of siting multiple facilities across rural communities.

Finally, bioenergy must be able to compete economically with fossil fuels and with other forms of renewable energy. If, as was the case in 2009, conventional energy prices drop, the bioenergy industry stagnates or goes into decline. Making bioenergy competitive with fossil fuels will likely require price supports, such as the monetized value of carbon reductions, in addition to higher-priced fossil fuels.

As recent volatility in ethanol prices and debates over the environmental sustainability of corn-derived ethanol have demonstrated, bioenergy is not without its challenges. Biomass is plant matter grown on a variety of soils; if biomass is not sustainably grown and harvested, the soil resources will be depleted over time. Sustainability concerns have also arisen as biomass is diverted from the food chain into the energy chain. Critics claim that this diversion contributes to increasing food prices, which negatively impacts the world's poor. These same voices contend that bioenergy development puts indirect pressure on developing countries to clear more native forests and grasslands to grow food crops, thereby accelerating deforestation and negatively impacting the environment.

Other challenges facing the bioenergy industry include the development of successful, local biomass supply chains. Developing a bioenergy industry is dependent upon the development of a biomass supply chain that can effectively and efficiently deliver an adequate supply of biomass at a reasonable price to the biorefinery. This process will require the formation of new business models and arrangements among those that grow, harvest, store, deliver, refine, and market biomass into bioenergy.

Despite the considerable challenges facing the bioenergy industry, there are a number of significant opportunities as well. New dedicated crops like miscanthus and switch grass, and short rotation woody crops like poplar and willow promise to provide environmental benefits such as carbon sequestration in addition to being excellent feedstocks. Emerging technologies like cellulosic ethanol promise to radically increase the efficiency of converting biomass to ethanol and to expand the range of potential feedstocks for bioenergy production. If these types of opportunities can be harnessed, bioenergy will continue to make a significant contribution to the expansion of renewable energy worldwide.

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See also Agriculture; Automobile Industry; Biotechnology Industry; Development, Rural—Developed World; Development, Rural—Developing World; Energy Efficiency; Energy Industries—Overview of Renewables; Facilities Management; Investment, CleanTech; Supply Chain Management

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Energy Industries—Coal

Coal continues to be an important energy and industrial resource. To make the coal industry sustainable, new technologies must address the emissions and poor coal utilization that occur during mining, transport, and conversion into power and chemicals. Potential sustainable technologies should improve coal conversion; reuse by-products and waste; develop efficient combustion, power generation, and gasification technologies; and implement carbon capture, storage, and utilization strategies.

Coal is widely used in the power, iron and steel, chemical, and construction materials industries, and in human daily life. But the coal industry consumes resources and affects the environment in numerous negative ways. Coal's use leads to higher emissions of acidic rain gases, heavy metals, particulates, and carbon dioxide. Historically, however, its use has prevented forests from being cut down for firewood and charcoal when one technology replaced the other. Even though the use of coal is widespread, it is often virtually invisible to the average consumer because it is mostly burned in large power plants (although its use for cooking and heating is common in China).

Continuous economic development requires a reliable and safe energy support. Coal, accounting for about 30 percent of the world's total primary commercial energy supply, is likely to remain a key energy resource into the mid-twenty-first century. The main challenges to the coal industry pertain to utilization efficiency and the emissions of various pollutants during mining, transportation, and coal conversion. Although many advanced technologies have been developed and deployed to address these problems, coal utilization industries still suffer from low efficiency and high pollution.

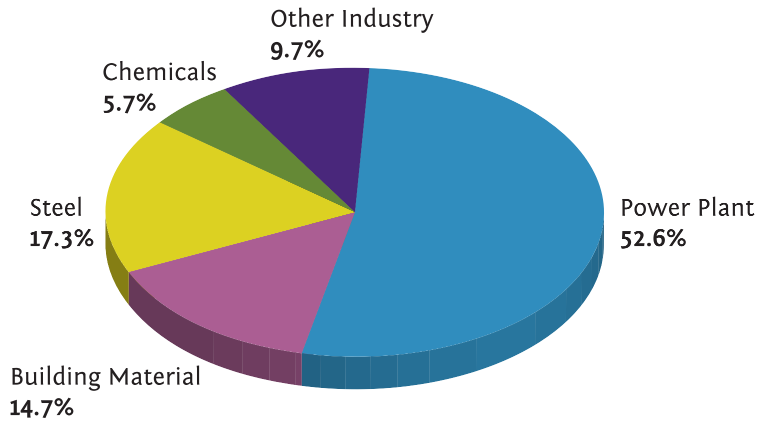
Coal Use and Processing

Coal is a "dirty" solid energy and carbon resource and is more difficult to use than natural gas and petroleum oil. It contains ash and many pollutant elements such as sulfur, nitrogen, halogen, and heavy metals (e.g., mercury, arsenic, and chromium). Compared with biomass fuels made from plants, coal is not renewable and is not carbon neutral because nothing offsets the carbon it releases when combusted. Nonetheless, coal takes the second highest share in the world's energy consumption, after oil (BP 2009, 5, 42).

Coal is primarily used as an energy resource to produce heat and electricity through combustion. In China more than 50 percent of the coal consumed annually is combusted to generate power (Market Avenue 2008). Coal generally is pulverized and then combusted in a furnace with a boiler. The furnace heat converts the boiler water to steam, which is then used to spin steam turbines that turn generators to produce electricity. Although the thermodynamic efficiency of this process has improved, conventional steam turbines with the most advanced technology have topped out at 37–38 percent efficiency for the entire process (combustion plus power generation). A supercritical turbine, which runs a boiler at an extremely high temperature and pressure—so high that the water in the boiler remains in liquid state—can realize a heat efficiency of 42 percent, while an ultrasupercritical turbine (with an even higher temperature and pressure) can achieve a heat efficiency of 45 percent or greater (World Coal Institute 2009).

Coal can be used as a raw material to produce coke, a solid, carbon-rich residue left after the volatile components (those that burn or evaporate at low temperatures) are removed from bituminous coal. Coke has many industrial uses; for example, in metallurgical processes, coke is used

Figure 1. Major Industries and the Shares of Utilized Coal in China, 2007



Source: Market Avenue (2008).

Over half of the coal consumed in China (the world's largest consumer of coal) goes to power plants.

as either a fuel or a reducing agent to provide heat and to smelt iron ore in a blast furnace.

Coal can also be used as a feedstock, or a carbon resource, in chemical production. Coal gasification converts coal to gaseous products composed of hydrogen, carbon dioxide, carbon monoxide, methane, and other hydrocarbons. Coal can be gasified to produce syngas, a mixture of carbon monoxide and hydrogen. Syngas can be converted synthetically to chemicals such as methanol, dimethyl ether (DME), or ammonia, or to transportation fuels such as gasoline or diesel. Alternatively the hydrogen obtained from gasification can be used for various purposes such as operating combined cycle power-generating plants, driving fuel cells, and upgrading fossil fuels.

There are three main gasification technologies: moving-bed gasification, fluidized-bed gasification, and entrained-flow gasification. These technologies, however, barely treat low-grade coals. Therefore further development of gasification technologies is in high demand. New technologies for gas cleaning, carbon dioxide capture, sulfur recovery, particulate removal, process intensification, and energy savings are also important for the clean development of coal gasification technologies (Chang 2005).

Coal is mainly used in two areas in the building material industry. First, pulverized coal is mixed with cement materials to provide the heat required by kilns to produce cement. Second, industrial ovens produce industrial fuel gas from coal via low-cost coal gasification. In China, fuel gas production is a big industry: more than 40 million metric tons of coal are consumed per year (Wang and Guo 2008, 7). All these coal utilization processes have the disadvantages of high cost, low efficiency, and severe pollution. Because coal will continue to be an important resource, clean coal technologies are required to ensure energy security and increase the coal industry's sustainability. Advanced coal utilization technologies are required as well for meeting the rapidly increasing energy demand and for cost-effectively reducing greenhouse gas emissions (primarily carbon dioxide). Technological opportunities for supporting the industry's sustainable development occur in coal mining, transportation, conversion of coal to power or chemicals, and in iron, steel, and construction materials production.

Mining

Coal mining is dirty and dangerous. It disturbs the land's surface and the underground water, which damages or adversely affects a region's commerce and public life. The Coal Mining Task Force of the Asia-Pacific Partnership on Clean Development and Climate (2006, 54) estimates that about 40,000 new hectares are disturbed by coal mining activities each year in China alone. Although regulations for land reclamation exist in most mining countries, they are often "piecemeal and less efficient" in developing countries (Xia 2006). Even in developed countries, the reclamation process—especially the removal of contaminants from the soil—is long and costly with the current technology; the United Nations Environment Programme estimates that between $10 billion and $22 billion are spent on land rehabilitation measures each year (Xia and Shu 2003).

In response to the deaths of thousands of miners per year in coal mining accidents, China's National Development and Reform Commission issued a five-year plan for the country's coal industry, starting in 2006, that placed stricter requirements on the security, efficiency, cleanliness, and environmental impact of coal exploration, mining, and delivery operations (Blueprint for coal sector 2007). The number of coal-worker deaths in China fell from 5,986 in 2005 to 2,631 in 2009; for comparison, only 34 mining deaths were reported in the United States in 2009 (Associated Free Press 2010; Alford 2010).

In addition to safety issues, the coal mining industry could also address sustainability and resource utilization. For example, it could develop technologies that use gangue (a commercially worthless rock found with coal and minerals) in building and road construction materials. Extracting coal-bed methane before the start of mining would reduce greenhouse gas emissions from this methane. Further progress in extracting and using coal-bed methane is needed to capture the energy in the associated ventilated air methane, a mixture of air and methane with concentrations too low for conventional uses of natural gas (Luo and Dai 2009). Another significant problem that receives little attention is the transport of coal from mining sites to power plants. Efforts are under way to make this transport more sustainable, for example, by locating processing facilities closer to mining sites.

Converting Coal to Power

Since 2007 the total amount of coal consumed in China to generate coal-fired power has reached as much as 70 percent, about twice the world average (Huang 2007). The amount of pollutant emissions from burning coal is much higher than from combusting oil and natural gas (USEIA 1999, 58). Thus the major pollutants and carbon dioxide emissions are mainly from coal combustion. (See table 1.) Potential clean coal-power-generation technologies include ultrasupercritical power generation, integrated gasification combined cycle (IGCC) systems, and polygeneration systems based on IGCC.

Table 1. **Pollutant Emissions from Burning Coal, Oil, and Natural Gas (in kilograms per billion kilojoules)**

Pollutant	Coal	Oil	Natural Gas
Carbon dioxide (CO_2)	99,500	78,500	56,000
Carbon monoxide (CO)	99.5	15.8	19.1
Nitrogen oxide (NO)	218.7	214.4	44
Sulfur dioxide (SO_2)	1,240	537	0.48
Mercury (Hg)	0.01	0.0035	0

Source: United States Energy Information Administration (1999).

Coal combustion produces significantly more pollutant emissions than either oil or natural gas.

Ultrasupercritical Power Generation

As mentioned earlier, traditional subcritical power plants are 37–38 percent efficient. Ultrasupercritical (USC) power plants can reach 44–45 percent efficiency. Because of the higher efficiency, carbon dioxide emissions per unit of electricity at USC power plants are about one-fifth that of traditional power plants. USC power plants have a high reliability, similar to those of supercritical and subcritical power plants (Cao et al. 2007). Many USC demonstration plants are operating around the world, and all have desulfurization, denitrification, and dust-removal sections that can lower emissions to meet stringent environmental regulation standards. USC power plants showed the improved thermal efficiency. Control of the reheater outlet temperature without spray water injection in normal operation also decreases the corresponding water consumption.

A key direction for coal-fired thermal power plants in the early twenty-first century is further development of USC power generation technology combined with the control of flue gas pollution. These efforts aim for high efficiency, high economic benefit, and environmental protection (Cao et al. 2007).

Integrated Gasification Combined Cycle Systems

Integrated gasification combined cycle (IGCC) systems reduce emissions and improve coal efficiency. These systems use coal gasification, syngas purification, and the gas-steam combined cycle of power-generation turbines. They concentrate and remove various pollutants from syngas and product gases. Existing IGCC power plants demonstrate efficiencies of sulfur, nitrogen, and carbon dioxide removals up to 99 percent, 90 percent, and 30 percent, respectively—the same as for the natural gas combined cycle system. IGCC technology also uses high-sulfur coal and some low-rank coals cleanly and efficiently. But the amount spent in 2010 to produce one kilowatt of power (called the capital expenditure, or CAPEX) was higher for IGCC power plants than for conventional subcritical and supercritical power plants operating without carbon capture and storage (CCS) technology; this is why IGCC is not widely applied. Further development of high-efficiency critical technologies and equipment is important for making IGCC technology practical. When combined with CCS technology and its applications, IGCC power plants will have lower costs than traditional coal-fired power plants. This indicates that IGCC will play an important role in future coal-power markets once advanced technologies are in place.

IGCC-Based Polygeneration

Polygeneration refers to the clean and highly efficient production processes that integrate a variety of coal conversion and synthesis technologies. These create a variety of clean secondary energy sources (e.g., oil, gas) and value-added chemical products. The Yankuang power plant is the first polygeneration industrial demonstration plant in China (Xiao 2007). It began operating in 2005 and successfully implemented the polygeneration of electricity and chemical products.

Polygeneration decreases CAPEX and OPEX (operating expenditure) costs and lowers emissions of sulfur, nitrogen, particulates, and other pollutants. These systems are flexible and commercially competitive because of their varied products and ability to regulate fluctuating power needs. Compared with traditional power generation and single-product synthesis technologies, the advantages of coal-based polygeneration systems are high efficiency, low cost, and low emissions. Opportunities for advanced IGCC systems exist in upgrading all the related technologies, including gasification, gas cleaning, gas turbines, and chemical synthesis.

Future of Sustainable Industry Strategies

There is much room for improvement in sustainable coal utilization strategies and technologies. Researchers should seek environmentally sustainable, affordable, high-efficiency conversion technologies as well as enabling clean technologies. Or they can pursue an integrated comprehensive solution that raises efficiency and lowers environmental damages.

Concrete actions include monitoring coal mine safety and efficiency and improving the investment environment for the construction and operation of advanced power plants, coking plants, and other coal chemical industry facilities. The main tasks for the coal industry include the following:

1. accelerating coal conversion industries at coal mines to develop a new coal utilization mode
2. promoting efficient utilization of coal-bed methane and coal gangue to reduce the consumption of high-rank coal resources and to control pollution
3. boosting land reclamation at coal mines and using coal mine water to protect the coal mine's eco-environment
4. developing advanced combustion technologies to generate heat and electricity
5. applying more supercritical and ultrasupercritical power generation technologies to raise the power industry's efficiency
6. developing large-scale, advanced gasification technologies for low-grade coal to extend resource availability and to create syngas or fuel gas
7. advancing low-cost, clean technologies and carbon capture, storage, and utilization strategies for controlling pollution, purifying products, and achieving a clean coal industry

In addition, process-intensification and scale-up technologies can maximize system efficiency and minimize pollution emissions. In the long term, a sustainable coal industry could be achieved by promoting a polygeneration technology system integrated with renewable energy and carbon dioxide capture and sequestration.

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See also Cap-and-Trade Legislation; Chemistry, Green; Energy Efficiency; Energy Industries (*assorted articles*); Investment, CleanTech; Mining; Steel Industry

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Energy Industries—Geothermal

Geothermal energy is derived from the natural heat found within Earth. Its direct use as a heating source—for homes, baths, and spas—has been employed for thousands of years, and it has been utilized since the early twentieth century as a source for the generation of electricity. Its advantages are that it is clean, renewable, and abundant. The number of nations using geothermal heat is growing constantly.

The word *geothermal* literally means "Earth's heat," which is estimated to be 5,500°C at the Earth's core—about as hot as the surface of the sun. Geothermal energy can be harnessed from underground reservoirs that contain hot rocks saturated with water and/or steam. Boreholes—typically two kilometers deep or more—are drilled into the reservoirs. The hot water and steam are then piped up to a geothermal power plant, where they are used directly for heating purposes or to drive electric generators to create power for businesses and homes.

Geothermal energy is considered a renewable resource because it exploits the Earth's interior heat, which is deemed abundant, and water that is piped back to the reservoir after use and cooling. Geothermal energy can be tapped by many countries, especially those located in geologically favorable places around the world—generally volcanic areas along the major plate boundaries on the Earth's surface.

Utilization of Geothermal Energy

Geothermal energy can be utilized directly for heating purposes, food processing, fish farming, bathing, agriculture, and other applications that require heat. Geothermal energy can also be used indirectly by employing steam or heat for generating electricity. In this, geothermal is unique compared to other renewable energy technologies. It not only provides a real base-load capacity (power output that can be produced nearly continuously) for electricity generation but also presents a cleaner alternative to fossil fuels for heat production.

Direct Uses

The oldest and probably best-known application of geothermal energy—dating back to Roman times—is in baths, spas, and for heating purposes. There are many other applications for geothermal energy today: in district heating systems, including one of the world's largest in Iceland, where about 90 percent of the homes are heated with geothermal energy (Orkustofnun 2009); in thermal baths and spas; in geothermally heated fish farms; and for food processing and dehydration. Furthermore the possibility to utilize ground source (geothermal) heat pumps to either warm homes directly or through energy efficiency programs, which allows savings in energy costs, has vast possibilities for individual or industrial use.

All those "direct use" applications utilize geothermal energy produced from lower temperature water (less than 150°C) that is derived from wells 100–1,000 meters deep. As of 2005, seventy-three nations utilize geothermal energy directly, with an overall energy output of 75,900 gigawatt-hours (GWh) thermal per year (Glitnir Geothermal Energy Research 2008). (A gigawatt-hour is a measure of energy, equal to one billion watts generated for one hour; one gigawatt-hour is enough to power approximately 89 U.S. homes for one year [calculation based on data from USEIA 2009] or 198 homes in the European Union for one year [Bertoldi et al. 2006, 12]. For more on this topic please refer to the sidebar "What's the difference between a gigawatt and a gigawatt-hour?"

on pages 148–149.) The number of nations using geothermal heat is growing constantly.

Power Generation

The utilization of geothermal energy for the generation of electricity is probably its most prominent application today. This application is a mature technology that began in a small power generation installation in Larderello, Italy, in 1904. To this day, geothermal energy is used to generate electricity and to provide heat directly in Larderello.

While the number of nations that generate electricity through geothermal energy is growing, only around twenty-four nations produced electricity from it in 2009. According to the International Geothermal Association (2009), the overall installed capacity is around 10 gigawatts (GW).

Electricity is generated from medium and high enthalpy fluids of more than 150°C derived from wells 1,000–3,000 meters deep in hot, permeable rock. The water from those wells is either used directly in a steam turbine or to heat up a secondary working fluid, which has a lower boiling-point temperature.

All applications mentioned in table 1 use water as a carrier of geothermal energy in the form of heat. This technology has been proven for hundreds of years, but it requires existing water flows in the ground. For electricity production, high temperatures are needed, but new technologies use a binary cycle system with fluids boiling at lower temperatures. This allows the generation of electricity in lower temperature regions and extends the prospects of geothermal energy utilization for electricity generation even further.

With "a higher capacity factor (a measure of the amount of real time during which a facility is used) than many other power sources" (Kagel, Bates, and Gawell 2007, i), geothermal has a huge advantage. Unlike other renewable energy resources, such as wind and solar power that are more dependent upon weather fluctuations and climate changes and have capacity factors of 20–30 percent, geothermal resources are available twenty-four hours a day, seven days a week. In real-life terms, this means that a 50 MW installation of geothermal power provides electricity for around 38,000 U.S. households, while the same installation for wind provides electricity only for around 15,000, and solar photovoltaic only provides enough electricity for 10,000 households, based on estimates by Glitnir (2008). This gives some indication of geothermal's usefulness on an individual basis. And for any industrial user, 24–7 accessibility to electricity is needed; the ability to receive electricity only when there is enough wind or sunshine simply is not an alternative.

New technologies—including engineered geothermal / hot dry rock systems—are in various stages of development and could provide further advancements to the geothermal energy industry. They are aimed at utilizing heat from nonpermeable rocks by creating hot-water reservoirs artificially. While those systems are not commercially viable yet, they are potentially extending geothermal energy utilization dramatically, allowing electricity generation all over the world, not just in "geologically favorable areas." Further advancements to drilling technology and the economics of

Table 1: **Geothermal Energy Applications**

Electricity Production—Hydrothermal	Wells drilled into a geothermal reservoir produce hot water and steam from depths up to 3 kilometers The geothermal energy is converted at a power plant into electric energy, or electricity Hot water and steam are the carriers of the geothermal energy
Direct Use	Applications that use hot water from geothermal resources directly include space heating, crop and lumber drying, food preparation, aquaculture, and industrial processes Historical traces back to ancient Roman times for baths and spas
Geothermal Heat Pumps	Takes advantage of relatively constant Earth temperature as the source and sink of heat for both heating and cooling, as well as hot water provision One of the most efficient heating and cooling systems available
Hot Dry Rock Deep Geothermal / EGS*	Extracts heat by creating a subsurface fracture system to which water can be added through injection wells Water is heated by contact with the rock and returns to the surface through production wells Energy is then converted at a power plant into electric energy as in a hydrothermal geothermal system

Source: Glitnir Geothermal Energy Research (2008).
*neither commercial as of 2009

Geothermal energy—in the form of heat and carried by water—has many potential uses, both direct (heating) and indirect (power generation).

deeper drilling also provide a great hope to further growth in geothermal energy exploration and utilization.

For electricity production, further technological developments will have a huge impact on the overall advances in this sector. While the carrier medium for geothermal electricity—water—must be properly managed, the source of geothermal energy—the Earth's heat—will be available indefinitely.

Outlook for the Twenty-First Century

The overall prospects for geothermal energy utilization, either for electricity generation or direct use, are excellent. While depending heavily on political and financial support, geothermal energy represents the only real baseload capacity alternative to fossil fuels like coal and oil.

The biggest potential and prospects for the shorter term are in the direct use of geothermal energy, particularly for heating and other direct applications. With technological developments in, for example, binary systems and engineered geothermal systems, geothermal could provide electricity throughout the world.

As of late 2009, there are more than 120 projects currently under development in the United States alone, which in total could more than double that country's currently installed geothermal power capacity, with estimations of a total increase to around 10 GW by 2020. Globally, geothermal power generation capacity is expected to triple to more than 30 GW by 2020 (Geothermal Energy Association 2008; International Geothermal Association 2009; Islandsbanki 2009). While power generation will be a prominent issue in the climate change debate, the more important role may be played by geothermal energy's direct use for heating and other heat-based applications, which gives geothermal the potential of replacing the fossil fuels largely connected with pollution.

The potential for geothermal direct use is tremendous and not quantifiable, particularly with the application of new technologies, such as enhanced geothermal systems (EGS). At the same time there are local concerns about earthquakes and emissions. There is an ongoing debate about how or if work on EGS systems might possibly induce seismic activity; while the likelihood of earthquakes is limited, concerns by the general public need to be addressed by companies in the sector early in the development process. The same applies to possible emissions, although geothermal plants have minor (or no) emissions and are considered a cleaner alternative to other thermal plants.

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The author would like it noted that he wrote this article both as an employee and team member of the geothermal energy team of Islandsbanki (a bank that promotes geothermal energy) and as a writer for ThinkGeoEnergy.

See also Energy Industries—Overview of Renewables; Facilities Management; Investment, CleanTech; Water Use and Rights

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Energy Industries—Hydroelectric

Hydropower is an important renewable source for the world's electricity supply, and even though it is a relatively mature technology, it has considerable untapped potential. Innovations include new turbine development that protects spawning fish and small hydropower plants that are more suitable for rural locales. Hydropower has social, economic, and environmental advantages and disadvantages, but the average cost of electricity production by hydropower will remain attractive.

Humans have harnessed water to perform work for thousands of years. About 2000 BCE, the Persians, Greeks, and Romans began using primitive waterwheels powered by river current for simple applications such as irrigation and grain grinding in mills; the 2,300-year-old Dujiangyan irrigation system in China's Sichuan Province is still used today. But such devices have very low efficiency and use only a small part of a stream's available energy from its velocity or motion, called the velocity head. (The vertical height that water falls is called the head; the higher the head, the greater the kinetic energy of the water as it falls on the waterwheel or turbine below. Engineers use the head and the volume of the water flow to calculate the amount of power a hydropower project can produce; this is called the potential power.)

Evolution of Hydropower

Waterwheel efficiency improved greatly with the overshot and pitchback waterwheels, which turn counterclockwise or clockwise, respectively, when water falls on the wheel. These use the weight of the water to turn the wheel and transform the water's unharnessed power into work. Turbines were the next major development in hydropower. They consist of curved blades attached to a rotating axis and are enclosed or are submerged in water. As water passes through the rotating blades, it gives up energy. Unlike waterwheels, turbines can be mounted horizontally or vertically.

The modern hydropower turbine began evolving in the mid-1700s when the French engineer Bernard Forest de Bélidor (1698–1761) wrote the four-volume *Architecture hydraulique*. In 1869 the Belgian electrician Zénobe Gramme set up the first prototype dynamo—an electric generator that produces direct current—and an electric engine. By 1881 a brush dynamo connected to a turbine in a flour mill provided street lighting at Niagara Falls, New York.

Since the 1880s, hydropower's main application has been electricity generation. By 1925, 40 percent of the world's electric energy production came from waterpower (Lejeune and Topliceanu 2002, 3), although by 2006 it had diminished to 17 percent (USEIA 2008a). This downward trend is not due to a change in global electric-energy production from waterpower, which actually increased by 74 percent during that time, but because the world's total energy production more than doubled from 1980 to 2006 (USEIA 2008a).

Importance

In 2006, the percentage of the world's electricity generated by hydropower (17 percent) represented nearly 90 percent of renewable electricity produced worldwide (Pew Center n.d.). Thus it is the most widespread form of electricity-generating renewable energy.

Since 1965, the world's total energy consumption from oil, natural gas, coal, nuclear power, and hydropower (which is the only renewable resource of those listed) increased from 44 million gigawatt-hours (GWh) to

131 million GWh (BP 2009). (A gigawatt-hour measures the total energy used over a period of time and equals 1 million kilowatt-hours; in one year, 1 GWh can power approximately 89 U.S. homes [calculation based on data from USEIA 2009c] or 198 homes in the European Union [Bertoldi and Atanasiu 2007, 12]. For more on this topic please refer to the sidebar "What's the difference between a gigawatt and a gigawatt-hour?" on pages 148–149.) As of 2007, the world's primary energy consumption was from oil (35.6 percent), followed by coal (28.6 percent). Their consumption has been growing, but it is curbed by the growth in energy consumption from renewable sources, including hydropower (6.4 percent; BP 2009).

Hydropower consumption and production vary by country. Four countries have been both the world's largest consumers of hydropower and its largest producers. In 2008 they consumed hydropower in this order: China, 1.54 million GWh, or 18.5 percent of the world's total; Canada, 972,000 GWh, or 11.7 percent; Brazil, 957,000 GWh, or 11.5 percent; and the United States, 659,000 GWh, or 7.9 percent (BP 2009, 38). According to the United States Energy Information Administration (USEIA 2008b), those countries producing the most hydropower were China (521,000 GWh), Canada (378,000 GWh), Brazil (361,000 GWh), the United States (259,000 GWh), and Russia (153,000 GWh). Conditions such as rainfall amounts and drought can affect hydropower production; U.S. hydropower production decreased from 2007 to 2008 because of drought-related issues. But government policies to invest in hydropower, such as China's Three Gorges project, can greatly increase production. From 2007 to 2008, China's production (20.3 percent) increased so much more than that of other countries that it skewed the world's net increase in production (BP 2009).

Although hydropower is an important source of renewable energy, it is controversial. A chief benefit is that it produces extremely small quantities of carbon dioxide (mostly from power plant construction and decaying organic matter growing in the plant's reservoir); the amount is less than those of wind, nuclear, and solar energy sources. Also, hydropower's supply is generally stable since water is abundant in many places.

One of its greatest drawbacks is cost. Hydropower's initial investment costs from dam and power plant construction are relatively high (partly because many geographic variables make project planning site specific). Other costs include the installation of (or hook up to) transmission lines, the operation and maintenance of the facility, and the financial and social costs of resettling people displaced by the dam and reservoir. Loss of agricultural land and potential damage to ecosystems are also important drawbacks (Williams and Porter 2006).

Hydropower's long-term costs, however, tend to be low because the energy source (flowing water) is renewable and free. In the United States, it costs on average 85 cents to produce 1 kilowatt-hour with hydropower, which is 50 percent cheaper than nuclear power, 40 percent cheaper than fossil fuels, and 25 percent cheaper than natural gas (Wisconsin Valley Improvement Company n.d.). A kilowatt-hour is the unit that electric companies use to charge residential customers for their energy use over time. Compilations of data for the cost of electricity generation in 2009 (USEIA 2009a, 89; 2009b) show that the average cost of electricity production by hydropower remains attractive. (See figure 1 on page 167.) Cost estimates for 2016 by the Institute for Energy Research (2010, 1) indicate that hydropower costs will remain at the same level as those for biomass and be cheaper than wind power and much cheaper than solar energy. (See figure 2 on page 168.)

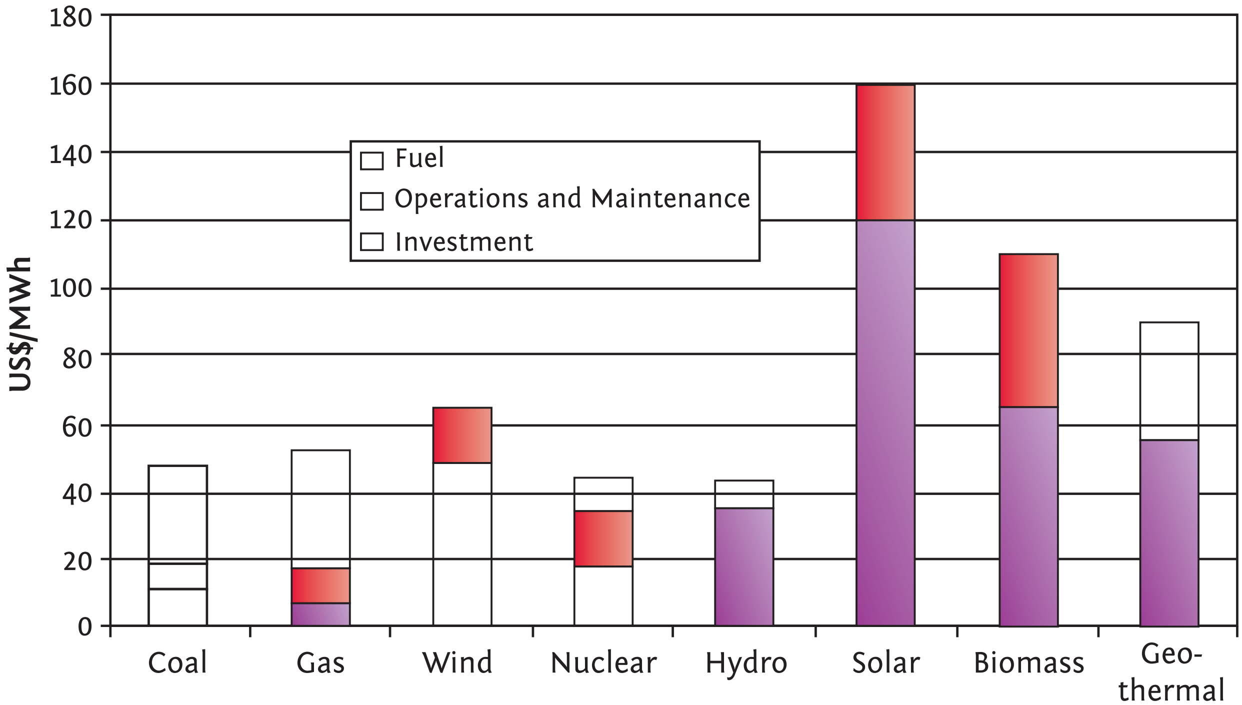
Hydropower and Dams

Most twenty-first-century hydroelectric power plants consist of a reservoir for holding water, a dam that can be opened or closed to control water flow, and a power plant that generates electricity as the water flows through the turbines that spin a generator. Some power plants, called run-of-the-river plants, are built along rivers with steady or regulated flows and don't require a dam. Not all dams have power plants; only 3 percent of the estimated 75,000–79,000 U.S. dams can generate electricity (Pew Center n.d.). The United States Department of Energy (2005) estimates that the remaining 97 percent represent up to 21,000 unused megawatts (MW) of hydropower.

Economics and safety are basic considerations in planning waterpower developments. Engineers must consider the maximum output of power at the minimum cost and construct safe and appropriate facilities that both control and manipulate the variable and uncertain natural forces of water. They must consider natural disasters and hazards due to floods and ice to ensure safety and minimize interruptions in plant operation.

Because waterpower developments frequently experience natural forces, engineers previously considered steam plants to be the most dependable prime movers. ("Prime movers" are machines that convert natural energy into work; a hydropowered steam plant transforms the energy of falling water into the steam that powers turbines.) But the interruptions in service at steam plants that were sometimes the only source of energy during fuel shortages have changed consumers' perspectives on steam plants, although they remain interested in hydropower because of high fossil fuel costs. The trend in hydropower plant design is toward simple and effective layout and greater use of stored water. (A large reservoir allows a plant to operate steadily while mitigating floods and storing water during droughts.) This

Figure 1. Average Cost of Generated Electricity by Source, 2009 (in US$/MWh)*



*US$/MWh = U.S. dollars per megawatt-hour

Source: USEIA (2009a, 89; 2009b).

Hydro power is one of the least expensive energy sources for electricity generation.

trend has increased waterpower's reliability and therefore the public's appreciation of hydropower.

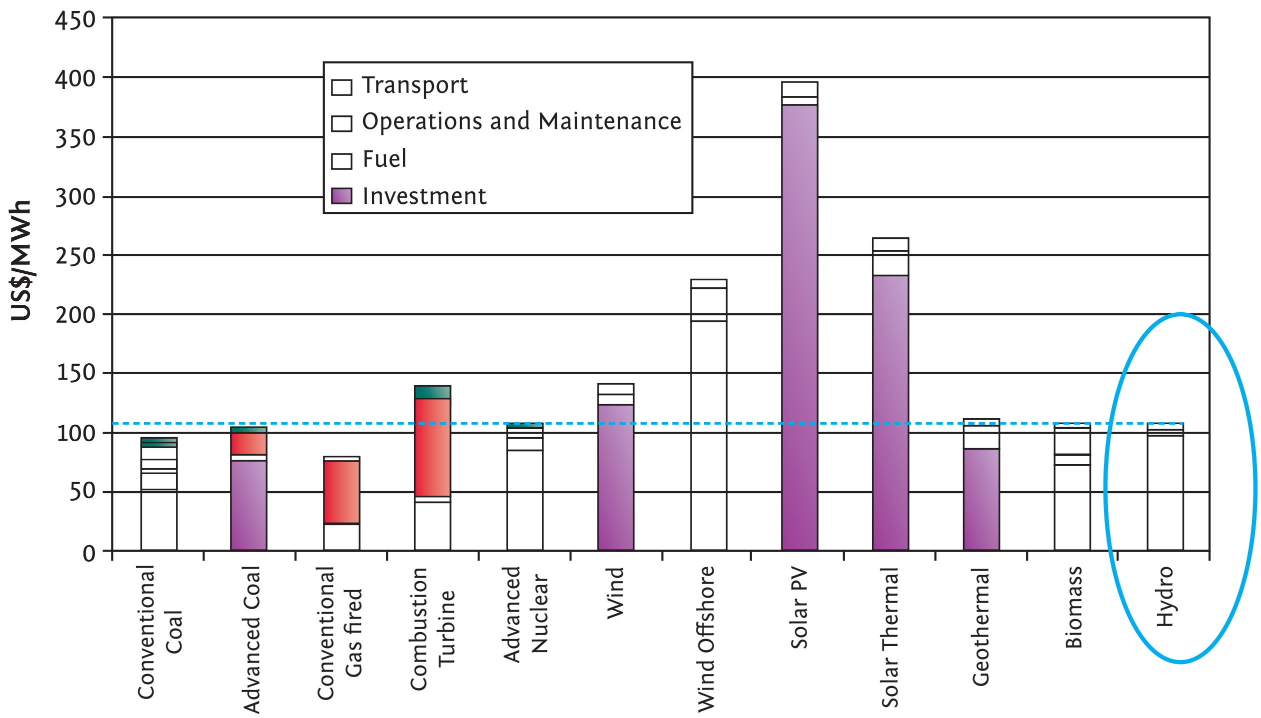
The likelihood of climate change and its consequences will lead to modifications of electricity generation and a demand for hydropower. But most of the "easy" potential dam sites are already developed. Because hydropower generation depends on natural conditions (availability of water and the head), every power site has unique design and construction problems, and no two waterpower developments are the same. Certain plant layouts correspond to the most-important site characteristics: head, available flow, and river topography. These characteristics are essentially interdependent and affect the dam's development, market characteristics (e.g., current technologies and regulatory policies), and type of load (i.e., whether the plant produces power constantly or on demand during peak times). These in turn affect the plant's size and the number of power-generation units. The development of future hydropower plants requires reducing costs (e.g., using low-cost roller-compacted concrete in dams) and increasing protection of the project's environment and those who live in it.

Concentrated Fall Dams

The Three Gorges power plant in China has a concentrated fall dam layout. These dams concentrate the water and provide it directly to a power station located near or in the dam. They are usually built in narrow valleys with mild slope, where concentrating the flow to a single point does not require an extraordinarily large—and extremely expensive—dam and where the spillway is located on the dam itself.

The Three Gorges dam is built at the end of Xiling Gorge in China's Hubei Province, one of three gorges on the Yangzi (Chang) River. As of 2009, it was the world's largest hydropower plant, with the dam measuring 185 meters high and 2,309 meters wide; it is expected to generate enough power to pay for its $30 billion construction cost within five to eight years. Its transmission and distribution systems will join three regional grids, making a network that will provide power from China's eastern coast to the Tibetan border in the west. The dam will also provide flood control downstream.

Figure 2. Future Cost of Generated Electricity by Source, 2016 (in US$/MWh)



Source: Institute for Energy Research (2010, 1).

The cost of electricity generated by hydro power in 2016 is expected to remain low among renewable energy sources and competitive with all others.

Divided Fall Dams

The Grande Dixence dam in Valais Canton, Switzerland, is a divided fall dam, with the dam and the power house in separate locations. These dams are usually built in rugged terrain, where dam construction that concentrates the entire flow would be prohibitively expensive. Grande Dixence's tunnels and pumping stations collect water from glaciers, and gravity moves the stored water to four underground power stations below the dam. It is the world's tallest gravity dam, at 285 meters. Although divided fall dams harness a smaller portion of the flow than concentrated fall dams, the diverted flow can be distributed to power stations at elevations lower than the dam's base, providing a greater head. Also, divided fall dams typically generate power using a higher head and less flow, resulting in a lower cost per kilowatt generated (Lejeune and Topliceanu 2002, 8).

The environmental impact of these dam layouts has not been assessed. Their impacts depend on individual parameters such as human and animal factors, location and catchment areas, discharge value and variation, and riverbed geomorphology.

Economies of Scale

Waterpower plants can be categorized by either the head or the generation of energy. Each category is divided into three ranges: low, medium, and high head or small, medium, and large power plant, respectively. Low-head plants have low heads, no water storage, and low energy capacity. (A plant's capacity is the maximum power it can provide in a given instant.) The McArthur Generating Station on the Winnipeg River in Manitoba, Canada, is one of the largest low-head plants, capable of generating 54 MW (Manitoba Hydro n.d.). Medium-head plants have heads 30–300 meters high and large reservoirs; the Three Gorges dam is an example, with a maximum head of 113 meters (Bridle 2000). High-head plants have heads over 300 meters high, large dams, and constant electricity generation. The Grande Dixence's Fionnay power plant receives water from a net height of 874 meters and has a 294-MW capacity (Alpiq Group n.d.). The definitions of small, medium, and large power plants vary, but the size indicates the number of megawatts the plant can produce. For example, the U.S. Department of Energy (2005) defines a small hydropower plant as producing between 100 kW and 30 MW.

Small Hydropower Plants: The Pros

One type of waterpower plant has gained prominence: the small hydropower plant (SHP). SHPs, which catch and channel water, are hydroelectric generating stations of low-power energy suitable for rural and developing areas. Engineers calculate that SHPs generate 5–8,000 kW for falls 1.5–300 meters high, for a flow from a few hundred liters per second to a few tons of cubic meters per second. Most SHPs are built on run-of-the-river power stations, with or without a small regulating tank for water storage. Engineers often need to know the river's conditions (e.g., dry season, wet season) in order to size the turbines and control production. SHPs can be connected to other power stations or used in isolated networks that provide electricity to a village, small city, or complex medical, industrial, or agricultural facility far from the principal network. Moreover, they only require a small building and one staff person without special training. Compared with other types of stations, SHPs are often completed at low cost, operate on a low budget that is usually reasonable for rural communities, and are easier to keep fully staffed, which can be an advantage in rural areas. Finally they are autonomous, starting and operating on their own without using fuel.

SHPs are often isolated networks managed by the community or a private individual or group. Energy production, however, may be uninterrupted because of the community's social events or needs. But if interruptions happen too frequently (due to water shortages, drought, malfunctions, poor maintenance, etc.), people may become frustrated and use power derived from other, more environmentally destructive fuels such as coal, or trees from deforested areas (which often occurs in the developing world). Overall, SHPs have a lower negative environmental impact than larger projects do. Their low impact and use of renewable natural resources affects the natural environment less than almost any other form of electrical energy production (International Energy Agency n.d.).

Small Hydropower Plants: The Cons

Economies of scale are important in determining a hydroelectric project's profitability. A negative aspect of SHPs is that construction costs are $1,200–$6,000 per kilowatt installed capacity (Minister of Natural Resources Canada 2004), which, despite the lower cost per project and lower operating costs, is generally three times more than large- or medium-sized hydropower plants. The risk of accidents is also higher because of the lack of continuous maintenance by qualified people.

Despite the global financial crisis that began in late 2007, new implementations or studies of hydropower plants are under way, especially small- and large-scale projects (e.g., Inga dam in the Democratic Republic of Congo [DRC], Romaine dam in Canada). Many medium-scale projects were postponed or canceled (e.g., Memve'ele in Cameroon). China continues to develop very large hydropower projects with a dam height over 300 meters and power around 6 gigawatts (GW) per plant. China's installed hydro capacity stands at about 155 GW, and it aims to increase this to 300 GW by 2020. Its total exploitable hydropower potential was estimated to be 542 GW in 2009, ranking it first in the world (Chen 2009). Brazil continues to implement projects with a dam height around 100 meters, mainly run-of-the-river plants, with power around 3 GW. Its largest hydropower plants in operation in May 2009 had an installed capacity of 50 GW; smaller-scale plants provide an additional 19 GW (Brazilian Committee on Dams 2009).

Economics

Conditions in the developed and developing world affect the economics of hydropower projects. An analysis of the cost of different power-generation systems in the United States indicates that hydroelectric plants are the most economical. These plants' mean cost of generation is only 40 percent of the cost of generation by fuel oil (Wisconsin Valley Improvement Company n.d.).

In Africa, Tanzania closed hydro plants in 2006, Kenya closed its 14-MW Masinga dam in 2009 due to recurrent droughts (Browne 2009), and the capacities of the DRC's Inga 1 and 2 dams diminished due to poor maintenance. But several large hydro projects are being planned or built there: the proposed Grand Inga complex in the DRC, which is expected to produce almost twice the electricity of the Three Gorges project (Wachter 2007); the construction of Lom Pangar dam in Cameroon; the rehabilitation and upgrading of the Kariba dam on the Zambezi River between Zambia and Zimbabwe; the construction of the Gibe III hydropower plant in Ethiopia; and the construction of the Gurara Water Transfer Project in Nigeria. In 2008, the World Bank invested more than $1 billion in small-scale and micro-hydro projects in the developing world, which displace fewer people than large projects and reduce the cost of transmitting electricity to rural areas, across vast distances, and over natural barriers such as the Sahara Desert (Browne 2009).

India's poor electricity supply stifles economic growth and reduces productivity. Hydropower in India generated nearly 37 GW in 2009 and constituted about 25 percent of India's total capacity. Each of India's twenty-eight (soon to be twenty-nine) states and seven union territories has its own power utilities that are connected through state, regional, and national transmission grids. As of 2009, two new main hydropower projects were being discussed: the 412-MW Rampur Hydropower Project and the 444-MW

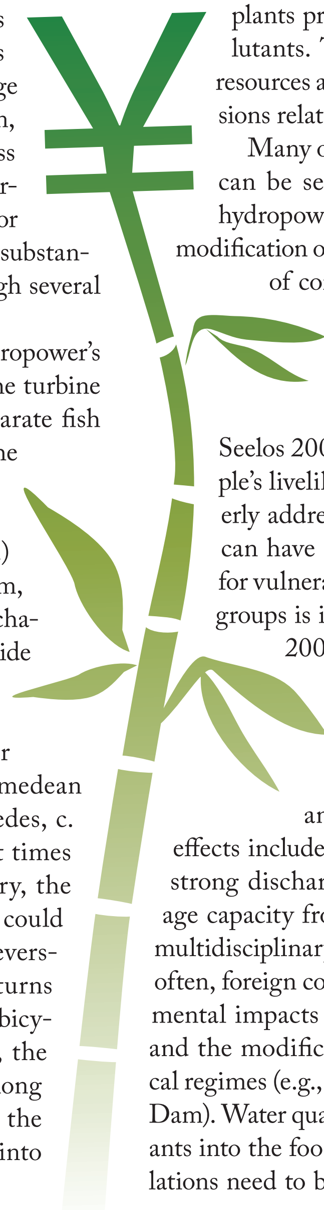
Vishnugad Pipalkoti Hydropower Project. In April 2008, workers protested unsafe conditions at the Rampur construction site; nearby villagers joined them, protesting the construction of a tunnel that would threaten their only source of drinking water (Asian News International 2008). Residents and farmers protested again in September 2009, claiming the project would disturb the region's ecological balance (Asian News International 2009).

New Turbine Development

Environmental and technological considerations affect the type of equipment used in hydropower plants. For example, turbines can be hazardous to fish passing through them; their effect on fish populations can be one of the most important criteria for selecting turbines in low-head hydropower plants. Fish injuries caused by a hydroelectric turbine are often quantified by model predictions rather than actual measurements. Survival rates measured for fish passing directly through a large modern turbine are 88–94 percent. By comparison, survival rates for fish moving through a fish bypass system typically are 95–98 percent, and 95–99 percent for a spillway system. The net survival rates for fish traversing dams without bypass systems are substantially lower, because each fish has to pass through several turbines during its journey to the sea.

Fish-friendly turbine designs are vital to hydropower's future and allow fish to pass directly through the turbine without injury, eliminating the need for a separate fish bypass system. (Fish bypass systems, such as the fish ladders installed on the Ice Harbor Dam in Washington State, require additional construction, which increases the plant's initial costs.) The main manufacturers of turbines (e.g., Alstom, Alden, Voith Hydro) have identified specific mechanisms that cause injury, and they design and provide turbines to remedy these situations.

For small-scale hydropower generation, Archimedean screw turbines, which push water uphill, are a promising technology. The Archimedean screw (named for the Greek scientist Archimedes, c. third century BCE) has been used since ancient times to help irrigate crops. In the twentieth century, the German manufacturer Ritz-Atro discovered it could use the screw to generate hydroelectricity by reversing the process so that the weight of the water turns the screw. It works the same as a dynamo on a bicycle wheel. Like the cyclist turning the wheel, the water turns the screw. The screw is installed along a dam or a river weir. Water is diverted above the weir, and then flows down the screw and back into the river.



Advantages and Disadvantages

The positive social aspects of hydropower implementation include flood protection (e.g., the Three Gorges dam); the enhancement of recreational facilities (e.g., Lake Mead, between the U.S. states of Nevada and Arizona); and job opportunities in construction and plant operation, mostly for the local populace. Sometimes the conditions created by hydropower construction enhance navigation in the affected body of water (e.g., the Three Gorges dam).

From an economic viewpoint, hydropower production saves fuel that would otherwise come from carbon-based sources. It offers a reliable and steady source of power, combined with low long-term operating and maintenance costs, and reservoirs help meet load flexibly. It also provides nations with energy independence.

Regarding environmental impacts, hydropower plants produce no waste and no atmospheric pollutants. They avoid depleting nonrenewable fuel resources and produce very few greenhouse gas emissions relative to other large-scale energy options.

Many of hydropower's positive aspects, however, can be seen as negative. The implementation of hydropower plants frequently involves resettlement, modification of local land-use patterns, and management of competing water uses and waterborne disease vectors. The same waters used for hydropower are often used in farming, fishing, navigation, flood and drought protection, and tourism (Truchon and Seelos 2004, 2). If the effects on the impacted people's livelihoods and cultural heritage are not properly addressed and managed, hydropower projects can have a detrimental social impact, particularly for vulnerable groups. Compensation of the poorest groups is inadequate in many projects (Maldonado 2009, 1–3) and nonexistent in a few, such as the Cana Brava dam in Brazil (BIC 2003, 2). Also, reservoirs of standing water increase the risks of waterborne disease, especially in tropical regions (Truchon and Seelos 2004, 3). Negative economic effects include dependence on precipitation (producing strong discharge variations); decreased reservoir storage capacity from sedimentation; and requirements for multidisciplinary involvement, long-term planning, and, often, foreign contractors and funding. Negative environmental impacts are the inundation of terrestrial habitat and the modification of aquatic habitats and hydrological regimes (e.g., the Nile River, downstream from Aswân Dam). Water quality, the temporary introduction of pollutants into the food chain, and species' activities and populations need to be monitored and managed. Hydropower plants are barriers for fish migration, especially for salmon. Poorly planned projects can contribute to global warming as much as fossil fuel sources; in its first three years, the reservoir behind the Balbina Dam in Brazil released four times the greenhouse gases of a coal plant producing the same power (Kozloff 2009).

The controversy over the Three Gorges dam highlights many issues surrounding hydropower projects around the world. The Three Gorges project had the capacity to generate 18.2 GW as of 2008 (22.5 GW by 2011), replacing the power provided by burning 36 million metric tons of coal (Panda Travel and Tour Consultant n.d.), and will prevent flooding that has killed thousands in its worst years. But the dam project has negative impacts. The reservoir behind it displaced over 1 million citizens, submerged 1,300 archaeological sites, and forever modified the ecosystem. Although the reservoir may create arable lands along its banks, lands responsible for one-tenth of China's grain production were submerged (Allin 2004). The resulting waterway provides a larger conduit for commerce with China's interior, increasing river shipping from 9 million to 45 million metric tons annually (Panda Travel and Tour Consultant n.d). The river will dump an average of 480 million metric tons of silt into the reservoir each year, but the sluice gate system for flushing the silt downstream will ensure the reservoir's value as a flood deterrent and transportation channel. Finally, the dam is designed to withstand an earthquake of 7.0 on the Richter scale (the same force that destroyed Port-au-Prince, Haiti, on 12 January 2010).

There is no system to quantifiably compare the advantages and the disadvantages of the hydropower industry. Scientific studies and multiple-criteria analyses must be performed to prepare the assessment, and those analyses should weigh the different impacts. The value of weighting will depend on who is doing the assessing, the timing, the location, and so on; who does the assessment also determines whether the focus is on the economic, social, or environmental aspects of a given hydropower project. The final assessment should combine all these aspects.

The permanent and universal criterion for the assessment of the hydropower industry's projects, implementations, operations, and related issues is their sustainability, that is, their ability to halt irreversible environmental degradation while balancing humankind's need for energy. The hydroelectricity industry cannot endanger nature's future. Even with the progress of knowledge and human behavior in the fields of biology, sociology, and economics and their related mathematical models, assessments are still unreliable, inaccurate, or missing.

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See also Development, Sustainable; Energy Efficiency; Energy Industries—Overview of Renewables; Investment, CleanTech; Water Use and Rights

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Energy Industries—Hydrogen and Fuel Cells

Since the late-twentieth century, hydrogen and fuel cells have developed as promising means of transitioning to a more sustainable economy. Hydrogen is a nonpolluting energy carrier that can be produced from almost all energy sources; fuel cells are technological devices that generate energy and heat using hydrogen or other fuels. They are clean, silent, and more efficient than combustion systems.

Over the last decade, hydrogen and fuel cells have emerged as possible resources for a more sustainable low-carbon economy. These technologies promise substantial benefits in terms of emission reductions and energy security, and thus the notion of a "hydrogen economy," defined as an energy distribution system supported by hydrogen gas, is appealing (McDowall and Eames 2006; Rifkin 2002). Several countries—the United States, the European Union, Germany, Scandinavian regions (including Iceland), and Japan—have implemented policies and research and development (R&D) plans to advance and promote these technologies, but significant technical breakthrough and cost reduction seem necessary to support actual industrial and market development (Pogutz, Russo, and Migliavacca 2009).

Hydrogen Industry

For many centuries hydrogen has fascinated scientists due to its innate properties: it is the most abundant chemical element in the universe; it is odorless, tasteless, colorless, and nontoxic; and it generates energy without exhausts when it burns. On the other hand, free hydrogen does not occur in nature; therefore it is not a primary energy source but a carrier that needs to be extracted through other energy sources.

The hydrogen industry is organized into three main stages: production, distribution and storage, and final application. Hydrogen is produced primarily from fossil fuels such as gas (48 percent), oil (30 percent), and coal (18 percent) through mature and efficient technologies such as steam reforming and coal gasification (International Energy Agency [IEA] 2007a, 1). Four percent of hydrogen production is obtained through water electrolysis, which uses electricity to split water into H_2 and O_2. Other innovative technologies—thermochemical, biological and fermentative processes, and photoelectrolysis—have been demonstrated in laboratories, but none of these solutions is economically efficient or viable yet.

With regard to the distribution phase, hydrogen can be transported in pipelines. Several thousand kilometers of hydrogen pipelines are in operation around the world, although this option is effective and convenient only for large amounts of hydrogen. Due to the low volumetric energy density of hydrogen, the investments and energy required to pump this gas are higher than for natural gas (IEA 2007a, 1). Liquid hydrogen can be transported by trucks, trains, and ships, but the amount of energy necessary for liquefaction makes these solutions more expensive than pipelines. Hydrogen distribution through either mode is more expensive than hydrocarbon logistics.

The storage of hydrogen is also complex, since it has a very low energy density by volume as a gas at ambient condition. Therefore, hydrogen must be pressurized or liquefied, which requires a large amount of energy. At present, two options are commercially feasible: gaseous compression at 350–700 bar and liquid storage at −253°C. There are also innovative solutions still under development, such as storage in solid materials. Among these, metal hydrides (a compound in which hydrogen is chemically bonded to a metal or metal-like element) are probably the most developed option, already available for niche applications, while more advanced alternatives are complex hydrides and carbon nanotubes (a cylindrical nanostructure of carbon or a carbon allotrope). All these technologies may lead to relevant breakthroughs in the future, but they still need intense R&D investments to be viable for the market and economically competitive.

Finally, with regard to market applications, large amounts of hydrogen are needed in chemical and refinery industries, but hydrogen is also used in the food industry as an additive, in food packaging, in aerospace, and in telecommunications. More than 65 million tonnes of hydrogen are produced globally every year (IEA 2007a, 1). New hydrogen markets continue to emerge, and its use in transit fleets, public transportation, decentralized power plants, and auxiliary power units has rapidly increased.

The proposal to use hydrogen in transportation in order to solve the negative effects related to hydrocarbons has been broadly discussed since the late 1990s. On the one hand, the efficiency of hydrogen as a carrier is lower when compared with other more mature technologies, and scientists and scholars have controversial opinions on the usefulness of introducing hydrogen technologies to reduce carbon dioxide (Hammerschlag and Mazza 2005). A central consideration is related to the benefit and efficiency of using renewable energies to produce carbon-free hydrogen for transportation instead of substituting coal- and oil-generated electricity.

In practice, the emissions of a hydrogen-based energy system depend on the "well to wheel" energy chain (a life cycle analysis of the efficiency of fuels used for road transportation), including primary energy sources, hydrogen production and infrastructures for transportation and storage, and end-use technologies (Simbolotti 2009). A net reduction in carbon dioxide emissions could be obtained if hydrogen is manufactured with renewable and nuclear energy, or when carbon capture and sequestration technologies are utilized at the site of hydrogen production. Finally, a sustainable transportation system needs the market diffusion of an innovative and highly efficient technology for energy conversion: fuel cells.

Fuel Cell Industry

Fuel cells are electrochemical energy conversion devices that produce electricity and heat by combining oxygen from air and a fuel, typically hydrogen or H_2-rich fuels. Fuel cells are similar to batteries, but they operate as long as fuel is supplied. The conversion process also takes place without combustion. When hydrogen is used as fuel, water and heat are the only by-products, which means that fuel cells are environmentally clean, silent, and more efficient than other combustion systems. Fuel cells' simple structure consists of two electrodes—cathode and anode—separated by an electrolyte (an electrically conductive substance). The electrolyte carries electrically charged particles from one electrode to the other. Another key element is the catalyst, such as platinum, which encourages and speeds up the reactions among the electrodes. Fuel cells can be combined into the fuel cell "stack," the core of the fuel cell system (Hall and Kerr 2003).

Fuel cells were invented in 1839 by the English scientist Sir William R. Groove, but only since the 1990s have they captured attention both from policy makers and industry as a potential answer to environmental pollution.

Fuel cells can be produced in a variety of ways, and depending on the nature of the electrolyte and the materials used, they are generally suitable for specific market applications: stationary power generation, transport, and portable devices (Lipman, Edwards, and Kammen 2004). There are primarily four different technologies used in fuel cells.

Proton exchange membrane (PEM) design uses a polymeric membrane as an electrolyte (acidic) and operates at a low temperature (80°C) with an electrical efficiency of 40–60 percent in converting fuel into power, twice that of a traditional internal combustion engine (United States Department of Energy [USDOE] 2009a). PEM fuel cells are used mostly to power vehicles and produce residential energy.

Molten carbonate fuel cells (MCFCs) use immobilized liquid molten carbonate (alkaline). The operating temperature is high (650°C) and the efficiency is around 46 percent, but if waste heat is recycled, the rate can rise to 80 percent (USDOE 2009a). Due to their characteristics, MCFCs are typically used for power stations.

Solid oxide fuel cells (SOFCs) use solid-state ceramic electrolyte (alkaline) and operate at a very high temperature (1,000°C) with an electrical efficiency of around 35–43 percent (USDOE 2009a). This technology is utilized for auxiliary power units, electric utility, and large distributed generation.

A last example of popular fuel cell technology is the direct methanol fuel cell (DMFC). This is a relatively new technology that uses a polymer membrane as an electrolyte. The operating temperature is between 50°C and 120°C, and the efficiency is around 40 percent (Fuel Cell Markets 2010). DMFCs can use pure methanol as fuel and are typically suitable for portable applications (for example, cell phones and laptops).

Several reasons exist to consider fuel cells as a disruptive technology with strong potentialities (Nygaard and Russo 2008). First, they produce power with a higher efficiency rate and almost zero environmental impact when compared to other power systems used in internal combustion engines. Second, their flexibility and modularity can efficiently generate power in a variety of system sizes.

On the other hand, fuel cells are emerging technology that must cope with different technical obstacles in order to achieve market acceptability. At the same time, they are in competition with mature technologies, like the internal combustion engine or turbines, and other alternative devices, such as electric batteries. Two specific barriers diminish the effectiveness of fuel cell performance: their reliability and cost. Reliability of fuel cells is influenced by several contingencies, including the start-up temperature, fuel purity, durability of materials and components, and degree of humidification. In any event, the technology requires significant R&D investments to become competitive with other viable solutions.

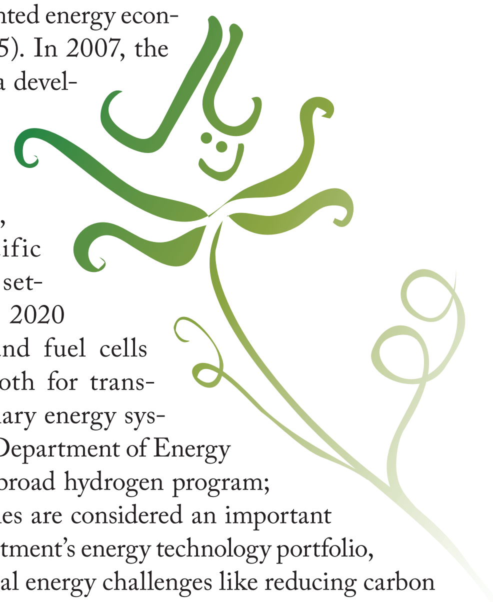
To improve fuel cell functionality in transportation, the costs per kilowatt (kW) must be dramatically reduced (a competitive cost is around \$60–\$100 per kW, while the current cost of a PEM stack exceeds \$1,000 per kW). (For more on this topic please refer to the sidebar "What's the difference between a gigawatt and a gigawatt-hour?" on page 148–149.) In the realm of stationary applications, however, the cost of fuel cells is expected to become competitive within a few years; while the current cost of the fuel cell stack is about \$5,000 per kW, the target is an installation cost of \$1,500 per kW (IEA 2007b; Simbolotti 2009). In order to reach these objectives, major reductions can be obtained abating manufacturing costs through economy of scale and learning curves (from prototype to continuous production).

As of 2009, a few hundred fuel cell–powered cars and buses operate worldwide in the transport industry; the United States has two hundred fuel cell vehicles and twenty hydrogen buses. In 2008 the production of small power-generation fuel cells was about 4,000 units, 95 percent of which were PEM (Adamson 2009). The amount of large power systems installed has reached 20 megawatts (MW), and the average size of these technologies has increased to one MW per unit (Adamson 2008). Moreover, the number of niche transport markets, such as marine applications and auxiliary power units, is growing. In particular, sales of warehouse vehicles and forklift applications have stimulated early market growth, including the distribution of a large number of demonstration units in North America and Europe.

Outlook for the Future

To achieve the goal of an environmentally sustainable, secure, and competitive energy system, there is the need for a rapid shift to new technological paradigm. Hydrogen as a carrier and fuel cells as conversion technologies have a unique position within a clean energy and transport system. According to HyWays (2008), an integrated project to develop hydrogen energy in the European Union, oil consumption could be reduced 40 percent by 2050 if 80 percent of cars were run on hydrogen. The transition, however, will take a long time. Path dependency on dominant market solutions and technological obstacles require huge public and private investments to be outbalanced. According to the U.S. roadmap implemented by the U.S. Department of Energy (2002), only a coordinated agenda will allow a real change toward hydrogen.

Several countries and governments have developed policies and roadmaps to implement hydrogen and fuel cells technologies. The European Union hydrogen strategy was launched in 2003 with the report *Hydrogen Energy and Fuel Cells—A Vision of Our Future* (European Commission 2003). In 2004 a formal public and private network called European Hydrogen and Fuel Cells Technology Platform (HFP) was launched with the goal to prepare and direct an effective strategy for implementing a hydrogen-oriented energy economy (HFP 2005). In 2007, the HFP endorsed a development strategy and the implementation plan (HFP 2007), defining specific scenarios and setting targets for 2020 for hydrogen and fuel cells technologies, both for transport and stationary energy systems. The U.S. Department of Energy has launched a broad hydrogen program; these technologies are considered an important part of the department's energy technology portfolio, addressing critical energy challenges like reducing carbon dioxide emissions and ending dependence on imported oil (USDOE 2006; USDOE 2009b). This program includes R&D support activities, demonstration projects and technology validation, codes and standards definition, and international cooperation. Other countries such as the United Kingdom, Canada, Germany, Scandinavian regions (including Iceland), Japan, and New Zealand have identified these technologies as desirable options to create a low-carbon, sustainable economy, and are developing similar roadmaps, policies, and plans.



But both the hydrogen and fuel cells industries look lively and dynamic: over two hundred hydrogen refueling stations are now operating around the world (sixty in the United States), compared with only fifty in 2003; many demonstration projects have been launched by central and local governments in partnership with industrial associations and firms. From 1996 to 2008, more than ten thousand fuel cells patents were issued, and a steady growth in strategic alliances was registered (Pogutz, Russo, and Migliavacca 2009).

At present, there are four major scientific and technical challenges that must be tackled for a transition to a hydrogen-based energy system (Blanchette 2008; Edwards et al. 2008): lowering the cost of hydrogen production to a level comparable with oil; development of carbon dioxide–free hydrogen production technologies from renewable energies at competitive costs; development of infrastructures for distribution and viable storage systems for vehicles and stationary applications; and dramatic improvement in the fuel cells efficiency and costs. Whether the "hydrogen economy" will happen is not certain, but surely the hydrogen and fuel cell industries will contribute to the revolution for a more sustainable energy system.

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See also Automobile Industry; Energy Efficiency; Energy Industries—Overview of Renewables; Investment, CleanTech; Public Transportation; Smart Growth; Telecommunications Industry

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Energy Industries—Natural Gas

Natural gas, a nonrenewable but relatively clean fossil fuel, accounts for almost 25 percent of worldwide energy consumption. Recent technological advances have made gas from unconventional sources more economical. With appropriate legislation, the substitution of natural gas for coal in the power generation industry can contribute to a more sustainable energy economy.

Natural gas is a fossil fuel, and thus its supply is finite. The use of natural gas to produce, for example, electricity also gives rise to carbon emissions that contribute to global warming. Moreover, the uncontrolled release of natural gas into the atmosphere contributes to global warming since methane, the principal component of natural gas, is itself a greenhouse gas. Yet because natural gas is the cleanest of the fossil fuels and is more abundant than previously believed, natural gas can contribute to a more sustainable energy economy.

Environmental Impacts

Environmental consequences are associated with the exploitation and use of natural gas resources. Natural gas that is inadvertently vented from wells, pipelines, and processing facilities directly contributes to global warming since methane has a global warming potential that is approximately twenty-one times that of carbon dioxide (United States Energy Information Administration [USEIA] 2008b). Adverse consequences to water supplies and wildlife habitats can also occur from the exploitation of natural gas resources.

The emissions associated with using natural gas as a fuel, although lower than those stemming from burning coal, are still nonzero. On average a traditional steam turbine using natural gas as a fuel releases 0.54 kilograms of carbon dioxide emissions for each kilowatt-hour (kWh) of electricity produced; this is approximately 43 percent lower than when a steam turbine produces electricity by using coal as a fuel (USEIA 2010a, 54, 106). When electricity is produced using a modern natural-gas combined-cycle generating unit (under this technology the waste heat arising from the turbine used to produce electricity is captured and used to create steam and generate even more electricity), the carbon emissions per kWh are about 57 percent lower than when coal is used as a fuel. (See table 1.) (For a reference to the various measurements used in this article, please refer to the sidebar "What's the difference between a gigawatt and a gigawatt-hour?" on pages 148–149.)

It is technically feasible to sequester a substantial proportion of the carbon emitted when natural gas is used as a fuel. According to the USEIA (2009b, 108), the capital costs of a power plant that captures and sequesters its carbon emissions are about 50 percent lower when the plant is fueled by natural gas as compared with coal.

Consumption

In 2006, the latest year for which data are available, natural gas accounted for about 23 percent of worldwide energy consumption (USEIA 2009a, 307). People increasingly appreciate the environmental benefits of natural gas compared with coal in the electric power sector, making natural gas the "go-to" resource for new electric generation facilities. In 2009, over 50 percent, or 12.3 gigawatts (GW), of all new generation plants planned in the United States were gas-fired units (USEIA 2010b). The USEIA believes that the costs per unit of capacity for these power plants are between one-third and one-half the costs of new nuclear plants or coal-powered plants (2009b, 108). Moreover, in contrast to coal, the owners of these plants will be well

Table 1. **Carbon Dioxide (CO_2) Emission Factors**

Fuel	CO_2 per Gigajoule (in Kg)	CO_2 per kWh (in Kg)*	Possible Conversion Technology	Typical Power Conversion Efficiency Factors (%)	CO_2 per KWh for Fuel and Power Conversion Technology (in Kg)
Bituminous coal	97.65	0.31	Steam	34	0.94
Distillate fuel oil	76.76	0.23	Combined cycle	31	0.81
Residual fuel oil	82.72	0.27	Steam	33	0.82
Natural gas	55.68	0.18	Combined cycle	45	0.40

*assuming 100 percent efficiency in power conversion.

Note: The figures in the table were converted to metric units.

Source: Based on data reported by USEIA (2010a, 54, 106).

The amount of carbon dioxide emitted by fossil fuels used for power generation varies by the type of fuel and power conversion technology. The higher the efficiency of the technology, the less carbon dioxide produced per kilowatt-hour produced (far right column). A steam generator using coal, for example, emits more than twice as much carbon dioxide per kilowatt-hour as a combined cycle generator using natural gas.

situated if cap-and-trade legislation, which limits emissions and allows companies to trade emissions credits, were passed and carbon emissions were penalized.

In the United States, this increase in power generation fueled by natural gas sharply contrasts with the situation in the 1970s when the Powerplant and Industrial Fuel Use Act (FUA) was enacted by the federal government in response to concerns over the adequacy of the natural gas supply. The FUA restricted the construction of power plants using natural gas and the industrial use of natural gas in large boilers. But in 2010, most scholars accept that the natural gas supply issues of the 1970s were largely due to price regulations that discouraged natural gas drilling and production. The FUA was repealed in 1987; as a result, between 1988 and 2002, natural gas consumption by the power and industrial sectors in the United States increased by approximately 45 percent (USEIA 2008a).

A major impediment to the additional use of natural gas in the power sector is that it typically has a premium price relative to coal. For example, the USEIA reports that the average cost of coal to electric utilities in the United States was US$1.94 per gigajoule (GJ) in 2008, while the average cost of natural gas was US$8.74 per GJ (USEIA 2010a, 39; USEIA 2010c). While the technology to produce electricity favors gas over coal (the technology is more efficient and also allows electricity producers to change output more quickly when the demand for electricity changes), the difference in the cost of the fuels is a major hurdle to the increased penetration of natural gas in the power sector.

There is without doubt some who would argue against the use of any fossil fuel to produce electricity; some would argue that 100 percent of electricity should come from wind and solar power. The reality is that the stability of a power system requires that demand equals supply at all times. Unlike solar- and wind-powered generating units, those fueled by natural gas have the flexibility to help maintain this balance.

How Abundant Is Natural Gas?

Natural gas is a nonrenewable resource. In its latest worldwide assessment of energy resources, the United States Geological Survey (USGS 2000) estimates that the world's remaining undiscovered conventional natural gas resources are approximately 147 trillion cubic meters (5,200 trillion cubic feet). Annual worldwide consumption of natural gas is about 3 trillion cubic meters. One widely accepted view is that the level of natural gas resources is a fixed amount that will be depleted over time, even as new resources are discovered and drilled (Dahl 2004, 336–337). For example, the researcher R. W. Bentley indicates that conventional gas production will peak by about 2030 and then decline rapidly due to depletion. According to Bentley, as production declines, "'demand' will not be met; users may have to ration; prices will rise; there is likely to be inflation, recession, and international tension" (Bentley 2002, 203).

An Alternative View

The fixed resource view of natural gas supplies has been called into question in the twenty-first century. Researchers increasingly recognize that viewing the resource base as fixed overlooks its heterogeneity in terms of cost. Under this alternative view, the resource base is thought of as a pyramid with a relatively small amount of high-quality resource that is inexpensive to find, develop, and extract at its top. Below are increasing amounts of lower quality resource that are much more costly to develop given existing technology. (See figure 1.) The resource base has three measures: the economically recoverable component, the technically recoverable component, and the "in-place" measure. The in-place measure of the resource base is the total quantity of the resource. The technically recoverable component is the quantity that can be exploited using current technology. The economically recoverable component is that portion of the technically recoverable component that can be exploited profitably under current market conditions. Resources that cannot be profitably exploited are known as subeconomic.

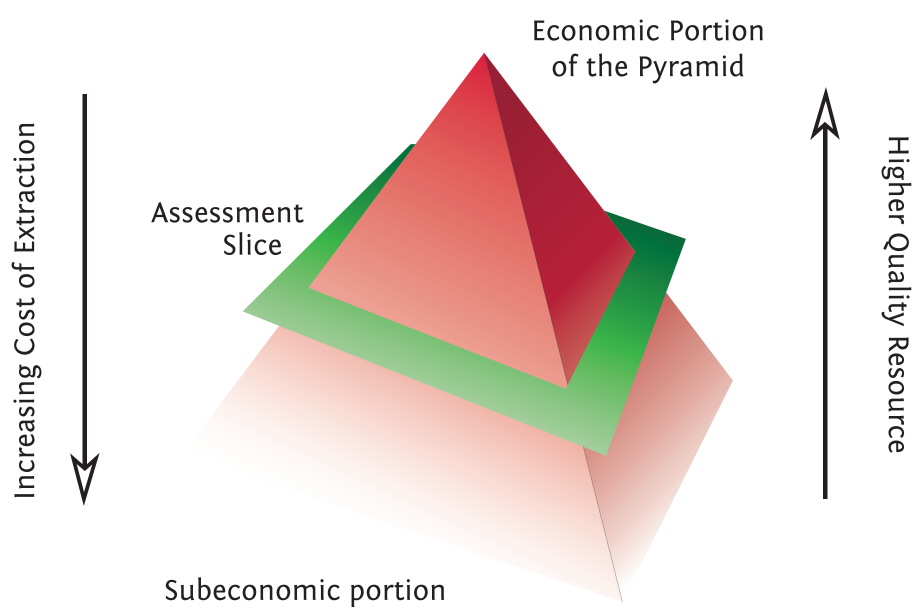
One important implication of the pyramid view of the resource base is that future supplies of oil and gas critically depend on the introduction of new technologies that can "move" the subeconomic portion of the pyramid into the economic component.

The heterogeneity in the natural gas resource base vividly illustrates the validity of the pyramid concept. Since the inception of the natural gas industry, its mainstay has been natural gas trapped in domelike rock formations. This gas is known as conventional gas. Natural gas from these reservoirs can be produced economically without large-scale stimulation to liberate the gas or sophisticated production equipment. Natural gas from conventional deposits deeper than 4,500 meters was once considered unconventional, but that label has faded as the average depth of wells has increased.

Unconventional Gas Sources

Other sources of natural gas—such as coal-bed methane (gas trapped within coal seams), tight gas (gas in very impermeable reservoirs with very low porosity), and gas shales (gas found in the shale rock created during the Devonian period of the Paleozoic era)—are referred to as unconventional gases. Compared with a representative conventional gas well in the United States from the 1960s, for example, the gas from these sources tends to have low ultimate recovery per well and low average production rates. Production depends on the application of horizontal

Figure 1. Pyramid View of Energy Resources



Source: Courtesy of USGS, from Ahlbrandt and McCabe (2002).

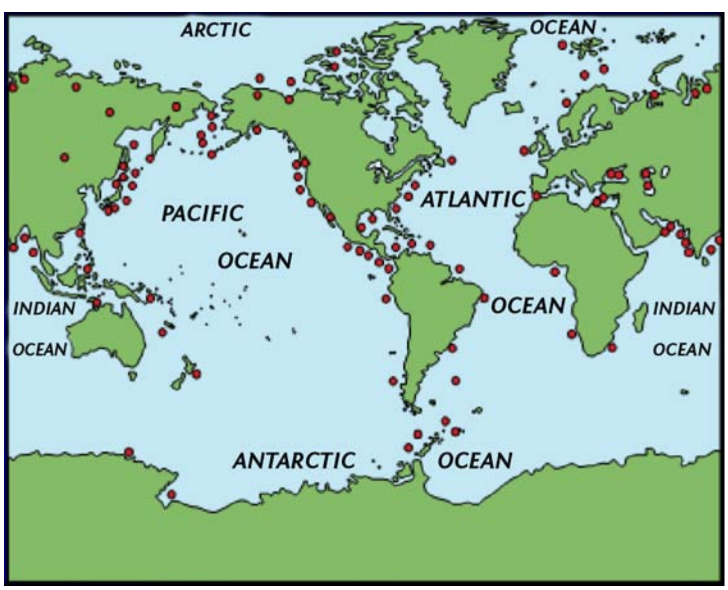
The resource base pyramid. The technically recoverable component of the pyramid (the middle) is that which can be exploited using current technology; the economically recoverable component (the top) is that portion of the technically recoverable component that can be exploited profitably under current market conditions.

drilling technology and artificially fracturing the methane-bearing rock. With a horizontal well, the operator drills vertically for up to thousands of meters and then steers the drill bit until it is sideways with the methane-bearing layer of rock. In terms of the environment, horizontal drilling makes it possible to exploit the energy resources that may lie beneath an environmentally sensitive location by drilling from a location that may be a kilometer or more away. With respect to fracturing technology, there are environmental risks if the chemicals used to help fracture the shale enter the water table. One well may use 2 to 4 millions of gallons of water that often ends up containing salt, hydrocarbons, and fracturing fluids (Groat 2009, 20). While these adverse impacts can possibly be mitigated, under current U.S. policy, hydraulic fracturing is exempt from Safe Drinking Water Act provisions (Groat 2009, 21).

A large proportion of the world's remaining natural gas resources are accounted for as unconventional gas. According to the USGS and the Minerals Management Service of the Department of the Interior, the technically recoverable natural gas resources of the United States were approximately 49 trillion cubic meters as of 1 January 2007 (USEIA 2009b, 115). To put this number in perspective, this quantity is about eighty-five times the level of domestic production around that time. Approximately 18 trillion cubic meters of these resources are from unconventional sources such as gas from tight formations, gas shale, and coal-bed methane. These resources have historically been viewed as costly relative to conventional gas and thus are sometimes considered midlevel on the resource pyramid. Resources at the base of the pyramid include gas hydrates, which are molecules of methane trapped within molecular structures, or "cages," of ice. A clump of these hydrates looks much like a snowball—a "snowball" that if set on fire burns with a clean blue flame.

In contrast to conventional oil and gas, the world's gas hydrate resources are geographically dispersed. (See figure 2.) They are also very large. Estimates of the world's *in-place* natural gas hydrate resources range widely from about 2,830 trillion to 7,640,000 trillion cubic meters (Collett 2009, 1, 2). These values are between 1,000 and 6,400 times the world's current level of natural gas production. And while large, they do not address the issue of recoverability, that is, how much of the gas we can expect to actually produce. There are potential hazards associated with the production of natural gas from hydrates (USEIA 1998, chapter 3). These risks include the inadvertent release of large amounts of methane. Among the interesting developments on this issue are the reports of approximately 2.4 trillion cubic meters of undiscovered, technically recoverable gas from natural gas hydrates on Alaska's North Slope

Figure 2. Likely Locations of Gas Hydrates Worldwide



Source: United States Geological Survey. (n.d.). Gas hydrates. Retrieved February 2, 2010, from http://energy.usgs.gov/other/gashydrates/

Gas hydrates, icelike solids formed from a combination of water and natural gas, are extremely abundant around the world. Economically feasible extraction, however, remains elusive, at least in the immediate future.

(USGS 2008, 3). In 2009 the USGS reported that the U.S. Gulf of Mexico contains gas hydrates that can produce gas using existing technology; this may be an important finding given that this area already has the necessary infrastructure (e.g., pipelines and drilling platforms) to produce the gas. Despite these developments, 2020 is probably the earliest that the production of gas from hydrates is commercialized in significant quantities.

The Shale Gas Revolution

Shale gas is largely comprised of methane trapped in shale rock. The gas is liberated from the rock and will flow through the wellbore, or drilled hole, to the surface when the rock is fractured. It is distinct from unconventional sources of oil such oil shale and oil sands, both of which are very carbon intensive in terms of extraction since both require heat to extract the resource. At one time, shale gas was considered a marginal supply source because the low permeability of the shale rock contributes to production levels that are largely subeconomic. Indicative of this is the fact the USEIA did not report shale gas reserves until 2007; since 1989 its focus was the reserves of conventional gas and coal-bed methane. This perception began changing in the late 1990s when natural gas producers in Texas reported success in developing the Barnett shale field by using horizontal drilling and hydraulic fracturing technology. By drilling wells horizontally, the rate of extraction is higher since the rock formations are also horizontally oriented.

Hydraulic fracturing technology uses high-pressure water or chemicals to induce fractures in the rock. These fractures liberate the gas from the rock and can lead to production levels that justify this high-cost well drilling. Refinement of these technologies has significantly altered the economics of shale gas production, both in the United States and throughout the world.

As of 2010, the Marcellus shale formation (which runs from New York through the western portion of Pennsylvania, into the eastern half of Ohio, and through West Virginia) is the epicenter of shale gas activity in the United States. As recently as 2002, the USGS believed that the undiscovered gas resources of the Marcellus shale are between 22.6 billion and 101.9 billion cubic meters of gas, with a mean of about 56.6 billion (USGS 2003, 1). By 2008, some believed that approximately 1.4 trillion cubic meters of shale gas could be recoverable, with significantly higher quantities possible depending on technology (Messer and Fong 2008).

Unlike conventional gas, there is little or no exploration risk (the financial risk of drilling a "dry hole") associated with shale gas—the shale deposits are known, and the only issue is locating the "sweet spots." Moreover, in contrast to gas located on the North Slope of Alaska (a "conventional but remote gas" not yet economically feasible to produce because it lacks a pipeline infrastructure), a large portion of the shale gas resources are located near market centers in the northeastern United States.

Worldwide Implications

The USEIA believes that advances in unconventional gas technology have worldwide implications for the natural gas supply. For example, both Europe and Asia are believed to have large quantities of gas shale resources that could be exploited (Sweetnam and USEIA 2009). According to Nobuo Tanaka, the executive director of the International Energy Agency (2009), "Unconventional gas is unquestionably a game-changer in North America with potentially significant implications for the rest of the world." Tony Hayward, the chief executive of BP, one of the world's largest energy producers, has indicated that BP is applying the gas shale technology to other regions, including North Africa, the Middle East, Europe, China, and Latin America; he has further stated that unconventional gas resources could contribute an extra 4,000 trillion cubic feet to reserves over the next few years (Watson 2009). BP is not alone in its assessment: BG, Petronas, StatoilHydro, Shell, and ConocoPhillips have expanded their activity in unconventional gas plays.

Exxon is also active in applying the technology and has obtained leases in prospective shale-gas formations in Germany, Hungary, and Poland (Gold 2009). If these prospects are developed, Europe's dependence on gas supplies from Russia could be significantly reduced. It is therefore not surprising that Alexander Medvedev, deputy chief executive of Gazprom (the world's largest natural gas extractor), has dismissed the significance of unconventional resources (Watson 2009). There is some truth to his skepticism; constraints on drilling and the absence of attractive fiscal terms are likely to be barriers to development. There are also legitimate environmental concerns about the effect of fracturing on water supplies.

The effect of the increase in natural gas supply on carbon emissions has recently been analyzed by the think tank Resources for the Future. It concludes that the additional gas supplies and improvements in drilling technologies make it possible for natural gas to be an important bridge fuel (a low-carbon alternative to coal used while renewable energy sources are being developed)—but only if either a carbon tax or cap-and-trade program are implemented (Brown, Krupnick, and Walls 2009).

Natural gas is a nonrenewable fossil fuel, and its use contributes to global warming. Yet because it is the cleanest fossil fuel, has lower sequestration costs relative to coal, and is far more abundant than previously believed, the substitution of natural gas for coal in the electric power sector can make a major contribution to a more sustainable world. This transition has already begun; it will accelerate only if carbon emissions into the atmosphere are priced into all fuels, that is, when either a carbon tax is imposed or cap-and-trade legislation is passed.

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See also Cap-and-Trade Legislation; Energy Efficiency; Energy Industries—Coal; Energy Industries—Overview of Renewables; Mining; True Cost Economics

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Energy Industries—Nuclear

The nuclear power industry evolved from the same technology that developed the atomic bombs used during World War II. While some advocates champion its abundant, clean, economical, and sustainable properties, others question the safety of power plants and storage and/or disposal of spent nuclear fuel. Research and innovations in nuclear technology will continue to inspire both sides of the debate.

Particle physics was about fifty years old in January 1939 when Lise Meitner and Otto Frisch used the word *fission* to describe a new process in which an atom's nucleus splits into two parts, releasing large amounts of energy. Researchers learned that uranium isotope 235 (U-235) would produce a chain reaction and an explosion thousands of times more powerful than any chemical explosive. In February 1941, the scientist Glenn Seaborg and colleagues reported a new element—plutonium—formed when the other uranium isotope (U-238) absorbed a neutron. Plutonium fissions like uranium, but it takes less plutonium metal to make a bomb.

The United States entered World War II on 7 December 1941, and everything nuclear under development by the Manhattan District Project was classified top secret. On 6 August1945, the uranium bomb exploded over Hiroshima, and on 9 August 1945, a plutonium bomb exploded over Nagasaki, Japan. Worldwide shock and fear about "the bomb" followed this event (Rhodes 1986).

Nuclear energy was tamed when Admiral Hyman Rickover's group developed a reactor to power submarines (Bodansky 2004, 31), and the USS *Nautilus* was launched 9 November 1954. During the same time frame, industrial firms that built the U.S. Navy reactors (including General Electric and Westinghouse) also constructed domestic electric power plants. Some of the navy's nuclear technology was declassified, and federal funds were made available to develop nuclear reactors to generate commercial utility electricity.

Nuclear Power Plants Today

A nuclear power plant replaces the furnace that burns coal, oil, gas, trash, or other fuels with a nuclear reactor designed to control the rate of fission to produce heat and steam that turn turbines to produce electricity. The 104 nuclear power plants in the United States, as of 2009, produce about 20 percent of the nation's electricity (WNA 2009a). The plants employ either boiling water reactors (BWRs) or pressurized water reactors (PWRs), the latter of which will be used to describe below how nuclear reactors work (Cochran and Tsoulfanidis 1990, 84–95).

Uranium from the mine is 0.71 percent U-235 and 99.29 percent U-238. The uranium metal is recovered as a "yellow cake" (U_2O_8) that is converted to uranium hexafluoride (UF_6), a solid at room temperature that melts at 64.6°C. It forms a vapor at low pressure that is passed through a series of high-speed centrifuges, which enriches the slightly lighter-weight U-235 to the PWR fuel composition of 3.75 percent U-235 and 96.25 percent U-238. This mechanical separation cannot remove all of the U-235 from mine-grade uranium. To make one tonne of enriched uranium fuel, about seven tonnes of natural uranium are required. This leaves about six tonnes of "depleted" UF_6 that contains about 0.2 percent U-235. The depleted uranium hexafluoride is not used and is stored in stainless steel cylinders (Bodansky 2004, 208).

The fuel-grade uranium hexafluoride is converted to uranium oxide powder that is pressed into pellets. The pellets are sintered (forming a solid much like fine china), and each pellet is precision ground to a diameter of 0.8 centimeters and length of 1.35 centimeters. The pellets are loaded into thin-walled alloy tubes 1.0 centimeter in diameter and 3.7 meters long, and each tube is filled with helium and sealed. Extra space in the tube allows the fuel pellets to swell because when a uranium atom fissions, it forms two fission product atoms that take a little more space. Xenon and krypton are fission product gases that collect in the fuel rod.

A 17 × 17 array of fuel rods forms a PWR fuel assembly. There are both top and bottom plates that distribute circulating water, and several spacer plates located between the end plates hold the fuel rods in a fixed position. Some tube positions hold radiation and temperature measurement probes, and there are control rods to maintain the fission rate at a constant or to shut down the reactor. A reactor core contains about 190 fuel assemblies (about 50,000 fuel rods), about 125 tonnes of the uranium oxide fuel pellets.

The core of the reactor is placed in a massive cylindrical steel pressure vessel that is about 12 meters high and 4.5 meters in diameter; the walls are 30 centimeters thick. Water remains liquid at about 15.5 MPa (2,250 psi) pressure while it is heated from about 290° to 325°C and is continuously pumped through the reactor core. (A megapascal, or MPa, is a unit of pressure measurement, as is "pounds per square inch," or psi.) The high-pressure hot water is circulated through steam generators to produce the steam that spins the turbine to produce electricity. The liquid water also serves to "slow down" the neutrons to increase the probability that fission will occur.

The nuclear reactor, water pumps, and the steam generators are located in a massive, reinforced concrete building (*reactor containment*) that is closed and sealed when the reactor is running. This isolates the reactor from the reactor operators and the public.

Each fuel assembly remains in the reactor for about three years. As the U-235 in the fuel assembly fissions, some of the U-238 captures a neutron and is converted to plutonium. The resultant plutonium is also a nuclear fuel that fissions, yielding about 40 percent of the energy produced during the three-year fuel cycle (Bodansky 2004, 212). The reactor is shut down, and new fuel assemblies replace half of the core assemblies on an eighteen-month refueling schedule.

The spent fuel elements are very radioactive and spontaneously release radiation and heat. They are stored in a pool of water containing dissolved boron, which absorbs neutrons that are released. The water collects the radioactive decay heat and serves as a shield to stop the penetrating gamma radiation (high energy X-rays). Each nuclear power plant has a storage pool designed to accumulate the spent fuel over the designed life of the power plant. Recently, the United States Nuclear Regulatory Commission (NRC) has approved applications to extend the operating license of some older nuclear plants from forty to sixty years. At these sites, "old" spent fuel is moved to dry storage containers on the power plant site.

Nuclear Power Plant Safety

Safety is a major concern in discussions about nuclear energy. Nuclear power plant safety has two components: (1) protect workers and the public from radiation and (2) minimize the risk of injury from using heavy equipment. Many occupational safety statistics have been reported over the past forty-plus years of nuclear reactor operations in the United States and the United Kingdom. The World Nuclear Association (2008) has collected data on the total number of "mine to electricity" fatalities (not including power plant construction) for the years 1970 to 1992. When each energy source produces the same amount of electricity, the number of deaths that occur for each energy source is shown in table 1.

The nuclear power industry is careful to maintain low employee exposure to radiation. In the United States, the NRC sets the limits for radiation exposure to workers. All procedures for operating the power plant reactor and handling radioactive material must comply with the NRC guidelines. Everyone (worker or visitor) must carry a radiation dosimeter while on the plant site, and the health physics staff maintains records of every individual's accumulated exposure to radiation. (*Health physics* is defined as the science of human health and radiation exposure). The NRC has authority to shut down any facility licensed to possess or handle radioactive materials that fails to observe the approved procedures.

The occupational radiation exposure to workers at nuclear installations world-wide in 2009 was about half

Table 1. **Comparison of Accident Statistics in Primary Energy Production**

Energy Source	Deaths per TWy* Electricity	Who is affected?
Coal	342	Workers
Natural Gas	85	Workers and public
Hydroelectric	883	Public
Nuclear	8	Workers

*TWy is one trillion (one-million million) watts produced for a year, or 876,600 gigawatt-hours.

Source: World Nuclear Association (2008).

The number of deaths related to electricity generation in the nuclear energy industry is considerably less than the coal, natural gas, or hydroelectric industries per unit of electricity generated.

that of exposures in 1990 (IAEA 2009, 17). Total population exposures continue to increase due to the increased use of radiation in medical procedures.

Civilian nuclear power plants have operated for fifty years—more than 12,700 cumulative reactor-years in thirty-two countries with two major accidents. Three Mile Island's reactor core meltdown near Harrisburg, Pennsylvania, in 1979 produced a financial loss, but radiation exposure was limited to the reactor containment building with essentially no health or environmental consequences (WNA 2008). In 1986 there was a steam explosion at the Chernobyl, Ukraine, reactor and a fire fueled by tonnes of graphite (pure carbon) in the reactor core, which produced widespread radiation poisoning since there was no reactor containment building. There were fifty-six deaths officially reported (although the actual number is thought to be much higher), and significant health and environmental consequences are still being monitored. These two accidents were a major blow to public confidence in nuclear power programs (Bodansky 2004, 436).

Radiation is everywhere, and at sea level exposure is about 300 millirem (mrem, an energy scale used for subatomic particles and radiation) per year (Idaho Department of Environmental Quality 2009). When proper procedures are followed, however, the radioactive burden presented to the public outside a nuclear power plant is nearly zero. The operating license requirement to protect nuclear power–plant workers and the public from radiation is a powerful incentive to maintain this low radiation exposure and should assure those who still fear nuclear power plants.

Nuclear Power Plant Economics

There are two important questions to consider when it is necessary to add any power plant to supply customer electricity: how much will the "metered" electricity cost, and how does the utility (usually an investor-owned firm) cover the power plant construction costs?

All electric power plants are expensive. It is very complicated to estimate the cost to build a nuclear power plant and the price of electricity over the forty- to sixty-year life of the plant. A panel of experts at Massachusetts Institute of Technology (2009) estimated the costs to build fossil fuel–fired and nuclear power plants, shown in table 2.

The "overnight cost" is the capital investment in dollars per kilowatt installed capacity ($/kW) that it will cost to build the power plant, assuming all funds are spent in one day (no site development, construction delay, or construction loan costs are included). The "base case" (engineering estimates based on today's "best available" power plant technology for each energy source) assumes nuclear power plant investments are risky, requiring 10 percent interest charge; interest for coal and natural gas are set at 7.8 percent. When the nuclear plant interest is dropped to an equivalent 7.8 percent, the estimate shows nuclear power is cost competitive with coal and natural gas "at the meter." The only real test of these estimates is to build the power plants and sell power over the years the plant operates. Most states within the United States have a public service commission that approves any plan to build a power plant, and they review (usually annually or when the utility requests a rate increase) the retail price of the power, a control on "free market" excesses.

Available Uranium for Nuclear Fuel

All new nuclear power plants built in the next thirty years will be water-cooled reactors based on the best available technology; any new reactor technology will not be ready to deploy for about thirty years. Reactors are designed to use a "once through" uranium fuel cycle that extracts only 3–4 percent of the energy available in the fuel. Spent fuel is removed, stored, and replaced by new fuel.

It takes about seven tonnes of natural uranium (0.71 percent U-235) to produce one tonne of pressurized water reactor (PWR) fuel (3.75 percent U-235). This will leave

TABLE 2. **Cost of Electric Generation Alternatives**

Plant type	Overnight Cost ($/kW)	Fuel Cost ($/million Btu)	Base Case Cost (¢/kWh)	w/carbon charge $25/tonne CO_2 (¢/kWh)	w/same interest ¢/kWh
Nuclear	4,000	0.67	8.4		6.6
Coal	2,300	2.60	6.2	8.3	—
Natural Gas	850	7.00	6.5	7.4	—

Source: Massachusetts Institute of Technology (2009, 6).

Although electricity generated by coal and natural gas is less costly when the perceived higher "risk" of nuclear energy is considered (base case), nuclear power is actually competitive with other energy sources when the assumed risks are equivalent.

about six tonnes of depleted uranium (0.2 percent U-235). Fuel enrichment in the United States has produced about 480,000 tonnes of heavy metal (MTHM) of depleted uranium; the figure worldwide is about 1,189,000 MTHM (Depleted Uranium 2008). Each year the power plants add about 12,600 MTHM to the U.S. inventory.

A report prepared for Congress stated that the U.S. inventory of spent nuclear fuel in 2002 was approximately 47,000 MTHM, and every year the 104 operating commercial reactors contribute an additional 2,150 MTHM of spent fuel (Andrews 2004, 3–5). Based on these figures, the current U.S. inventory of spent nuclear fuel is estimated at approximately 64,200 MTHM.

Current spent fuel inventories present a very long-term disposal problem and a serious objection by those opposed to nuclear power. The spent fuel remains radioactive for tens of thousands of years because it contains the heavy metals neptunium, americium, and curium in addition to uranium and plutonium. It is possible to chemically separate all five elements, leaving the fission products for disposal (Bodansky 2004, 213–222). All of the elements beyond uranium in the periodic table (including all of the heavy metals listed above) become fuel in next-generation fast neutron reactors that are being developed (Bodansky 2004, 186–190).

Nuclear Reactors Worldwide

As of 2009 thirty-one countries with 436 nuclear reactors operate with an installed capacity of about 370 gigawatts (GW). One gigawatt is equal to one million watts and is enough to power 780,000 average U.S. homes in a given instant (calculation based on data from USEIA 2009). (Please refer to the sidebar "What's the difference between a gigawatt and a gigawatt-hour?" on pages 148–149 for more on this topic.) There are fifteen countries that have fifty-three plants under construction with nameplate capacity (maximum rated output) of 47 GW. Table 3 on page 187 lists the countries with substantial nuclear power in operation and with new reactors under construction (European Nuclear Society 2010; WNA 2010). The new plants should become operational during the period 2015–2017. The new reactor construction initiative is clearly outside the United States.

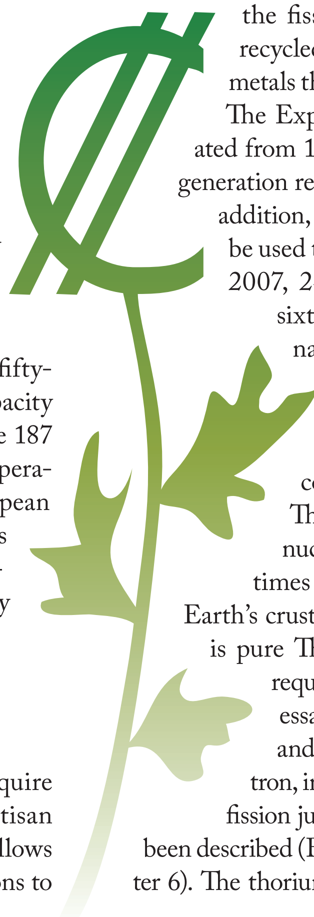
The Future

All future energy options for the United States require a long-term (thirty to fifty years) politically bipartisan energy policy that provides funds for research and allows operating-plant scale comparisons of all energy options to produce sustainable commercial electricity. The safety and competitive cost of nuclear power have been demonstrated with the global fleet of reactors operating today. Since the 1980s when the United States stopped developing nuclear energy systems, growth has moved global. (See table 3.) Nuclear energy development into the next century must adhere to the following strategic components (Lister and Rosner 2009):

- The energy produced must be "cost effective."
- Safety must be a primary design objective.
- Design must minimize risk of nuclear theft and terrorism (weapons proliferation).
- Size must be appropriate to match the national distribution grid.
- New systems development should be "evolutionary" rather than "radical."

The BWR and PWR nuclear reactor technology "fine tuning" during the past twenty years has been done outside the United States. These are the reactors that will be added to the worldwide nuclear fleet in the next thirty years.

Nuclear energy becomes sustainable in the long-term when the "whole tonne" of uranium is used as fuel. Opponents of nuclear energy contend that spent nuclear fuel inventories are especially risky, thus work on the chemistry to separate the heavy metal fuel values from the fission products should continue. This recycled fuel will be a mixture of fissionable metals that cannot be used as a nuclear weapon. The Experimental Breeder Reactor II (operated from 1965 to 1995) is an example of a next-generation reactor that can use reprocessed fuel. In addition, all the U-238 in depleted uranium can be used to "close the nuclear fuel cycle" (Stacey 2007, 244). This strategy produces roughly sixty times as much energy per tonne of natural uranium as the "once through" PWR (MacKay 2009, 162).



Early in the development of domestic nuclear energy, there was concern about a shortage of uranium. Thorium was considered to be a good nuclear fuel because there is over three times as much thorium as uranium in the Earth's crust (Lide 2005, 14–17). Natural thorium is pure Th-232, so isotope enrichment that is required for PWR uranium fuel is unnecessary. When Th-232 is placed in a reactor and a thorium atom nucleus accepts a neutron, in a short time it becomes U-233 that will fission just like U-235; a thorium fuel cycle has been described (Benedict, Pigford, and Levi 1981, chapter 6). The thorium fuel option supplementing uranium

TABLE 3. **Nuclear Reactors Worldwide**

Country	Reactors In Operation	Current Output (GW)	Reactors Under Construction	Additional Output (GW)
China	11	8.4	16	15.2
France	59	63.2	1	1.6
Germany	17	20.5	0	0
India	17	20.5	6	2.9
Japan	53	46	2	2.2
Russian Federation	31	21.7	9	6.9
South Korea	20	17.6	6	6.5
Ukraine	15	13.1	2	1.9
United Kingdom	19	10.1	0	0
United States	104	100.7	1	1.1
All Others	90	48.3	10	8.8
Total	436	370.2	53	47.2

Source: European Nuclear Society (2010).

Construction of new nuclear power facilities for 2010 and beyond is concentrated in countries outside the United States, currently the world leader in nuclear power generation output; China, currently the world's largest consumer of coal, has the most nuclear power plants planned.

fuel can supply the growing world energy demand for thousands of years (MacKay 2009, 166).

Sustainable energy options into the future will include solar, wind, biofuels, and nuclear. Today nuclear power plants provide 20 percent of the electricity in the United States and about 16 percent globally using incremental improvements on 1960s technology. Sustainability depends on closing the nuclear fuel cycle. The chemistry and physics required to develop "new reactor technology" and use these fuels has been identified. But science and technology is fourth on the list: there must be the national political will, funding must be provided, and public opinion must be supportive before new nuclear technology will be demonstrated.

The energy infrastructure is huge, and additions to meet demands will be expensive, so any changes will be incremental. This provides time to analyze all of the energy options, choose among sustainable energy paths, conduct the science-based research, and demonstrate commercial-scale advanced technologies (Peters 2009). Nuclear energy is about fifty years old, and the developments described here could take another one hundred years. That is enough time.

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See also Consumer Behavior; Energy Efficiency; Energy Industries—Overview of Renewables; Mining; True Cost Economics

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Energy Industries—Oil

Over one-third of the energy consumed globally is supplied by the oil industry, which has been criticized widely for the environmental damage done by oil extraction, transportation (including oil spills), and carbon emissions. Industry reactions to charges about their responsibility for climate change are mixed; some companies have made worldwide efforts to improve both their environmental impacts and humanitarian contributions.

One day historians may call the latter half of the twentieth and early twenty-first centuries the Oil Age; oil is the world's most used fuel, accounting for an estimated 35 percent of the world's energy consumption in 2008 (BP 2009b, 42). Although this energy-rich, portable mixture has been used to heat buildings, generate electricity, and (briefly) provide light, it is the dominant fuel source for land, air, and sea transportation. Demand for nonfuel products of oil refinement, such as lubricants, asphalts, and the raw materials for plastics, has also risen around the world. In 2008, over 29 billion barrels—81 million barrels daily—of crude oil were extracted from the Earth, making its production one of the world's largest industries (BP 2009b, 8). (One barrel of oil contains the energy equivalent of 1,700 kilowatt-hours [ORNL n.d.], enough energy to power an average U.S. home for 55 days [calculation based on data from USEIA 2009b]. For more on this topic please refer to the sidebar "What's the difference between a gigawatt and a gigawatt-hour?" on pages 148–149.) In 2009, seven out of the top ten companies on *Fortune's* Global 500 list, which ranks the world's companies by total revenue, were petroleum producers; the magazine also ranked crude oil production as the most profitable business, with an approximate 20 percent return on revenue (CNN 2009).

The oil industry has had a tremendous impact on the world, yet that impact hasn't always been positive. The extraction and transportation of crude oil disrupts the environment above the reserves, altering the natural landscape and leeching oil and sometimes other hazards into the surrounding water supply. Oil spills, such as that of the *Exxon Valdez* in 1989, can have detrimental effects on the surrounding ecosystems. Oil production adds to air pollution, while oil combustion is one of the world's leading sources of greenhouse gases. Since oil is essentially a finite resource, there has been widespread concern about massive shortages, possibly leading to economic collapse. Each of the six "supermajor" oil producers (ExxonMobil, Royal Dutch Shell, BP, Chevron, ConocoPhillips, and Total SA) has been accused of involvement in human rights violations, political corruption, or both (Erman 2008; Kahn 2009; O'Reilly and Decker 2009; Rose 2004; Stancich 2003). And in 1988, an offshore oil rig explosion in the North Sea resulted in 167 deaths; this accident and other incidents led to concerns regarding worker safety. Such issues have caused some oil producers to look to their long-term survival, adopting principles to minimize their activities' negative impacts—or to make even a positive impact—on the environment, the economy, and society.

End of the Oil Age?

There is no exact method for measuring the amount of oil below the Earth's surface; therefore there is no certainty as to when the world might run out of oil. Because of the resource's primacy on the energy market and the growing energy demand, debate (often heated) and speculation (sometimes wild) surround the subject. Estimates of the amount ultimately recoverable vary as new reserves are discovered and improved drilling technologies, such as directional drilling, allow oil producers to tap reserves that were previously inaccessible. According to the World Energy

Council, just over 1 trillion barrels have been extracted—a majority of that over the last twenty-five years, and slightly less than 3 trillion barrels remain (World Energy Council 2007, 55). The U.S. Geological Survey (2000), however, estimates the worldwide expected ultimate recovery (the quantity produced plus the quantity left) at only 3 trillion barrels.

Oil is trapped in reservoirs within porous or fractured rock and requires pressure to flow into a well bore; when more than approximately 10 percent of a reservoir has been removed, the rate at which hydrostatic pressure forces the oil into the well drops dramatically—this is known as "primary recovery" (US DOE 2008). At this point, oil producers force oil into the well bore by pumping water into the surrounding rock; an additional 10–20 percent can be recovered in this manner (known as "secondary recovery"). According to one U. S. Department of Energy report, enhanced oil recovery techniques, such as carbon dioxide injection and steam injection, allow oil companies to extract 30–60 percent or more of the oil in a reservoir, but the cost of these measures has often been prohibitive. Improvements in carbon dioxide capture technology since 2005 will allow enhanced recovery in areas where it had not been feasible, which means an additional 89 billion barrels of crude might be recovered in the U.S. alone (US DOE 2008). As rising global demand spurs oil companies to develop better recovery technology, estimates of the amount ultimately recoverable can be expected to rise.

Conventional oil wells are not the world's only source of petroleum; synthetic crude oil can be extracted from oil sands (bitumens), oil shales, and extra-heavy oil deposits. According to the World Energy Council's *2007 Survey of Energy Resources*, the total volume of bitumens (oil sands) and extra-heavy oil is estimated to be close to 5.7 trillion barrels, with an additional 2.8 billion barrels in oil shale, although estimates of the amount that is ultimately recoverable vary widely (110, 133).

Higher recovery rates and these new sources may not be enough to sustain the oil industry. Unfortunately the extraction, processing, and transportation costs (in dollars and in energy) for oil sands and oil shale are higher than those for conventional oil. Capturing these resources also contributes to deforestation and water, land, and air pollution—oil sands operations in Alberta produce more greenhouse gas than some European countries (LaForest 2009). Some organizations, such as the Association for the Study of Peak Oil and Gas, predict that even with the additional sources, world oil production will peak and begin to decline before 2020, as the periods of prime output end for many wells in the Middle East (World Energy Council 2007, 63). While the U.S. Energy Information Administration (2009) predicts that global oil production will increase by 20 percent from 2010 to 2030, the same report predicts that the world energy demand will rise by more than 30 percent over the same period.

As the Saudi oil minister Sheikh Zaki Yamani pointed out in the 1970s (in a statement that has been widely quoted ever since): "The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil." Oil replaced coal as the world's energy source only after improvements in technology (internal combustion engine, diesel engine, rolling rock-cutter bits, offshore drilling, and catalytic cracking) made oil-powered transportation more economical than coal-powered transportation. In 1866, the British economist William Stanley Jevons's *The Coal Question* predicted the collapse of the British Empire due to depletion of its coal reserves; he failed to recognize the role petroleum would play in the future of the world energy market. Similarly, those predicting a crisis upon the depletion of the world's oil assume that it will not be replaced by other fuel sources as alternatives become more economically viable. Few would argue that oil will continue to meet the world's growing energy needs in the coming centuries.

From Petrochemical Company to Energy Company

In response to the threat of an energy deficit, some of the world's largest oil and natural gas producers have reframed themselves as "energy companies." For example, in 2007 BP Solar announced plans to construct a 300 megawatt (MW) solar plant at its headquarters in Tres Cantos, Spain, along with a similar facility in Bangalore, India. As part of a twenty-five-year contract with the Spanish government, BP Solar will sell electricity from the Tres Cantos plant to Spanish utilities at 575 percent the cost of production (Foreign Policy 2008). Chevron Energy Solutions has installed rooftop solar-energy systems at public facilities, such as the Los Angeles Metropolitan Transportation Authority, and developed a system that converts methane from wastewater sludge and kitchen grease into electricity without combustion (Chevron Corporation 2009b). Chevron (2009a) also claims to be the world's largest producer of geothermal energy, while Shell (2009a) was involved in the construction of a 108 MW wind farm off the coast of the Netherlands. Although such projects show a commitment to promoting stationary renewable energy sources, they do little to address the world's transportation energy needs.

Alternative Fuels

Since the beginning of the twenty-first century, big oil companies have set aside billions of dollars toward the search for viable alternates to gasoline, diesel, and aviation fuel (Krauss 2009). The push is due in part to mandates by state and federal governments. Shell, for example, quadrupled their investment in renewable fuel research after the U.S. Congress passed the Energy Independence and Security Act of 2007, which requires a total of 34 billion liters of renewable fuel to be added to fossil fuels sold in the United States in 2009, and 136 billion liters by 2022. But the sanctions are not the only incentives for oil companies to find a renewable fuel source; Phil New, the president of BP's biofuels unit says, "We can see biofuels as being a really big potential reservoir" (Krauss 2009). The existing processes for making biofuels—hydrocarbon fuels made from biological sources such as wood, corn, or plant waste—cost more than producing the energy equivalent in fossil fuels, and the use of some biofuels requires special modifications to vehicles and distribution equipment. For instance, ethanol is already used as a gasoline additive in concentrations as high as 15 percent, but in higher concentrations it causes corrosion of fuel lines and requires additional measures to prevent accidental combustion.

Reducing Emissions

The oil industry's reaction to climate change and greenhouse gas (GHG) emissions has been mixed. In 1989, Exxon, Royal Dutch Shell, BP, and Texaco became members of the Global Climate Coalition, a group whose main objective was to oppose restrictions on greenhouse gas emissions. BP was one of the first major industry players to withdraw from the coalition in 1997 and even voiced support for setting a global carbon price. Until 2005 ExxonMobil continued to refute a correlation between carbon dioxide emissions and global warming and funded the Competitive Enterprise Institute, which ran ads extolling the benefits of carbon dioxide; the oil giant also openly opposed U.S. participation in the Kyoto Protocol—an agreement that would set limits on the carbon emissions of member nations. In early 2009, however, Exxon executive Rex Tillerson announced the company's support for a carbon tax (Johnson 2009). Even though the oil industry has publicly softened its stance on GHG legislation, some nonprofit groups, such as Greenpeace, claim that oil companies continue to covertly oppose emission restrictions (Davies 2009).

According to a study commissioned by the American Petroleum Institute, between 2000 and 2008 U.S. oil and natural gas companies invested more than $50 billion in technology aimed at reducing carbon emitted during petroleum production, and developing lower emission vehicles and lower emission fuels (Bush 2009). Royal Dutch Shell's Quest project, which received a funding boost from the Canadian and Albertan governments in late 2009, is expected to reduce the carbon dioxide emissions of its oil sands operations by 40 percent using carbon capture and storage technology (Taylor 2009). The system collects exhausts and sequesters it deep underground in oil reservoirs, or the gases can be used to enhance conventional oil recovery. Other GHG mitigation efforts include cogeneration, which uses the same source for powering and heating a production operation. Several oil giants have also invested in research into more efficient processes for synthesizing cleaner-burning fuels from methanol, natural gas, or gasified coal, but the current processes for making these fuels release more carbon than they save. The U.S. Environmental Protection Agency's *Inventory of Greenhouse Gas Emissions and Sinks: 1990–2007* listed combustion of petroleum as the top source of carbon dioxide emissions in the United States, with the burning of coal for electricity generation a close second (US EPA 2009a, 95).

Cleaning Up Their Acts

The *Exxon Valdez* incident raised public concern about the release of oil into marine environments. (In March 1989, the *Exxon Valdez* spilled 41.6 million liters of crude oil into Alaska's Prince William Sound, the largest spill in U.S. history.) In 1990, the U.S. Congress passed the Oil Pollution Act, which created a fund for oil-spill cleanup, increased the owner liability for facilities and vessels that spill oil, and required oil producers to create contingency plans for spill events (US EPA 2009b). Accidental spills account for about 10 percent of the oil released into the oceans each year; normal marine transportation contributes roughly a quarter, but nearly half of the oil entering the oceans comes from natural seepages (Woods Hole Oceanographic Institution 2009). ExxonMobil reported $5.2 billion in environmental expenditures in 2008, and BP reported spending $4.0 billion in 2006 (ExxonMobil Corporation 2009b; BP 2009a). These figures include increased operating costs, remediation efforts, and cleanup costs, but they also include the costs of maintaining and replacing equipment, which are not strictly environmental (BP 2009a).

Social Responsibility

The oil industry has also suffered from a tarnished humanitarian image, which it has tried to clean up in recent years. In 2001 Indonesian workers sued ExxonMobil for human rights violations allegedly committed by a security force under the company's employ, but the case was dismissed in 2009 because the workers were not legal U.S. residents (O'Reilly and Decker 2009). Similarly, Royal Dutch Shell was sued for alleged complicity in the 1995 hanging deaths of Nigerian environmentalists and settled before the case reached the U.S. District Court (Kahn 2009). The six supermajor oil companies each support community development initiatives. In 2009 Shell won an award from the Global Business Council for its support of a program aimed at treating and slowing the spread of HIV/AIDS in Nigeria (Shell 2009b). Since 2000 ExxonMobil has committed $50 million to a program for combating malaria in Angola and Nigeria, called the African Health Initiative (ExxonMobil 2009a). The U.S. Bureau of Labor and Statistics (2009) reported that the 2008 U.S. fatality rate for the oil industry was more than six times that of the national rate—but lower than the logging, fishing, and crop production industries and on par with water and truck transportation.

Future of the Oil (Energy) Industry

Whether the sustainability efforts of the oil and gas giants are genuine or just greenwashing remains to be seen. Even though the oil industry was the most profitable in 2008 (ExxonMobil reported $45 billion in profit), it spent less on advertising than the auto, restaurant, wireless, pharmaceutical, and several other industries (Nielsen 2009). Expenditures on sustainability efforts could be interpreted as a form of public relations. In 2009 Shell cut funding to its renewable energy programs, except for biofuel research, and BP shareholders voted against further funding for sustainability efforts, in spite of its "Beyond Petroleum" slogan. ExxonMobil's Outlook for Energy predicts that oil will provide 34 percent of the world's energy needs in 2030, a slight decrease from 2009 (2008, 15). Some petroleum companies may be preparing for a transition to renewable energy sources over the next fifty to one hundred years, but oil and gas companies are likely to remain primarily oil and gas companies for as long as the sale of petroleum products remains highly profitable.

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See also Automobile Industry; Airline Industry; Cap-and-Trade Legislation; Corporate Citizenship; Energy Industries–Overview of Renewables; Energy Industries (*assorted articles*); Greenwashing; Human Rights; Marketing; Travel and Tourism Industry; True Cost Economics

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Energy Industries—Solar

With continuing advances in technology, solar power has the potential to become an important source of renewable energy. The vast majority currently comes from solar thermal systems that use the sun's energy to heat water either for direct use or to generate electricity. Less solar power results from photovoltaic technology, which produces electricity from specific light frequencies of the sun.

In a given hour, the Earth receives more energy from the sun than humanity uses in a year. Only a fraction of this energy is usable due to limits in available surface area and technology inefficiency, yet solar power has the potential to meet much of humanity's energy needs. At the beginning of the twenty-first century, solar power is used in handheld devices, toys, hiking and camping equipment, street and landscape lighting, utility-scale solar power plants, and much more. As solar technology and manufacturing continue to advance, solar power has the capability to become an increasingly integral part of society.

Solar power comes in a variety of forms, and solar technologies can be categorized and compared in several ways, including solar thermal versus photovoltaic and concentrated solar versus flat panel solar.

Solar Thermal Technologies

Solar thermal systems use sunlight for heat, which can be used to provide warm water, to produce electricity, or for other applications. According to the policy network REN21 (2009, 9), approximately 145 gigawatts (GW) of solar thermal capacity have been installed globally, which represents more than 90 percent of total installed solar capacity (see table 1 on page 195). (A watt is a measure of power, the *rate* at which energy is converted to electricity. One gigawatt is equal to one billion watts and is enough to power 780,000 average U.S. homes in a given instant [calculation based on data from USEIA 2009b]. For more on this topic please refer to the sidebar "What's the difference between a gigawatt and a gigawatt-hour?" on pages 148–149.)

A common solar-thermal configuration consists of enclosed tubes filled with a heat transfer fluid (HTF). Sunlight strikes the tubes and warms the HTF, which in turn heats a water supply. Solar hot-water systems can function in diffuse sunlight and below the freezing point of water. They reduce the need for heating water by other means, and these systems constitute more than 145 GW of installed capacity, providing hot water for tens of millions of people (REN21 2009, 9).

Other solar thermal systems use heat to produce electricity and are often referred to as concentrated solar power (CSP). In some CSP systems, reflective surfaces are arranged to concentrate sunlight, which warms an HTF. In a trough system, a parabolic trough of reflective material focuses sunlight on a coaxial tube of oil. In a tower system, reflective surfaces are arranged over a large area to focus sunlight onto a tower, perhaps filled with molten salt. In both trough and tower systems, the HTF carries heat to a power generator, such as a steam turbine. Concentrating thermal systems can be used as independent sources of electricity, or they can be used to augment heating at coal or natural gas plants to reduce fossil fuel use.

There are numerous advantages for CSP. Because heat dissipates slowly from an HTF reservoir, system operators can capture heat throughout the day and then use the captured heat to produce electricity based on consumer demand. These systems require relatively inexpensive materials, which reduce costs, and technology for thermal power

Table 1. **Key Statistics**

Technology	Installed Capacity (December 2008)	Capacity CAGR* (2002–2008)	Market Potential, All Solar Technologies (% of Global Energy Use)
Thermal	146 GW		
Water Heating	145 GW	17%	
Concentrated	0.5 GW		Estimates vary widely. UN: 30% by 2040 USEIA**: 2% by 2030 ExxonMobil: <1% by 2030
Photovoltaic	13 GW		
Flat-Panel	13 GW	55%	
Concentrated	< 0.1 GW		

* CAGR = Compound Annual Growth Rate

** USEIA = United States Energy Information Administration

Sources: Installed capacity figures from REN21 (2009, 23); CAGR figures from REN21 (2009, 9) and REN21 (2005, 9); market potential figures from Resch and Kaye (2007, 63), USEIA (2009a, 109), ExxonMobil (2008, 38).

Most installed solar capacity (almost 90 percent) uses solar thermal (heating) systems, although photovoltaic technologies saw a greater percentage of growth from 2002 to 2008.

generation is well understood. Concentrating thermal systems currently account for less than 1 GW of installed global capacity, although the technology's advantages make it a promising future source of energy.

Solar thermal systems are not without disadvantages, however. In order to operate efficiently, each reflective surface must accurately follow the path of the sun. Solar thermal systems perform best in continuous, direct sunlight, which makes CSP impractical for many parts of the world. Solar thermal systems require water for cooling and for cleaning the reflective surfaces. Existing CSP plants are located in low-latitude deserts to utilize the abundant sunshine, but water is a limited resource in the desert.

Not all solar thermal systems use an HTF. Parabolic dishes can be used to concentrate sunlight as a heat source for a Stirling engine, a closed-system engine in which a working gas (typically air, helium, or hydrogen) is alternately heated (expanded) and cooled (contracted) to push and pull the piston and generate electricity. A Stirling system benefits from components that are very cost-effective, and it does not require an expensive HTF. Because there is no special fluid or separate steam turbine, a Stirling system may involve simpler engineering than some CSP technologies. Finally a Stirling system may be more scalable than other solar thermal systems because a field of Stirling dishes can be expanded simply by adding more dishes.

Solar thermal power can also be used in what is called a solar convection tower, or solar updraft tower. In such a system, a large area is covered by a greenhouse with a tall chimney in the middle. Sunlight warms the air in the greenhouse, and the warmed air is drawn to the middle of the structure in order to rise through the chimney. One or more turbines are located at the base of the chimney or in the chimney itself, and as the air rushes by them, the turbines produce electricity.

Solar updraft towers use inexpensive and plentiful materials and enable dual-use of land: the greenhouse retains moisture in the air and soil, which can enable agriculture in the structure. Providing both electricity and food could make a solar updraft tower appealing in an arid climate. A utility-scale facility would need to cover hundreds of hectares, however, and would need a chimney hundreds of meters tall.

Photovoltaic Technologies

Photovoltaic (PV) materials produce direct current (DC) electricity when exposed to light of a specific frequency. When a photon strikes a PV material, the photon can excite an electron and liberate it from its atom. In a PV cell, one side of the semiconductor is n-type (with an abundance of free electrons) and the other is p-type (with an abundance of available holes for electrons). Creating n-type and p-type semiconductors can be achieved by adding impurities such as phosphorous or boron. When n-type and p-type materials are brought together, an electric field forms. The electric field provides resistance for electrons moving from the n-type to the p-type, and it encourages electrons to move from the p-type to the n-type. The result is that incoming sunlight produces a steady build-up of positive charge on one side of the material and a negative charge on the other. Proper wiring creates a circuit with an electric current.

Photovoltaic materials are often categorized as either crystalline silicon (c-Si) or thin film. Crystalline silicon includes both monocrystalline and polycrystalline technology. Thin film includes a variety of materials, including amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium gallium selenide (CIGS). The PV market has averaged an annual growth rate of approximately 55 percent from 2004 to 2008, with both c-Si and thin film segments growing rapidly (REN21 2009, 9; REN21 2005, 9).

Crystalline silicon's high efficiency makes it an appealing technology where area is at a premium, such as on satellites and rooftops. Thin film PV material and manufacturing costs may be substantially cheaper than those for c-Si, although thin film PV is less efficient at converting sunlight into electricity. As a result, thin film is most common in large ground-mounted arrays, such as utility-scale power plants.

In the second half of the twentieth century, silicon was widely used in electronics because of its semiconductor properties. Much of the silicon used early in the PV industry was waste material from the semiconductor industry, which reduced the cost of the primary PV material. Refining and manufacturing processes remain costly, and silicon accounts for as much as half of the total cost of a c-Si PV system.

To produce monocrystalline silicon, raw silicon is purified using chemical processes and then melted. The molten silicon is allowed to cool slowly while in contact with a single crystal, called a "seed." The result is an ingot of very pure silicon, which is then sliced into thin wafers no more than a few millimeters thick. These wafers are treated to add the desired amount of specific impurities to produce n-type and p-type silicon.

An alternate method of producing silicon cells is using a process referred to as "ribbon growth." In this process, molten silicon forms a sheet as it is passed between two seed crystals. Ribbon growth dramatically reduces waste that results from slicing ingots into wafers, although wafers from ribbon growth are generally lower quality than those from ingots.

Producing polycrystalline silicon often involves casting molten silicon into a mold where the silicon cools to form an ingot. Polycrystalline wafers are less costly to produce than monocrystalline wafers because the process is simpler and can make use of lower quality feedstock. The trade-off is that polycrystalline wafers are less efficient than monocrystalline.

Completed wafers make solar cells, which are grouped to form a module (sometimes called a "panel") that has a protective coating and conductive strips to carry electrical current away from each cell. Modules are arranged to make a string, and strings are combined to form a solar array, which are often seen on a rooftop.

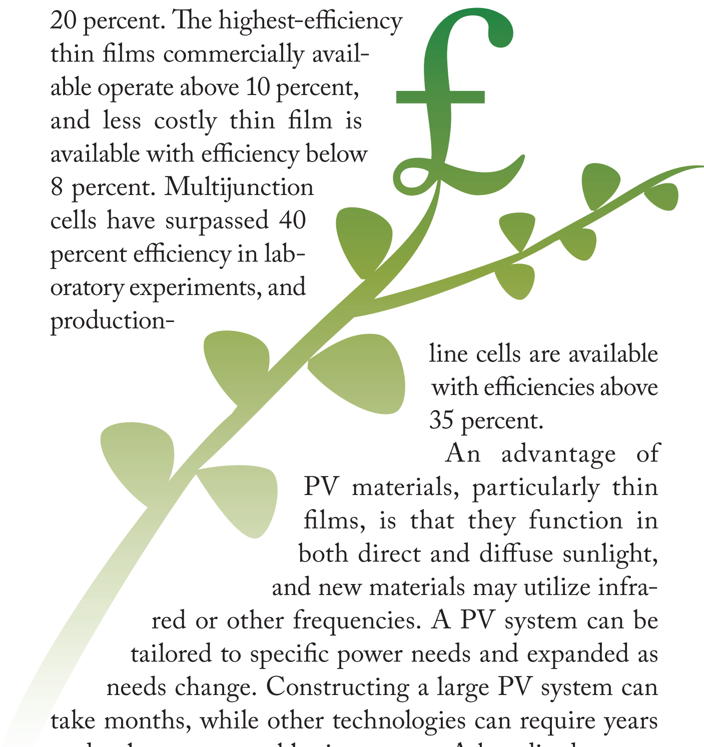
Thin film does not require wafers and cells; instead, it uses homogenous layers of PV material deposited on a substrate, or backing. There are multiple options for the deposition method, the PV material, and the substrate, which creates a great deal of diversity within the thin film market. Of particular interest for thin film is the ability to employ a flexible backing material, such as plastic or thin metal. The resulting PV material could be unrolled quickly onto a surface and could be shaped to fit curved surfaces.

Amorphous silicon was the first thin film technology used commercially and remains a commonly used material. Another thin film PV material is cadmium telluride (CdTe), which has become increasingly common in the twenty-first century. Compared to c-Si, CdTe has gained ground because it is cheaper to manufacture; from 2006 to 2008 in particular, crystalline supply issues caused c-Si prices to be both high and volatile. More recently, copper indium gallium selenide (CIGS) technology has emerged as another alternative, and experiments indicate that CIGS may be able to attain higher efficiencies than CdTe. (Efficiency is a measure of how much electricity is produced by a given amount of sunlight.) But CdTe has benefited from being first to market: CIGS and CdTe use similar manufacturing methods, and so both profit from low marginal costs, but the first thin film company to establish high-volume, high-quality product used CdTe.

Sunlight contains a broad electromagnetic spectrum, but a given material is only photovoltaic for a limited band of the spectrum. One way to improve solar PV efficiency is by using multijunction cells, which are essentially layers of PV materials. Each material layer captures photons of a different frequency.

Producing multijunction cells is a complicated and costly process, which makes these cells substantially more expensive than other PV materials. One important application for multijunction cells is in concentrating PV (CPV) systems. CPV systems use lenses or reflective surfaces to focus sunlight on a small area of high-efficiency PV material. CPV systems require far less PV material than do other PV systems. This reduction in material reduces system cost and can make an expensive, high-efficiency PV material worthwhile. But CPV systems are ill suited for many regions because concentrating technology requires continuous, direct sunlight. CPV systems require precise tracking mechanisms to follow the sun's daily and seasonal movements. In addition, extreme temperatures lower the PV efficiency and risk damaging the PV cells, so particular care must be taken to cool the PV material.

Photovoltaic technologies offer ample efficiency and cost combinations to meet the needs of a given application. For single-junction monocrystalline cells, laboratory experiments have achieved efficiencies of approximately 25 percent; production-grade cells can operate at efficiencies as high as 20 percent; lower quality c-Si cells perform below 15 percent efficiency. Laboratory experiments with thin films have achieved efficiencies near 20 percent. The highest-efficiency thin films commercially available operate above 10 percent, and less costly thin film is available with efficiency below 8 percent. Multijunction cells have surpassed 40 percent efficiency in laboratory experiments, and production-line cells are available with efficiencies above 35 percent.



An advantage of PV materials, particularly thin films, is that they function in both direct and diffuse sunlight, and new materials may utilize infrared or other frequencies. A PV system can be tailored to specific power needs and expanded as needs change. Constructing a large PV system can take months, while other technologies can require years to develop a comparable size system. A key disadvantage of PV materials is the constant need for sunlight, which makes changing cloud cover an issue and nighttime operation impractical. Another drawback for PV systems is cost. Improvements in materials and manufacturing processes have resulted in substantial cost reductions, but PV systems remain a costly source of electricity.

The Future of Solar Power

Concentrated solar technology continues to advance, which has led to increased investment in CSP projects: CSP accounts for less than 5 percent of global solar power capacity, but CSP accounts for more than a quarter of planned solar power projects. With further improvements in technology, CSP could provide an on-demand source of electricity, and CSP may become a viable source of electricity for ever-broader regions. Continued cost reductions could make CSP increasingly cost-competitive with other forms of utility-scale electricity. Thermal storage systems may allow CSP to provide power from sunset one day until sunrise the next.

Solar PV technology is often divided into three "generations," and by most accounts, the industry is completing its transition from the first to the second generation. The first generation involved the most basic materials and technology, such as selenium and silicon, and solar cells were very costly. The c-Si cells in use today are still considered first generation, although efficiencies and manufacturing processes have improved substantially over the last fifty years.

Second generation technology is marked by improvements in materials, efficiencies, and costs. Multijunction cells and thin film solar both represent advances into the second generation of solar PV with improved cost per energy output.

Third generation solar cells will be characterized by further advances in materials and manufacturing and may approach properties of photosynthetic plants. Graphene (a single sheet of graphite only one atom thick) or quantum dot (another very thin semiconductor) technologies may serve as solar semiconductors, or semiconductors may be eliminated by advances with polymers (synthetics) or organics. In a world of third-generation solar technology, PV devices may be as common as cloth or paint are today, and any man-made surface could produce electricity.

An alternate approach would use orbiting satellites as large solar arrays, transmitting energy to the surface of the Earth using low-intensity microwave radiation. The most significant advantage for this technology would be the ability to produce electricity at all times of day in all weather conditions. Solar power transmitted from satellites may seem like science fiction, but serious research is underway. In early 2009, a California utility company announced an agreement to purchase electricity from just such a space-based solar array beginning in 2016 (Riddell 2009). Later in 2009, a consortium of Japanese manufacturing companies announced plans to develop the technology for large-scale application (Sato and Okada 2009).

Innovation and technological advances will continue to play an important role in the development of solar power. New materials, improved manufacturing processes, and creative ways of using solar power will all be critical. Solar power has the potential to become an integral component of energy production for human civilization.

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See also Cap-and-Trade Legislation; Development, Sustainable; Energy Efficiency; Energy Industries—Overview of Renewables; Facilities Management; Investment, CleanTech

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Energy Industries—Wave and Tidal

In the mid-twentieth century researchers began examining how to develop cost-effective methods for generating energy from tides and waves. Marine energy comes from the water's motion, which is caused by the wind and by gravitational interactions between the water, Earth, its moon, and the sun. Whether the various technologies, methods, and devices can efficiently generate energy from the water remains unproven.

It is obvious that there is great power in the oceans and the seas of the world. What is not so clear is whether such energy can be harnessed in a cost-effective manner. The prospect of capturing energy from the motion of the waves and the changes in the tides has received considerable interest. It is difficult to quantify exactly what contribution wave and tidal energy could make to sustainable energy generation. One current tidal energy project generated 1 gigawatt (GW) within the first five years of introducing a commercial-scale device. (A watt is a measure of power, the *rate* at which energy is converted to electricity; one gigawatt is equal to one billion watts and is enough to power 780,000 average U.S. homes in a given instant [calculation based on data from USEIA 2009]. For more on this topic please refer to the sidebar "What's the difference between a gigawatt and a gigawatt-hour?" on pages 148–149.) Locations such as the Korean peninsula, New Zealand, the United Kingdom, and the northeastern coast of the United States all offer considerable potential. Likewise, wave energy can be generated on any coast that faces a prevailing wind and has a large expanse of ocean. Estimates for the world's total coastal wave power potential indicate that it could be as high as 1 terawatt, or 1,000 GW (Falnes 2007), which is similar to that of all existing power stations.

Tidal energy has been used for centuries to grind flour. In the mid-twentieth century, researchers conducted studies on the use of tidal barrages to generate electricity, and a number of schemes were implemented worldwide, notably the 240 megawatt (MW) barrage at La Rance in northern Brittany, France. (Tidal barrages span estuaries and tidal channels; their power plants generate electricity as the tide flows in and out.) Since 2000, research has also been done in the use of tidal currents to generate electricity. Significant wave energy extraction research was initiated following the oil supply scares of the early 1970s, although as yet there are no significant schemes generating commercial electricity.

Sources of Marine Energy

Two distinct mechanisms generate the motion of the oceans and offer the prospect of renewable sources of environmental energy. The first is the movement of the wind. This arises from the solar radiation, internal heat, and the rotation of the Earth. As the resultant wind blows over the surface of the sea, a small fraction of its energy is transferred to the water. The longer the distance that the wind blows over the sea, the greater the energy transferred. The waves generated over longer distances will also have larger amplitudes (or maximum heights of the wave crests) with a wider spectrum of wavelengths (distance between wave crests). These waves travel long distances and are reflected, radiated, and refracted by the barrier of land and the changes in sea depth. As a result, any given location in the wave environment, or sea state, will contain a spectrum of differing wavelengths. The larger the wave amplitude of any given wave, the greater its energy content.

The challenge of wave energy extraction is to "tune" the wave energy device to best capture that energy. In general the best locations for wave energy are near land where the ocean remains deep and the prevailing wind can transfer energy for thousands of kilometers. Good examples are the western coasts of Spain and Portugal and the Outer Hebrides off the northwest coast of Scotland.

Although tidal energy is also a form of wave motion, the origin of the energy is in the complex gravitational interaction between the Earth, moon, sun, and the water in the oceans. The water is effectively "pulled" by these gravitational forces, transferring energy into the sloshing of the oceans. The regularity of this second mechanism for generating motion is a key benefit for energy production. At any given location, the tidal height (or the corresponding current) is made up of the twice-daily maximum (or high) tide. Tidal height is moderated by the fortnightly variations that give rise to the so-called spring tides (which have the greatest range between high- and low-tide levels) and the neap tides (which have the lowest range between the tide levels). These can be predicted with great accuracy and they ensure a known amount of this energy supply.

Tidal energy is at a low density in the deep ocean, and thus a suitable combination of coastline or islands and a variation of sea depth are required to create a large tidal range and/or strong currents. As the time of high tide varies along a given coastline, this lag can be used to further smooth the generation of electricity if a series of sites are connected to a regional electrical grid. The difference in energy available between spring and neap tides, however, can typically result in an eightfold reduction in power.

Wave Energy Devices

The successful generation of viable amounts of electrical power has proved elusive, despite forty years of evolving technology for capturing wave energy. The devices range from concepts such as the Scottish professor Stephen Salter's "nodding duck" to the snakelike Pelamis wave energy converter and the even-more-radical deforming Anaconda rubber tube. Nevertheless there are two basic concepts for wave energy devices:

1. Waves break over an enclosed floating or fixed barrier, thereby generating a difference in water height. This difference in water height, or head, can then be used to drive a low head turbine connected to an electrical generator.
2. An oscillatory device, comparable to the weight at the end of a pendulum, responds to the periodic movement of the waves, and its motion is used to pump hydraulic fluid or to directly move a linear induction generator. An example is the Pelamis device, which consists of a series of interconnected cylinders aligned with the wave direction. The flexing of the joints between cylinders is used to pump hydraulic fluid to drive a turbine.

Many related variants on these systems exist, including a cliff-mounted chamber that uses the motion of the sea's surface to force air continually in and out of a suitable turbine. Operators of such systems have had very little experience under real conditions and at production-scale generation. As a result, the suitability of these systems for cost-effective power generation is difficult to assess.

Tidal Energy Systems

Two physical principles exist in harnessing the energy of waves: capturing the tidal range to generate a suitable water head to drive a turbine-generator set, or using the tidal current itself to directly drive a turbine.

The first principle is used in tidal barrage schemes. Usually these schemes have a barrier built across an estuary. It can generate power on the incoming, the outgoing, or both cycles of the tide. The combination of sluices and turbines limits the flow rate and thereby ensures a sufficient head of water to drive the turbine. These schemes require a large investment in the civil works needed to build the barrier and will alter the marine environment on both sides of the barrage and for a long distance upriver. But there are advantages: a large amount of power is generated at predictable times, and, if the turbines can be used as pumps, the scheme can be used for energy storage to regularize the power from more variable sources of renewable energy, such as wind.

The use of the tidal currents, or other ocean circulation currents, is relatively new. Device development has been rapid, with the demonstration systems installed from 2003 onward. The largest single device generated 1.2 MW in winter 2008 in Strangford Lough, Northern Ireland. The systems are based around wind turbine concepts that are revised for use in the sea. The successful devices have blades that rotate around a horizontal axis that is aligned with the main tidal direction. Ideally the turbines need to be able to generate power for both directions of tidal flow by either employing a yaw (side to side) mechanism or bidirectional blades. Variations use an accelerating duct to capture more flow, but the disadvantages are that the extra energy generated needs to overcome the increased structural costs and that the design of the duct must not choke the flow through the turbine. When many such systems are located as an array or fence, a significant change in the local flow will determine the maximum energy extraction.

Future Challenges

Wave energy and tidal energy systems face many barriers before it can be determined whether such schemes can extract energy at a large enough scale to make a major contribution to a more sustainable energy future. The main barrier is an economic one, although, by necessity, the installation and operation of such schemes will affect their local environment. A considerable challenge is assessing whether this impact is significant when set against the benefits of using environmental energy.

Tidal barrage schemes require large investment with a payback period running into many decades; they also cause a significant change in the estuarine environment. They are relatively low risk as they use tried and trusted technology.

Wave energy is still an unproven technology. Designing devices that can survive the harshest storms and yet still be cost-effective is only one difficulty to surmount.

Tidal current systems benefit from being submerged away from the worst wave loadings, but that comes at the cost of difficult access for installation and maintenance. It is likely that these systems will improve progressively to become a viable alternative source of renewable energy. Unfortunately this commercialization phase is the most expensive part of the development cycle and requires the accumulation of many years of operational experience before cost-effective and reliable systems can be installed.

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See also Energy Efficiency; Energy Industries–Overview of Renewables; Energy Industries–Wind; Investment, CleanTech; Water Use and Rights

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Energy Industries—Wind

In the early twenty-first century, wind power supplies a very small percentage of energy worldwide for electricity generation. But as a renewable source with no carbon emissions, there is global interest in increasing its role. The high cost of wind turbines, reaching demand centers, its relative unpredictability, and the variation in actual wind speed (not the theoretical capacity) are its primary disadvantages.

Approximately 50 percent of the electricity consumed in the United States in 2008 was produced using coal as fuel. According to the United States Energy Information Administration (USEIA), the independent statistical agency of the U.S. Department of Energy, coal-fired generation accounted for 41 percent of world electricity supply in 2006, the latest year for which data are available (USEIA 2009e, 74). In light of the scientific evidence documented by the Intergovernmental Panel on Climate Change (2007) and other organizations, this is clearly not sustainable; based on data reported by the EIA, for every kilowatt-hour of electricity produced using coal, approximately 1 kilogram of harmful carbon dioxide is released into the atmosphere (USEIA 2009c, 106)

One sustainable alternative to coal is wind energy. According to the Energy Information Administration, the share of electricity generation in the United States from wind turbines was 1.3 percent in 2008 (USEIA 2009c, 11). In 2007, 3.7 percent of the European electricity demand was met by wind power (European Wind Energy Association 2009). Because there are no carbon emissions associated with wind energy, there is considerable support for increasing this share.

The U.S. Department of Energy has indicated that it is feasible for wind energy to supply 20 percent of U.S. electricity consumption by 2030 (U.S. Department of Energy 2008). The European Union (EU) has set a binding target to provide 20 percent of its electricity supply from wind and other renewables (European Wind Energy Association 2009). The achievement of these targets is dependent on the cost of wind power, energy regulatory policies, transmission access, climate legislation, and the success of electricity system managers in integrating wind energy into their operations.

Cost of Wind Energy

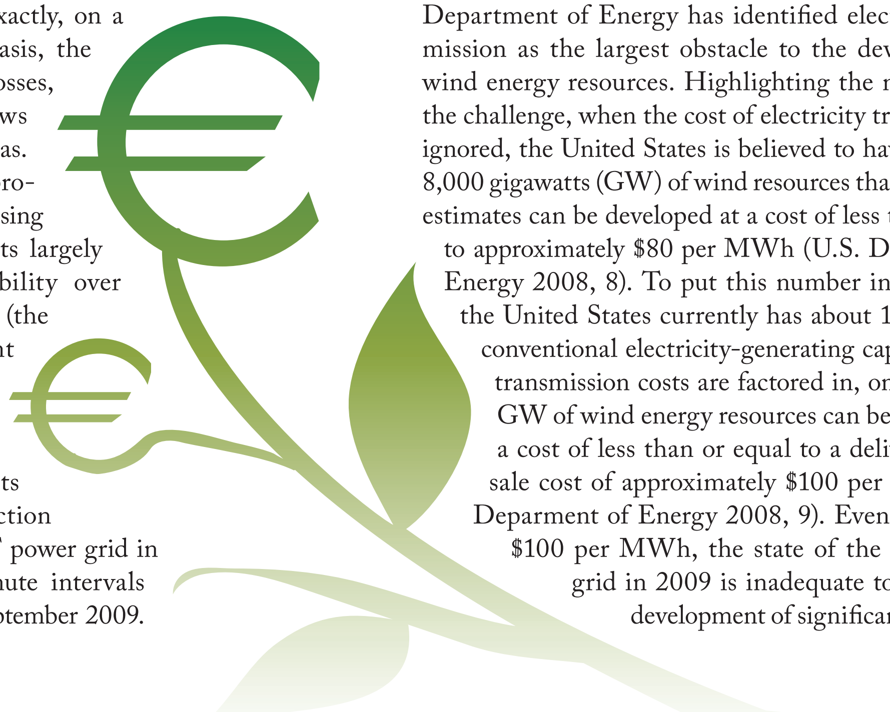
The Energy Information Administration has reported that the capital costs of a new wind project can be expected to be more than double the capital costs of an equivalent-sized conventional power plant (USEIA 2009a, 93). Globally these capital costs are dominated by the price of turbines (European Wind Energy Association 2009). Despite the savings from not purchasing fuel (as would be the case for a conventional power plant), this capital-cost disadvantage has tended to discourage investment in wind energy. Compounding this drawback is the fact that variations in wind speeds mean that the annual wind-energy production level from a typical onshore wind turbine is only about 40 percent of its theoretical capacity (USEIA 2009a, 161).

Government intervention, as well as high fossil-fuel prices, has allowed wind in some countries to come close to achieving what is known as "grid parity" (Komor 2009). Grid parity occurs when electricity generated from a renewable source is cost competitive with electricity generated from more traditional sources such as coal and natural gas. An example of government intervention in the cost of wind power is the U.S. production tax credit (PTC), which provides developers of renewable energy projects a ten-year credit of approximately $20 per megawatt-hour (MWh) generated, which is about 20–30 percent of the generation costs by wind (U.S. Department of Energy 2008, 28). (A megawatt-hour is a measure of energy equal to one thousand kilowatt-hours; the average U.S. home consumes 0.94 MWh in a month [calculation based on data from USEIA 2009f]. For more on this topic please refer to the sidebar "What's the difference between a gigawatt and a gigawatt-hour?" on pages 148–149.) Originally passed as part of the Energy Policy Act of 1992, the PTC has been extended repeatedly and also has been permitted to lapse three distinct times since its inception. When the U.S. Congress has allowed this credit to expire in the past, the development of wind resources has significantly decreased, demonstrating the importance of an incentive to the industry.

Subsidies are also an important driver of wind energy development in Europe. In Germany, the Electricity Feed Law (StrEG),adopted in 1991, obligates public utilities to purchase renewably generated power from wind, solar, hydro, biomass, and landfill gas sources on a yearly fixed-rate basis, based on the utilities' average revenue per kilowatt-hour (kWh). Compensation to wind producers was set at 90 percent of the average retail electricity rate (Runci 2005). This is substantially higher than the wholesale price received by traditional generators. This renewable energy payment—a "feed-in tariff"—has since been modified, but at this point, twenty-one European countries have introduced some form of feed-in tariff (Crystall 2009).

Wind Energy Intermittency

Under currently technology, it is not economically viable to store large quantities of electricity. Moreover, the stability of an electricity grid requires that that the amount of power generation in a given "control area" area matches exactly, on a near-instantaneous basis, the system load, net of losses, and electricity flows with other control areas. Unfortunately the production of electricity using wind turbines exhibits largely uncontrollable variability over the course of a day (the upward deployment of wind energy is not possible). This is illustrated in figure 1, which depicts wind energy production levels in the ERCOT power grid in Texas by fifteen-minute intervals over the month of September 2009.



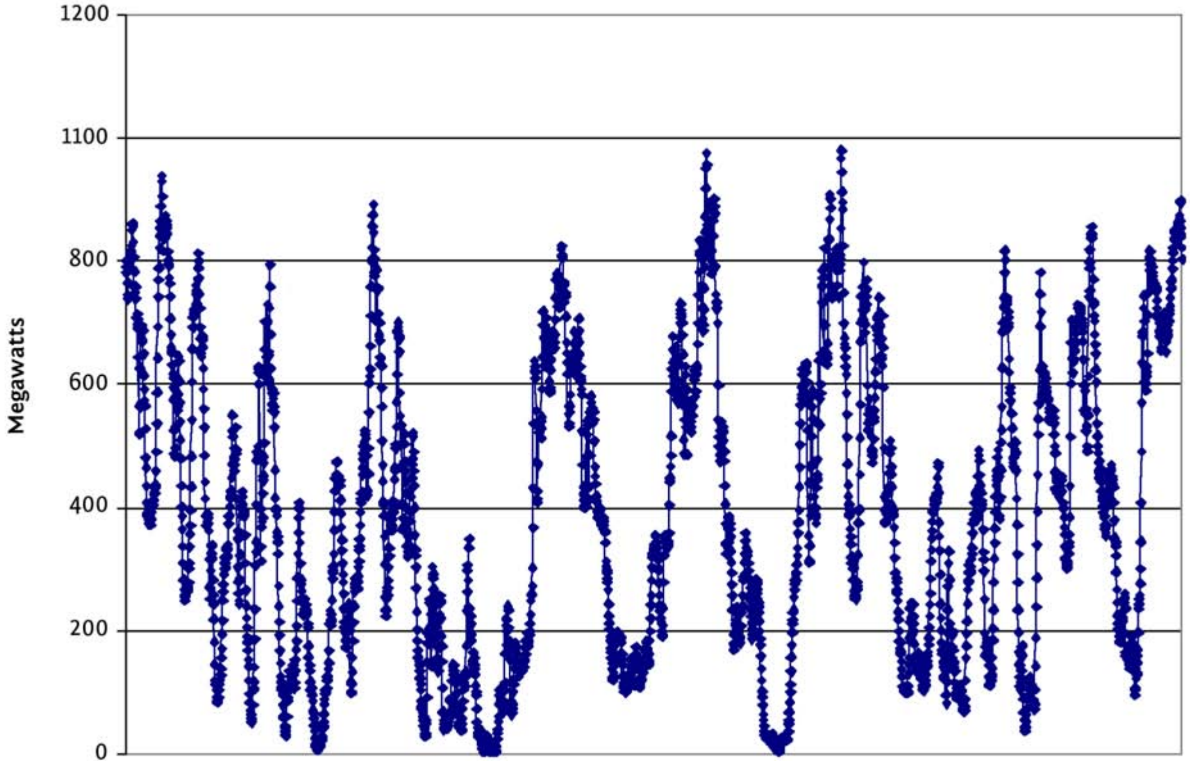
(ERCOT accounts for about 85 percent of the electricity load in Texas.) Inspection of data for other control areas such as western and eastern Denmark, two of the world's most wind-intensive power systems, reveals a similar level of variability in the hourly production over the same time period (Energinet.dk 2009). This variability in production needs to be compensated for by dispatching conventional energy and/or importing power from other regions. Operators of power grids attempt to adapt to this variability in production by forecasting wind energy production levels on a day-ahead basis using meteorological data.

Unfortunately it is difficult to accurately forecast wind energy production levels on a day-ahead basis. A recent study (Forbes, Stampini, and Zampelli 2010) indicates that the ERCOT's mean day-ahead wind-energy forecasting error rate was more than 50 percent of the average wind energy production from the period 15 June 2009 through 30 November 2009. The ability to store electricity in large quantities that could be used when the actual level of wind energy is less than forecasted is one possible solution to this challenge. Fortunately in the United States there are several Department of Energy–funded projects underway that are designed to advance this solution (U.S. Department of Energy 2007).

Transmission Access

In the United States, wind resources are typically most robust in remote interior locations such as the Great Plains and the Rocky Mountains, while most of the population lives along the East and West coasts (American Wind Energy Association 2009). Because of this mismatch between resources and demand centers, the U.S. Department of Energy has identified electricity transmission as the largest obstacle to the development of wind energy resources. Highlighting the magnitude of the challenge, when the cost of electricity transmission is ignored, the United States is believed to have more than 8,000 gigawatts (GW) of wind resources that the industry estimates can be developed at a cost of less than or equal to approximately $80 per MWh (U.S. Department of Energy 2008, 8). To put this number in perspective, the United States currently has about 1,000 GW of conventional electricity-generating capacity. When transmission costs are factored in, only about 600 GW of wind energy resources can be developed at a cost of less than or equal to a delivered wholesale cost of approximately $100 per MWh (U.S. Deparment of Energy 2008, 9). Even at a price of $100 per MWh, the state of the transmission grid in 2009 is inadequate to support the development of significant amounts of

Figure 1. September 2009 Quarter-Hour Wind Energy Production Levels in the Electric Reliability Council of Texas (ERCOT) Power Grid



Note: The data are reported in fifteen-minute intervals.

Source: Forbes, Stampini, and Zampelli (2010).

As an energy source, the wind can be variable, uncontrollable, and unpredictable, which influences its reliability for electricity generation.

wind resources. The infrastructure in the United States is antiquated, which causes capacity issues and interconnection backlog. Moreover, there is an insufficient level of transmission capacity from the regions with the best wind resources (Komor 2009). The transmission issue must be addressed in order for wind to become a more integral piece of energy supply in the United States.

According to the European Wind Energy Association (EWEA), transmission grid improvements and fair interconnection rules also must be instituted in Europe in order to achieve the targeted amounts of wind energy penetration. It is estimated that in many areas of Europe it could take ten to twelve years to construct a new transmisssion line due to lengthy planning and permission processes (EWEA 2009). Countries such as Denmark, however, have been able to achieve high levels of reliance on wind energy due in part to their concerted effort to link their tranmission system with other countries (Komor 2009).

Energy Regulatory Policies

Regulatory policies have been and will continue to be a key driver of renewable energy development (Wiser and Barbose 2008). The wind industry has gained particular momentum since the 1990s as regulatory mandates have been passed in Europe and the United States. In some countries, including the United States, mandatory goals have been established requiring utilities to include a certain percentage of renewable energy in their supply portfolio; this is commonly known as renewable portfolio standard (RPS). The percentages typically increase on an annual basis, and the accompanying regulations usually include a penalty if the goals are not met. As of July 2009, twenty-nine states and the District of Columbia had RPS policies in place (North Carolina Solar et al. 2009). In addition, in June 2009 the U.S. House of Representatives passed H.R. 2454, the American Clean Energy and Security Act of 2009 (ACESA), which requires retail energy suppliers to have at least 20 percent of their portfolio originate from renewable sources by 2020. Denmark, the Netherlands, Austria, Italy, Belgium, and the United Kingdom, all of which have significantly higher levels of wind energy penetration, have also adopted or proposed RPS programs (Geller 2003). For example, approximately 20 percent of electricity consumption in Denmark during 2008 was generated using wind energy (Energinet.dk 2009). This achievement is a clear example of how government intervention can increase the use of wind power: Denmark has invested more in wind energy than any other European nation, namely through subsidies and a strong financial commitment to research and development.

Although it is difficult to say definitively that RPS policies are the primary reason renewable energy projects are built in certain areas, it is clear that countries and U.S. states that have RPS policies in place have seen an increase in renewable development (Wiser and Barbose 2008). Strong renewable policy (such as an RPS) signals the market and spurs capital investment. Projects are typically built by independent power producers who sell the power and any associate environmental attributes associated with their projects to utilities with an RPS obligation. Wind power has seen the largest growth as RPS has become more popular (Geller 2003). Specifically from 1998 to 2007 in the United States, 93 percent of all non-hydro renewable energy capacity that has come online in RPS states has come from wind power (Wiser and Barbose 2008). Although the U.S. wind industry is enjoying strong policy support as of 2009, it continues to urge the federal government to adopt a national RPS, thereby providing a wide signal for capital investment (American Wind Energy Association 2009). The EU has set such a binding renewable target, which is expected to spur continued investment throughout Europe (EWEA 2009).

In some U.S. states, renewable energy credits (RECs) can be used by utilities to comply with their RPS obligations. An REC is a separately tradable certificate of proof that one megawatt-hour of electricity was generated from a renewable energy source. When an RPS program allows RECs to be used for compliance, sellers of wind energy have access to two distinct revenue streams, one for the REC and the other for the energy itself. Although REC prices vary from state to state, the revenue from REC sales can be considerable. Take for example, the price of a wind REC in Pennsylvania, which was worth between $10 and $13 in 2008, while the average day-ahead wholesale energy price in the same region was approximately $70. In addition there are several optional green programs whereby RECS are available to end-use customers for a premium.

The Future

The technical potential of wind energy is substantial; thousands of gigawatts of wind energy capacity have the potential to be developed. Because of favorable government policies, wind energy is currently one of the fastest-growing supply sources of electricity throughout the world. The Global Wind Energy Conference (GWEC) forecasts a 119 percent increase in wind energy capacity from 2009, reaching 332 GW of installed capacity by 2013 (GWEC 2008, 15). The economics of wind energy are challenging, however, and thus in order for wind energy to be more than a niche source of electricity, there needs to be a cap on carbon emissions, which will make wind energy more economically attractive. In addition, substantial investments in transmission are needed to move the wind energy to demand centers, and research and development in energy storage needs to be accelerated to address the issue of intermittency.

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See also Cap-and-Trade Legislation; Climate Change Disclosure; Energy Efficiency; Energy Industries—Overview of Renewables; Energy Industries—Coal; Energy Industries—Wave and Tidal; Investment, CleanTech

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Equator Principles

Created in 2003 by ten international private-sector banks, the Equator Principles serve, according to the website, as "a benchmark for the financial industry to manage social and environmental issues in project financing." Since their inception, more than sixty-five financial institutions around the world have become signatories to the revised set of principles. It was the first global, sectorwide set of voluntary codes of conduct.

At the official launch of the Equator Principles (EPs) for financial institutions on 4 June 2003, ten leading international project finance banks (led by ABN AMRO, Barclays, Citi, and WestLB) adopted ten principles as a framework to ensure that projects funded by participants use socially and environmentally responsible practices. Upon publication of the first revision of the EPs on 6 July 2006, more than fifty-five banks and financial institutions (including two export credit agencies, which implied governmental support and appreciation of this initiative) from twenty-one countries were signatories. This represented more than 85 percent of the world's project finance institutions, which indicates that EPs have become a true global standard applied by banks, seriously taken into account by their clients, and actively monitored and from time to time challenged by leading nongovernmental organizations (NGOs). They have proven to be fit for the purpose—banks have started to take these issues more seriously and also have intensified dialogue with respect to challenges of the banks' performances by NGOs. In addition, an increasing number of banks have started to develop internal policies that incorporate many of the principles underlying the EPs in their nonproject-related lending and advisory business. Hence, the impact of the EPs has been quite significant in scale and scope.

Moreover, as a business-initiated, practitioner-written, voluntary initiative to set a common, global baseline, the Equator Principles have been a catalyst and benchmark for similar sectorwide projects by leading companies in other industries. It raises the bar of competition: competition on price, structure, and quality of service but not on some fundamental values or principles. The EPs are generally seen as a turning point in the application of sustainability in the financial sector. The Principles for Responsible Investment (PRI) for long-term asset owners (such as pension funds) and investment managers, sponsored in 2006 by the U.N. Global Compact and the U.N. Environment Programme's (UNEP) Finance Initiative, were inspired by the EPs.

Origins of the Equator Principles

According to the preamble of the Equator Principles, project financing is "a method of funding in which the lender looks primarily to the revenues generated by a single project both as the source of repayment and as security for the exposure." Project finance plays a major part in funding global development.

The Equator Principles were triggered by credit and reputational risks that banks increasingly faced in their project finance practice: self-interest was a driving factor. The reason why banks were deemed more complicit by civil society organizations (affected communities, labor organizations, and environmental and social advocacy groups) in the financing of projects was related to the large size of these projects ($50 million to sometimes billions of dollars); the public nature and demonstrable impact thereof (extractive industries, infrastructure); the high loan-to-cost ratio (sometimes as high as 90 percent); and limited recourse to the industrial project sponsors. Thus criticism was rising; in 2002 leading international NGOs adopted a broader vision of sustainable finance with the Collevecchio Declaration for Financial Institutions. These factors caused banks to improve their due diligence; tighten their credit requirements beyond just financial/economic issues; and require broader, stricter monitoring of social and environmental factors.

ABN AMRO's Herman Mulder and Peter Woicke of the International Finance Corporation (IFC) took the initiative in October 2002 and hosted a meeting in London of twelve leading project finance banks to discuss the challenges they were facing. At the beginning of this meeting (which was attended by loan officers from the banks, not public relations officials) there were twelve different causes; at the end of the day there was one common purpose. Initially called the Greenwich Principles, they later were renamed the Equator Principles, reflecting the global ambition of the participating banks. It took only nine months of intensive cooperation and consultation with leading industrial companies, official development agencies, and NGOs to agree to the EPs.

The implementation of the EPs is supported by training and toolkits (screening procedures with attention points to be addressed while evaluating a project). Although the commitment by the bank is individual, participating banks meet at least twice per year to share experiences and review the EPs. A leadership committee is rotating.

Content of the Equator Principles

The EPs are based on the Performance Standards on Social and Environmental Sustainability of the International Finance Corporation (IFC), a member of the World Bank Group. The second version of the EPs, published in July 2006, took into account a revision of these standards, as well as commentaries on the initial 2003 EPs from several NGOs, which have been actively engaged in the drafting and execution of the document. The scope of the EPs is global, and they apply to projects in all sectors—both new projects and upgrades or expansion of existing projects—costing more than $10 million. The EPs cover advisory, arranging, and lending operations.

Each of the participating banks commits itself to the following principles:

- Principle 1: Review and Categorization. Projects are categorized in relation to social and environmental impact and risks, with category A indicating the highest impact or risk and category C the lowest.
- Principle 2: Social and Environmental Assessment. For each project in categories A and B, the borrower must conduct a social and environmental assessment.
- Principle 3: Applicable Social and Environmental Standards. The assessment process must address compliance with relevant host-country laws, regulations, and permits.
- Principle 4: Action Plan and Management System. For projects in categories A and B, the borrower must prepare an action plan that addresses the issues raised in the assessment, including mitigation measures, corrective actions, monitoring measures to manage impacts and risks, and decommissioning.
- Principle 5: Consultation and Disclosure. For all category A and many category B projects, the borrower must have disclosed the project plan and consulted with affected people (in local language and a culturally appropriate manner) before project construction commences.
- Principle 6: Grievance Mechanism. For category A projects and many category B projects, the borrower ensures ongoing consultation, disclosure, and community engagement throughout construction and operations, allowing facilitation and grievances to be addressed.
- Principle 7: Independent Review. The financing banks will be advised by an expert, independent from the borrower, to assess compliance with the assessment, the plan, and the consultation process.
- Principle 8: Covenants. The borrower pledges to incorporate several social and environmental covenants linked to compliance with the Action Plan; if they do not, it may constitute a default under such agreement and result in cancellation of the loan.
- Principle 9: Independent Monitoring and Reporting. The borrower is to retain external experts to verify its monitoring information, which will be shared with the banks.
- Principle 10: Equator Principles Financial Institution (EPFI) Reporting. Banks will report publicly about their EP implementation at least once a year.

Issues and Concerns

There are some relevant issues and criticisms, many coming from various NGOs, in relation to the EPs:

- Although the number of participating banks is increasing, there are still a number of absentee (nonparticipating) banks, including many from Asia.
- NGOs have criticized the EPs for vagueness; absence of enforcement mechanisms; limited coordination among the banks; indirect (or no) coverage of project bonds; consultation only (not consensus) with affected communities; and the implicit, indirect reference to human rights (just "socially responsible"). NGOs also have questioned the fact that inactive and even noncompliant

banks ("free riders") may still call themselves an Equator bank or an EPFI.

- Because the EPs are individual commitments on principles, each bank uses its own discretion in project selection. It is possible that one bank considers a project or structure EP compliant, while another may not.
- Not all banks apply the same standards, and some banks have even stricter policies than EPs require, especially in areas such as agriculture, fisheries, forestry, natural resources, dams, biodiversity, climate change, human rights, toxic substances, and taxes.
- With the growing importance of significant local capital markets in emerging countries, the question is how these principles may be made applicable for domestic infrastructure projects.

Implications

The Equator Principles are a good example of how even in a highly competitive, diverse environment like the financial sector, leading competing practitioners are able to agree to adhere to a common baseline in an effective and credible way and raise the bar for the entire sector. It also shows that external pressure may work in the interest of the sector, as initial "pain" inflicted on all banks from challengers may become "gain" for EP-adhering banks; governments, partners, and (affected) communities prefer a bank that has made certain public commitments.

The financial crisis that began in 2007, however, has clearly shown how important business principles, good governance, and transparency are. Moreover, the environment-social-governance agenda is gaining importance. Governments and society increasingly insist on a greater commitment by companies and banks to traditional voluntarism (like the Equator Principles), more forceful mandatory self-regulation, and greater public disclosure on environmental, social, and ethical issues, including standards, targets, and performance.

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See also Activism—NGOs; Corporate Citizenship; CSR and CSR 2.0; Financial Services Industry; Global Reporting Initiative (GRI); Transparency

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Facilities Management

Facilities management is a rapidly changing and diverse field that aims to seamlessly link the secondary support needs of an organization to its core business function in order to maximize business effectiveness. Much of facilities management involves planning, constructing, and maintaining built assets—sustainability and product life-cycle have become important topics for the industry.

In order to understand what sustainable facilities management (FM) involves, it is first necessary to understand what FM is and, to some extent, its relatively brief history.

There is no single, definitive, and universally accepted definition of facilities management. Most explanations generally relate to a common goal. Various bodies and organizations have developed their own definitions, and they are largely concerned with what FM does, how it is done, or what difference it makes. One of the first definitions of FM was set out by the scholar Franklin Becker in 1990. He describes FM as being responsible for the coordination of all efforts relating to planning, designing, and managing buildings and their systems, including equipment and furniture. The aim is to enhance the organization's ability to compete in a world that is rapidly changing (Becker 1990, 8).

The British Institute of Facilities Management (2009) officially adopted the definition of the European Committee for Standardization, which was ratified by BSI British Standards:

> Facilities management is the integration of processes within an organisation to maintain and develop the agreed services which support and improve the effectiveness of its primary activities.

The Royal Institution of Chartered Surveyors (2006) succinctly defines FM as "the total management of all services that support the core business of an organization." And an achievement- and objective-based definition was generated in the 1990s:

> [Facilities management is] an integrated approach to maintaining, improving and adapting the buildings of an organisation in order to create an environment that strongly supports the primary objectives of that organization. (Barrett and Baldry 2003, xi)

It is tempting to assume that there is one FM industry; in reality, the FM industry is no more unified and singular than the construction industry. Both the lack of a universally accepted definition of facilities management and a lack of industry unity go hand in hand with a slightly chaotic start to the FM industry. FM as a concept originated in the early 1980s in the United States. In 1982, the term "facilities management" had not been heard in the United Kingdom, and the International Facility Management Association (IFMA) had only just formed in the United States. In 1985, a study of FM in the United Kingdom found a lack of synergy and integration among FM functions, a neglect of long-range planning, and a laissez-faire approach to space planning. It concluded, in general, that buildings were an underused resource.

As a result of a widespread lack of holistic business thinking, early FM initiatives lacked the strategic emphasis required to make FM effective. This thinking rendered FM an extension of maintenance management and too facilities oriented. Many business managers did not understand the link between primary (or core business function) and secondary (or support) business processes. More recent themes have centered on the need to simultaneously understand FM's strategic and operational aspects. Ultimately, a client is looking for effectiveness in support services (noncore activities) and facilities. The full value of FM is released when it is seamlessly integrated with the core operations of an organization; yet it needs to remain distinct enough such that it is measurable, and its value is appreciated.

A definition of sustainable facilities management should encompass the aims of sustainability and the strategic and operational importance of FM. Based on the original definition of sustainability from the U.N. World Commission on Environment and Development (1987), facilities management could be described as designing, constructing, and managing buildings and resources in such a way that building occupants' needs are met without the profligate use of energy and resources so that sufficient provision is left for future generations to provide for themselves.

The key to social, economic, and environmental sustainability in FM lies in a balanced approach to building design, renovation, operation, and maintenance while maximizing productivity and minimizing energy consumption, resource depletion, and waste.

FM and Sustainability

The facilities manager is well positioned within an organization to understand both the daily operational activities that keep the core business effective and the strategic implications of long-term planning decisions. He or she understands how employee satisfaction and efficiency affect productivity, as do the appropriate use of energy, materials, and resources. The subheadings that follow discuss some of the initiatives, tools, and programs that promote sustainable FM.

Environmental Management Systems

An environmental management system (EMS) is the overall framework for the actions that an enterprise takes to manage its environmental effects. Environmental management takes into account the policies, strategies, procedures, and practices that form the response of an organization to its surrounding environment.

Environmental management systems exist to ensure legislative compliance with both present constraints and anticipated future ones. Management systems and legislation were developed to minimize the risk and liability from environmental effects on the health of employees, surrounding inhabitants, and animal habitats. To this end, the reduction in the use of raw materials and primary energy will bring about increased productivity and higher resource efficiency. Decisions to improve waste-handling facilities will influence the quantity of waste produced and the associated handling costs. With higher efficiency, improved productivity, and greater environmental awareness, organizations can boost their company image and attract higher quality workers.

According to ISO14000, a global standard for environmental management systems developed by the International Organization for Standardization (2004), the environmental policy of an organization should incorporate a commitment to continual improvement in environmental performance; it should also be available for public consultation and be understood at all employee levels within the organization. ISO14000 requires a holistic approach with regard to product design, encompassing the entire lifecycle to ensure that minimal environmental burdens result from new product development. Improved public image, increased asset value, improved customer satisfaction, and increased investor confidence in corporate activities can result from a well-managed EMS: increased profitability results when waste output, energy input, and resource consumption are minimized. Organizations that take responsibility for their environmental impact, and subsequently take action, are enabled to secure a more prosperous position within the global economy (Roper and Bear 2006). Five significant factors were found to support the business case for sustainability in the design and operation of buildings: resource efficiency; energy efficiency; pollution prevention; harmonization with the environment; and integrated and systemic approaches, including EMS.

Energy Use in Buildings

The built environment is the largest contributor to greenhouse gas (GHG) emissions and accounts for up to 50 percent of global carbon dioxide emissions (DTI 2002). The building construction industry consumes 40 percent of all materials entering the global economy and generates 50 percent of the global output of GHG emissions and the agents of acid rain (CEPA 2000, 2). Throughout their construction and occupation, homes in the United Kingdom are responsible for 31 percent of primary energy use (DTI 2002). From a social and economic perspective, the construction industry is the largest global industrial employer, accounting for 7 percent of total employment and 28 percent of industrial employment (Sustainable Building and Construction 2003, 5). The construction industry is responsible for a high rate of energy consumption, environmental impact, and resource depletion. In response to the Kyoto Protocol, most European governments have introduced new policy instruments to reduce the negative impacts from the building sector. The European Community's Energy Performance Directive for Buildings is one example.

Energy Performance Directive for Buildings

The European Parliament and Council's Directive 2002/91/EC on the energy performance of buildings—known as the Energy Performance Directive for Buildings, or EPDB—came into force on 4 January 2003 and aimed to increase and influence awareness of energy use in buildings. It was intended to lead to substantial increases in investments in energy-efficient measures within buildings. In December 2008, the U.K. government committed to an 80 percent reduction from 1990 levels of carbon dioxide emissions. Heating is the largest contributor (57 percent of domestic energy consumption; 52 percent of nondomestic energy consumption). Water heating accounts for approximately 25 percent of domestic energy consumption and 9 percent of nondomestic energy consumption; and lighting also accounts for up to one-fourth of energy consumption in commercial buildings (DTI 2002). The EPBD introduced higher standards of energy conservation for new and refurbished buildings beginning in April 2006 and requires energy performance certification for all buildings when sold or leased. In addition it introduced regular inspections for larger air-conditioning systems and made recommendations on more efficient boiler operation for commercial property.

EPCs and DECs

The EPBD has resulted in two performance certification systems within the United Kingdom. The first, Energy Performance Certificates (EPCs), gives a property an energy-efficiency rating similar to a white goods (home appliances) energy rating. They also recommend further cost-effective improvements. They are produced using standard methods and assumptions about energy usage so that the energy efficiency of one building can easily be compared with another building of the same type. This allows prospective buyers, tenants, owners, occupiers, and purchasers to see information about the energy efficiency and carbon emissions of their building so they can consider energy efficiency and fuel costs as part of their investment.

An EPC is accompanied by a recommendation report that lists cost-effective measures and other means (such as low- and zero-carbon generating systems) to improve the energy rating. A rating is also given that shows what could be achieved if all the recommendations were implemented. EPCs can be produced by accredited energy assessors only.

Since October 2008, all newly constructed and existing commercial buildings over 500 square meters require an EPC upon construction, sale, or lease. Beginning in April 2008, all public buildings over 1,000 square meters also require a Display Energy Certificate (DEC). DECs are based on actual energy consumption over a three-year period (if available). The building is given an operational rating based on its past performance, and the ratings are renewed annually. When a public building is sold or leased, an EPC is required in addition to a DEC.

BREEAM

In recognition of the fact that construction, use, and demolition of buildings account for a large share of environmental impacts arising from economic activity, the U.K. environmental assessment method, Building Research Establishment Environmental Assessment Method (BREEAM), was launched in 1990 and has been widely adopted there; it has inspired similar systems in the United States, Australia, and France. It offers a scheme for environmental labeling of buildings and sets targets for achievement in relation to a number of key performance indicators. It is a voluntary and self-funding exercise that makes assessment of global, local, and indoor impacts. BREEAM (2008) aims to:

- encourage designers, engineers, and architects to become more environmentally sensitive
- enable developers, designers, and users to respond to a demand for buildings that are friendlier to the environment and then to stimulate such a market
- raise awareness of the large impact that buildings have on the potential for global warming, acid rain, and the depletion of the ozone layer
- set targets and standards that are independently assessed and thus help to minimize false claims or distortions
- reduce the long-term impact buildings have on the environment
- reduce the use of increasingly scarce resources such as water and fossil fuels
- improve the quality of the indoor environment of buildings and hence the health and well-being of their occupants

The Scottish Natural Heritage HQ in Inverness, Scotland, is an example of a commercial project led, designed, and built by the developer yet constructed within tight budget constraints. It achieved the highest BREEAM score for offices in the United Kingdom and has an annual carbon footprint that is 30 percent below conventional best practice (26.3 kilograms of carbon dioxide per square meter) (Carbon Trust 2007). The building has been well received by its occupants, who report that they work more productively in a light and airy open-plan environment that fosters creative thinking. The internal layout is designed to stimulate casual work conversations and to allow occupants to move freely around the work space. It is a good example of how a green building can be constructed without excessive cost, while aiding productivity, supporting occupant satisfaction, and lowering carbon emissions.

LEED

The U.S. system, Leadership in Energy and Environmental Design (LEED), is similar to the United Kingdom's BREEAM. It is based on a 0 to 100 points system and awards certificates at Certified, Silver, Gold, and Platinum levels. They can be awarded by LEED-accredited individuals only and are industry standard in the United States. Buildings constructed to LEED standards can save more than 250 percent of up-front costs over the course of a forty-year usable lifecycle. The LEED rating systems can be awarded for a variety of project types including:

- new construction, designed to distinguish high performance buildings
- existing buildings, aimed at providing an operational benchmark for buildings and facilities managers
- commercial interiors, aimed at empowering tenants to make sustainable choices

Additionally there are programs for the design of core and shell systems only, schools, homes, retail and health care. The Genzyme Center in Cambridge, Massachusetts, is an example of the highest (Platinum) LEED rating for new construction, boasting a high-performance curtain-wall glazing system that allows for opening windows on each of its twelve floors. Almost one-third of its building envelope is a double-skin façade that blocks solar gains in the summer months, while trapping them in the winter. The building's central atrium allows daylight to penetrate into the heart of the building and also acts as a large return air duct. Responsible sourcing of components ensures that locally sourced and/or recycled materials have been used where possible (USGBC 2003).

Carbon Versus Cost

If the facilities manager's role is to seamlessly coordinate all activities that support the core business function and to achieve this in a sustainable manner, incorporating and embracing the initiatives set out above, then it is clear that the facilities manager's (or management team's) role should be neither position inhibited nor time bound. The facilities manager should have sufficient responsibility to endorse organizational changes that are environmentally beneficial and the authority to make decisions at the boardroom level. Often the facilities manager is uniquely positioned to understand how aspects of both the building design and operation positively or negatively influence the core business function, and how the core business requirements drive the need for built asset acquisition and disposal. At the same time the facilities manager is responsible for generating a productive and comfortable working environment. The author of a report for the Massachusetts Technology Collaborative, Gregory Kats (2003) acknowledges that the relationship between worker comfort / productivity and building design / operation is complicated, but concludes that green buildings offer better lighting quality as well as improved thermal comfort and ventilation. As a result the report recommends that a 1 percent gain in productivity and health be attributed to LEED Silver buildings, and a 1.5 percent gain to LEED Gold and Platinum buildings. The triple bottom line (social, economic, and environmental sustainability) has been described as the mechanism that has brought sustainability to the boardroom. This highlights the economic importance of improved care of the environment. Indeed, the benefits of good environmental stewardship to an organization are numerous and include:

- reduced running costs through reduced energy consumption
- increased productivity and worker retention
- improved community standing
- increased market value
- reduced environmental impact
- reduced health liability risks

Typically the facilities manager has taken responsibility of a property at building handover, being in charge of its efficient and effective operation and management, its energy profile, maintenance, and occupancy issues. Not the least of these pressures is to achieve effectiveness at least present cost. These responsibilities are made easier when the facilities manager has input at the design and procurement stages of the building. A new facility that does not adequately satisfy a client's business needs is not capable of contributing optimally to a client's core business function.

A major controversy in the built environment and construction industries is essentially a financial one. There are two aspects to this: first is the belief that a sustainable or environmentally friendly building will cost more, and, not unrelated to the first, is an emphasis on lowest present cost rather than lowest lifecycle cost.

Kats (2003) reports on the twenty-year financial net benefit of green buildings, based upon the U.S, Green Building Council E Analysis. When compared to conventional buildings, LEED-rated buildings consume 25–30 percent less energy, are characterized by lower peak-energy levels, are more likely to generate renewable energy on-site, and are more likely to purchase grid electricity from renewable energy sources. The twenty-year net present value (NPV) per square foot of energy savings averaged around $5.80; emissions savings, $1.20; water savings, $0.50; operations and maintenance savings, $8.50; and productivity and health benefits, $36.90 to $55.30. The associated average extra cost of building green was estimated to be between $3 and $5 per square foot. The total twenty-year NPV per square foot was $52.90 to $71.30. The direct financial benefit of improved working environments is subjective and relies on honest and objective analysis of absenteeism and employee turnover rates. There is still a clear argument, however, in support of green buildings if the analysis is based on what is truly measurable. Eliminating productivity and health benefits from the analysis still reveals a twenty-year NPV per square foot of between \$11 and \$13.

The overall decision to construct a sustainable building is made up of many smaller decisions that relate to issues such as occupant comfort, energy use, embodied energy, transportation, maintenance, client needs, and budgets. Raising awareness from the outset about the need for a green building with the full design team is essential in maintaining the right focus. Some of the most powerful aspects of sustainable design are passive: site selection, building orientation, internal layout, thermal mass, building fabric, solar gains, daylighting, and services. A good design team can remove the need to choose between design strategies that save energy and those that aim to boost productivity.

As an example of this teamwork, the Scottish Natural Heritage HQ has a central atrium that runs the full length of the building. It provides natural daylight, thus lowering the need for artificial lighting; it stimulates a bright and airy working environment; and it drives a passive ventilation system via heat generated in the apex. This system is operated by a stack or chimney effect whereby the velocity of escaping air increases and drives natural ventilation. The geometry and architecture of the building are designed such that the depth promotes natural cross ventilation, while a high building thermal mass limits overheating by storing heat in concrete floors and walls. The excess heat stored during the course of a day can be vented, or "night flushed" with cool air, removing the need for air conditioning. This type of "evacuated tube solar thermal system" generates 65–85 percent of the hot water requirement (Carbon Trust 2007).

The market for green products is wider than ever before: designers can specify "passive," low U-value timber windows with low-embodied energy, energy-efficient lifts or elevators, carpets with backings that don't contain polyvinyl chloride (PVC), and low–volatile organic compound (VOC) paints, to name a few. There is more competition among manufacturers, and competition has driven down the costs associated with low-energy, high-efficiency recycled goods. This widening market, which naturally contains more competition, should help to drive down the costs associated with green buildings.

Capital Versus Running Costs

Northern Europeans spend an average of 90 percent of their time indoors (Weir 1998). Compounded with the fact that most organizations attribute around 80 percent of their total costs to salaries, it is clear that lifecycle issues in buildings are critical. The annual labor costs of office employees are so much greater than the those relating to the buildings they occupy that even a 25 percent saving on annual energy, maintenance, utilities, or operations are negated if the rate of absenteeism due to illness increases by one to three days per year per employee, or a loss of about two to six minutes a day of productive concentration per person (Woods 1989). It has been found that it can take about a year for an employee to reach their maximum efficiency, while the administrative costs and disruption involved in replacing a skilled employee can be as much as one-and-a-half times their annual salary (Philips 1990).

That is not to say that savings in energy, maintenance, operations, and utilities cannot be made as a result of sound management decisions and pertinent operational actions, but that it should be done with occupant comfort and productivity foremost. As legislation and initiatives regarding the office environment increase (such as EPBD, EPCs, ISO14000, BREEAM, and LEED), the wisdom of cost savings that do not consider the well-being of building occupants is questioned even further, often with the risk of litigation and accusations of professional negligence.

Achieving an effective triple bottom line therefore relies upon many factors. The use of two complimentary tools—lifecycle assessment and lifecycle costing—could aid in achieving this.

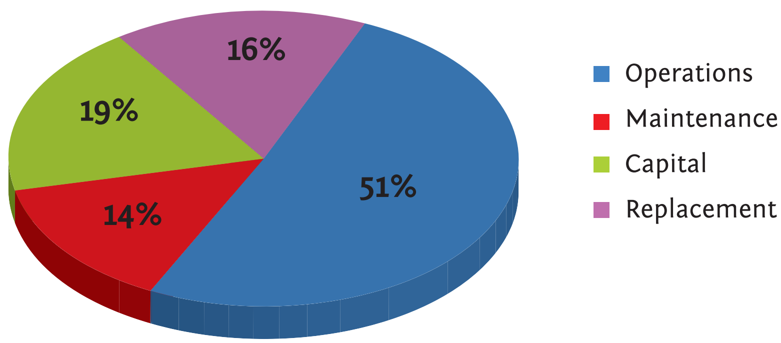
Lifecycle Assessment (LCA)

LCA is a methodology for evaluating the environmental impact of products, processes, and activities during their entire lifecycle. The assessment includes a whole lifecycle, encompassing the extraction and processing of raw materials; manufacturing, transportation, and distribution; use, reuse, maintenance, recycling; and final disposal. The facilities manager is not expected to deploy a full LCA, or any of its derivatives (such as lifecycle energy analysis or lifecycle carbon analysis). But an appreciation that materials and services have an embodied history attached to them, and that material and component selection is a complex combination of service life, embodied energy, carbon, efficiency of use, and possible future recycling/reuse, could significantly alter the triple bottom line of any organization.

Lifecycle Costing (LCC)

It is impossible to judge any construction project without considering its budget. LCC concerns all costs that arise from an investing decision and can be used to evaluate complete buildings, elemental parts, systems or components,

Figure 1. For most buildings, the initial capital cost is less than 25% of the total cost of ownership



Source: RLB Building Quality Assessment, Rider Levett Bucknall, www.rlb.com/life, accessed 24 Nov 2009.com/life/oceania/pdfs/Life%20Cycle%20Cost%20Modelling.pdf

and materials. LCC crosses all professional boundaries and can be used by building owners, surveyors, architects, engineers, facilities managers, contractors, and material manufacturers alike. In each case, LCC is used to aid and improve the decision-making process.

LCC is defined as the present value of the total cost of an asset over its operating life, including initial capital cost, occupation costs, operating costs, and the cost or benefit of the eventual disposal at the end of its life, that is, the total cost that the project will impose throughout the whole of its life. As shown in figure 1, the initial capital cost for most buildings is less than 25 percent of the total cost of ownership. All future costs and benefits are reduced to present values by the use of discounting techniques, and therefore, the economic worth of a project can be assessed.

The facilities manager wears many hats. There is a need to satisfy energy and carbon reduction requirements, provide healthy and stimulating working environments, and to achieve these at lowest overall cost.

FM in the Twenty-First Century

The working environment is changing rapidly. Employees are increasingly becoming knowledge workers—employees whose skills are not easily transferred and whose knowledge and experience is difficult to replace, while the workplace is increasingly devoted to 24/7 activities, and a rising number of professional employees work from their own home or a mobile office. Facilities management is also evolving to keep abreast of these changes; an organization must commit to the health, safety and well-being of all its employees, regardless of work location.

The facilities manager ideally can be positioned to understand how building design and choice of materials influence the working environment, the use of energy, and the emissions of carbon; facilities managers who are responsible for the day-to-day running of built assets need an effective understanding of how those buildings were constructed and how they operate. This understanding needs to accompany a good knowledge of building-occupant needs in relation to job function, satisfaction, communications, work-life balance, future prospects, and control of the working environment. With this mind-set, buildings are an asset that should be used efficiently and maintained effectively; the view of a building as a liability that consumes resources should diminish.

It is possible to construct low-cost, sustainable buildings that contribute to the triple bottom line of any organization. Facilities management involvement from the building conception phase through construction and operation should ensure lower environmental impact, improved productivity, better company image, and greater investment potential. The tools and methods mentioned above should guide the facilities manager to make the right decisions or even to ask the right questions. Effective FM involves being a part of a coordinated team, with influence on and direction from the boardroom.

As governments worldwide work towards satisfying the agenda set by the Kyoto agreement, the role of the facilities manager in administering buildings sustainably is likely to grow. There is a significant need for professionals who understand not only how to build new structures that are low carbon and sustainable, but who also know how to manage existing buildings more responsibility and can advise how to lessen their environmental burden.

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See also Accounting; Building Standards, Green; Design, Landscape; Energy Efficiency; Lifecycle Assessments (LCA); Natural Step Framework, The (TNSF); Property and Construction Industry; Smart Growth

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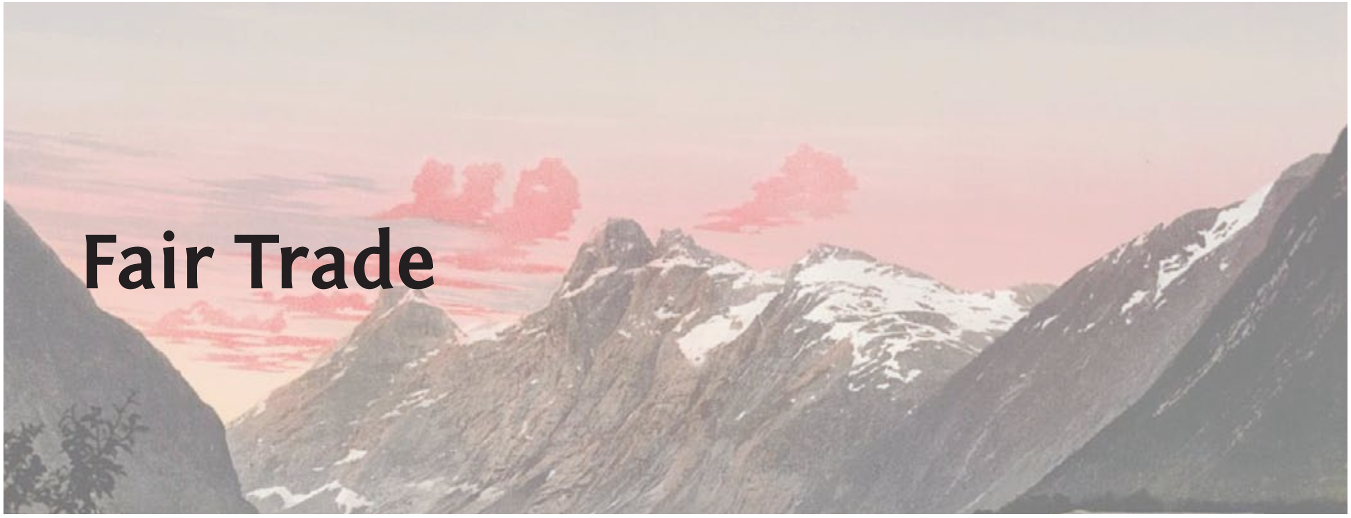

Fair Trade

The fair trade movement began in the mid-twentieth century when nonprofit organizations bought textiles and crafts from poor regions and sold them to developed regions. By 2000, agricultural products made up the majority of products. The fair trade model, recently adopted by multinational corporations, includes direct trade with producers, long-term trading relationships, standardized labeling and pricing, environmental sustainability, and sustainable production.

The term *fair trade*, coined to contrast with the "unfair" practices of the global trading system, historically referred to a wide range of initiatives involving government intervention in the market. The fair trade movement, as it is understood in the twenty-first century, is a network of producer-consumer partnerships that aim to promote development for small-scale producers. The hallmarks of these fair trade partnerships are fair prices and wages.

The fair trade network developed from a prototype launched in the middle of the twentieth century by the Oxford Committee for Famine Relief (now Oxfam) in the United Kingdom and the Mennonite Central Committee in Canada. Both organizations independently bought goods from poor regions of the world for sale in industrialized regions and countries. Initially their efforts to provide a living wage and fair prices for producers in the developing world were largely charitable.

The fair trade movement became more market oriented in the 1980s due to the widespread acceptance of neoliberal economic ideas. The movement, described by Fairtrade Labelling Organizations International (FLO) as an effort to reform the trading system from within, is made up of labeling organizations, retailers, importers, and organized groups of fair trade producers that have established a goal to inform consumers about (and create a market niche for) ethically traded goods. The key international fair trade organizations are the FLO, the World Fair Trade Organization (formerly the International Fair Trade Association), the Network of European World Shops, and the European Fair Trade Association (all based in Europe); and the U.S.-based Fair Trade Federation. Each provides resources, research and development, and networking for fair trade producers, importers, and retailers.

Fair Trade, Economics, and the Environment

Four principles shape the fair trade model: direct trade between importers and producers, the establishment of long-term trading relationships, minimum pricing, and a price premium added to the goods (Nicholls and Opal 2005, 33). These principles underlie the basic standards required for fair trade certification. Direct trade increases the producers' market access, in part by providing information and credit to improve their businesses. Long-term trading relationships ensure that both producers and importers have an interest in sustainable production practices. The minimum price, or price floor, plays the most direct role in establishing fair prices and wages. It incorporates the costs of production, the cost of living, and any additional costs incurred by complying with fair trade standards, potentially encouraging poor producers to remain in their trade rather than leave it in favor of subsistence farming and unemployment. Importers must pay producers a social premium that is added to the base price of every fair trade product. The premium is earmarked for social development projects in the community and for business development. In some cases, farms have used fair trade premiums to become certified for organic production, a step toward environmental sustainability.

Environmental sustainability and sustainable production are defining characteristics of the fair trade movement. Every set of fair trade standards contains a section on environmental development that requires resource management systems, awareness of environmental impacts, and compliance with all local laws and regulations. The movement also promotes the use of nonsynthetic fertilizers and biological pest controls and even encourages organic farming where practical. Finally, proponents of the fair trade model advocate for including the environmental and social costs of production into the product price.

Impacts and Corporate Responses

The fair trade market is concentrated in two sectors: agriculture and textiles/crafts. Although crafts and textiles originally made up the majority of fair trade goods, food makes up about 80 percent. Key crops include coffee, tea, cocoa, sugar, and bananas. Since 1988, when the first Fairtrade organization established in Holland adopted the name Max Havelaar for use on its label—this character from a popular nineteenth-century Dutch novel was a government official who struggled for economic reform in the Dutch colonies—global sales in fair trade products have exploded. During the 1990s, the value of these products in Europe grew more than 400 percent, and it increased by 3,000 percent in the United Kingdom between 1994 and 2003 (Fridell 2007, 64; Nicholls and Opal 2005, 192–193). But studies since 2003 have shown slowed growth and even a decline in countries such as Switzerland, Germany, and the Netherlands, where fair trade products have been available since the beginning of the movement (Fridell 2007, 64).

Although fair trade grew substantially since its inception in the late 1980s, it made up only 0.01 percent of all global trade in 2001. Nevertheless, the fair trade movement's value cannot be measured in dollars and cents alone. The movement traditionally involved small producers selling to relatively marginalized alternative trading organizations. Now, some twenty years later, large multinational corporations (MNCs) have begun to invest in fair trade goods. Companies such as Dole (bananas) and Starbucks (coffee) entered the fair trade market, devoting a small percentage of their overall sales to fair trade. The "mainstreaming" of the fair trade movement has shifted the focus to consumer demand, leading to renewed profitability for firms in the fair trade market (Nicholls and Opal 2005, 100).

Consumer demand has driven many companies to promote market-based ethical consumption. Perhaps the best-known example is Starbucks' commitment to buying coffee that is "responsibly grown, ethically traded" (Starbucks Coffee Company 2009), and whose partnership with TransFair USA and FLO, beginning in fiscal year 2009, will help small-scale coffee growers develop sustainable practices of production. The U.S.-based Whole Planet Foundation, likewise, has committed to ethically traded goods by establishing economic partnerships with Whole Foods Market suppliers in the developing world. Anecdotally, the evidence shows that, whether or not fair trade is effective, it has spawned a larger movement of consumer awareness that is changing the face of agricultural trade (House of Commons International Development Committee 2007, 9).

Challenges and Controversies for the Future

The fair trade movement has not been without critics. Despite many anecdotes of success and empowerment, some have argued that fair trade is, at best, ineffective, and at worst, economically stunting. As mentioned in the discussion above regarding the impact of fair trade and corporate responses to it, fair trade goods make up only a tiny fraction of the global market. At most, fair trade coffee amounts to 5 percent of coffee sales in any consumer economy (Sidwell 2008). Furthermore, fair trade production is concentrated in the richer developing countries. Fifty-one of the world's fair-trade certified producer organizations are located in Mexico, where the average annual income is US$9,000. In Ethiopia, where the average citizen earns US$700 per year, there are only four (Sidwell 2008, 10–11). Fair traders point out, however, that compared with the conventional global markets, the fair trade movement is relatively new. Every movement begins at the bottom, and fair trade growth patterns indicate that, even if growth slows, the addition of new markets could allow the movement to continue to expand in years to come (Fridell 2007, 65).

Another critique of the movement points out that the price floor may keep people working in economically unsustainable agriculture rather than increasing production efficiency or improving the quality of their products (Sidwell 2008). Fair trade proponents argue instead that the minimum price actually increases market efficiency by allowing people to continue farming when they would otherwise be engaged in only subsistence agriculture or nothing at all (Nicholls and Opal 2005). As of 2009, no research has proved or disproved either viewpoint. The best conclusion is that fair trade policies may not have the same effect in every location and that positive effects may be counteracted by negative ones elsewhere.

Despite potential weaknesses in the fair trade model, the past twenty years have shown that consumer awareness and ethical consumption programs are here to stay. The fair trade movement and its products will likely continue to grow, albeit at a diminished rate, and companies will continue to seek new ways to promote goods that are both grown sustainably and responsibly and traded ethically.

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See also Agriculture; Consumer Behavior; Corporate Citizenship; CSR and CSR 2.0; Ecolabeling; Equator Principles; Global Reporting Initiative (GRI); Human Rights; Investment, Socially Responsible (SRI); Sustainable Value Creation

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Fast Food Industry

Over the past fifty years, fast food establishments have become an international presence, but they have come under increasing pressure since the 1980s for many issues, including their environmental impact, treatment of animals, and employment practices. As a result, new trends and alternative business models have emerged, and traditional fast food has attempted to adopt many "green" practices.

The industry standard for fast food or quick service is serving a meal or other food item in three minutes or less. For such a quick experience, the industry's impact in the United States over the last half century has been startling. Over this time, fast food has grown from a few restaurants started by rebels to a ubiquitous presence within the United States and a growing presence internationally. Within the United States, fast food grew with the interstate highway system, spreading across the country and weaving its way into every aspect of daily life. Today fast food is available everywhere, from restaurants and gas stations to hospitals and schools. In 2009, the fast food industry is projected to pass $163 billion in sales, making it a larger industry than higher education, new cars, or computers (Schlosser 2001). Beyond the numbers, it has broadened waistlines, transformed family farms to industrial enterprises, and suppressed the minimum wage. Perhaps its greatest impact was launching the franchise business model that has penetrated every industry from child care to funeral services. Internationally (which is the focus of growth today) the largest fast food chains such as McDonald's, Starbucks, and Kentucky Fried Chicken are symbols of the American culture that are at different times either lauded or reviled.

A New Model Emerges

Since the early 1980s, fast food has been under increasing pressure to change its ways. The quick service industry has been targeted for its environmental impact, treatment of animals in industrial feeding operations, and employment practices. A harbinger of change happened in 1989 when McDonald's teamed up with one of its fiercest critics, the Environmental Defense Fund, to replace ozone-depleting polystyrene foam containers with unbleached paper products. But it wasn't until a decade or so later that a shift to sustainable operations happened in the fast food industry. In the late 1990s and early 2000s, a series of forces coalesced to create systemic alternatives to traditional fast food. Culturally, books such as *Fast Food Nation* and *Omnivore's Dilemma* and films like *Super Size Me* raised awareness of fast food's impact on culture, health, and society. Fueled by these shifts, as well as a merger of organic and gourmet and the establishment of a uniform organic standard by the United States Department of Agriculture in 2000, consumer demand led to an explosive 20 percent annual growth rate in organic products for over a decade (Organic Trade Association 2009a). While the total sales of food in the United States remained flat, the sales of organic products grew from approximately a $4 billion industry in 1997 to $23 billion in 2008 (Organic Trade Association 2009b). Over the last decade, organic foods have become popular among all segments of society. In fact, the discount retail chain Walmart is the top vendor of organic items in the United States today.

Ironically, these same organic consumers with their busy lifestyles were also heavy users of fast food. They began demanding changes in the quick service experience. As a result, a new sector emerged within the fast food industry called "fast casual." These companies, like Panera Bread and COSI, offered higher-quality food served quickly in an upscale atmosphere and experienced success. For example, Panera Bread saw average unit sales almost 50 percent greater than the fast food giants Wendy's and Burger King (Nation's Restaurant News 2009). By 2006, fast casual was one of the fastest growing segments of the fast food industry with over $11 billion in sales (Business Wire 2006).

A few small, privately held companies decided to merge organic food principles with the burgeoning fast casual segment. The first restaurant of this kind was O'Naturals, which opened in Falmouth, Maine, in 2001. The store's efforts went beyond serving local, wild, and organic foods whenever possible. The company followed strict guidelines that prohibited foods containing artificial colors, flavors, or ingredients. More importantly, sustainable business practices were incorporated into every aspect of its operation from construction through employment practices. Rather than following the industry practices of paying minimum wage and relying on part-time employees, O'Naturals paid a living wage along with health benefits and vacation time. Instead of buying everything frozen and ready to cook, some of the preparation was carried out at the store, lowering food costs and giving workers an opportunity for full-time employment. O'Naturals and other early innovators, like Chipotle, Better Burger, Organic to Go, and Pret A Manger, were pushing the boundaries of sustainable fast food practices. The larger chains kept up through acquisition and broadening selection. For example, McDonald's bought Chipotle and a 30 percent stake in Pret A Manger. They also selectively placed organic items on their menu and partnered with premier organic brands like Newman's Own Organics to gain credibility. As the industry leader, McDonald's has steadily adopted more green construction and sourcing practices. These trends were not lost on the fast casual players. Panera Bread has continually added products to meet the demands of this new group of consumers. For example, in 2007 they began adding organic milk for kids' meals and naturally raised chicken to their menu.

There are financial, operations, and marketing benefits to adopting these new practices. Financially, companies save money or increase sales through their use. For example, reducing energy needs or eliminating packaging saves costs; composting food waste reduces trash-hauling fees. On the sales side, start-up companies and industry giants such as McDonald's opened new markets or reinvigorated same-store sales by bringing new or lapsed customers into the store. Today, based on sales of natural and organic products in the grocery segment, it is estimated that the demand for natural and organic restaurant products exceeds $12 billion (Natural Food Merchandiser 2009; Organic Trade Association 2009a; Schlosser 2001).

On the marketing side, start-up companies rapidly build their brands and receive international recognition both inside and outside the industry for their efforts. Even small companies like O'Naturals are covered in media outlets from *Vogue* and *Inc.* to the *New York Times* and CNN. Sustainable establishments also often received a warm welcome from planning boards and local communities. This is a far cry from the community resistance to larger players and the activists outside their doors protesting issues ranging from antibiotic use in animal feed to globalization. Instead of following the fast food model of marketing by being amongst the largest mass-media purchasers, these new companies invested in the service experience through higher wages and training and ran community-based marketing programs bolstering local schools and organizations as well as building sales.

An International Movement

The new focus of the fast food industry on building economically, environmentally, and socially sustainable operations is a global phenomenon. From Europe to Japan, companies are responding to the burgeoning demands of customers for food made from organic ingredients and free of genetically modified organisms. British-based Pret A Manger, founded in 1986 and consisting of 190 units, is an industry leader. Their website exclaims, "We shun the obscure chemicals, additives and preservatives common to so much 'prepared' and 'fast' food" (Pret A Manger 2009). Le Pain Quotidien (Daily Bread), founded in Brussels, Belgium, in 1990, has grown to eighty locations in thirteen different countries. The centerpiece of each store is a communal table shared by customers who enjoy crusty rustic breads, pastries, and Mediterranean specialties made from organic and natural ingredients. Responding to Japan's surge in organic demand, California-based sno:la recently opened units of its frozen yogurt concept in Kyoto. They employ sustainable construction practices, use biodegradable packaging, and donate sales proceeds of specific products to the United Nations World Food Program.

Challenges and Controversies

There are many challenges to establishing a national brand of sustainable restaurants, the largest of which are product selection and distribution. While there has been incredible growth in the distribution of organic and local products, the industry is still largely geared toward the supermarket sector. Because of this, restaurants are limited in their product selection, but with the massive consolidation of the organic industry, distribution problems and the associated price premiums should ease. Unfortunately, this consolidation may also dilute the meaning of *organic* to the point where it no longer symbolizes sustainability. Another roadblock in the industry is a lack of clear standards to judge a restaurant's green credentials. While there are some government efforts, such as the Maine Environmental Leader program or the United States Department of Agriculture's National Organic Program, there is no standard for examining the entire operation from food and waste to energy usage and employee practices. Finally, while the organic industry is growing, it still represents only 3.5 percent of United States food sales. With such a small penetration, concepts need to make sure they can crossover to mainstream consumers.

Sustainable Trends Remain Strong

In the short term, the 2009 economic downturn has caused some customers to return to the low prices of traditional fast food restaurants; it is unclear if these gains are at the expense of sustainable restaurants. A March 2009 national poll by Harris Interactive (Green Restaurants 2009) and company activities (Chiu Yu-Tzu 2009) show that green restaurants' practices still give companies an advantage over their counterparts. Companies of all sizes understand this and are continuing to roll out scores of environmentally focused projects. They know that customers increasingly request environmentally and socially beneficial practices. Customers are becoming more demanding, and even organic is no longer seen as good enough. One of the largest trends impacting restaurants in 2009 is the local foods movement. According to the National Restaurant Association (2008a), almost 30 percent of fast food operators are serving locally sourced items, and nearly 50 percent feel these items will become more popular in the future. These operators are simply listening to their customers: an astonishing 70 percent of restaurant patrons say they are more likely to visit a restaurant that uses local goods.

In addition, as other inputs rise, more restaurants are looking to cut costs by reducing energy and water use. In the same survey, approximately 30 percent of fast food operators planned on devoting more resources to green initiatives. As more restaurants try to follow these trends, groups such as the Green Restaurant Association are attempting to address the standards issue by rolling out new stringent guidelines on what it takes to become a green restaurant. As environmental and traditional green demands are met, customers may start demanding a different social contract from these companies, especially as issues of a living wage and health care coverage become more prevalent.

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See also Agriculture; Ecolabeling; Health, Public and Environmental; Fair Trade; Hospitality Industry; Local Living Economies; Marketing; Packaging

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Financial Services Industry

The financial services industry's environmental impacts are primarily related to its carbon footprint, its reach through loans, and its financial standard setting in other industries. Despite this, the industry has done surprisingly little to decrease its environmental footprint. To change this situation, the most important potential actions exercise the precautionary principle, including defined environmental sustainability standards, collective action, and environmental requirements for investor decisions.

The financial services industry is a vast combination of various types of companies, spanning insurance, commercial banking, investment firms, and asset management. For the purpose of an analysis of the industry's approach to sustainability, the Global Reporting Initiative (2009) divides the industry into four segments:

- *Retail banking* includes the provision of private and commercial banking services to individuals. This category includes banking for more affluent clients, such as wealth management and portfolio management services. Also, retail banking covers other services to individuals such as transaction management, payroll management, small loans, foreign exchange services, derivatives, and similar types of instruments.
- *Commercial and corporate banking* covers transactions for organizations and businesses of all sizes, including commercial and corporate banking, project and structured finance, transactions with medium-size enterprises, and the provision of financial services to government and government departments. Services include advisory services, mergers and acquisitions, equity/debt capital market services, and leveraged finance.
- *Asset management* involves handling pools of capital on behalf of third parties invested in a wide range of asset classes, including equities, bonds, cash, property, international equities, and private hedge funds. This category includes investment banking with trading in shares and share derivatives, fixed income trading, and trading of credit derivatives.
- *Insurance* covers both pension and life insurance services provided directly or through independent financial advisors to the general public and company employees. This category includes insurance products or services for businesses and individuals and reinsurance services.

Some financial services organizations try to be full service, usually referred to as universal banks. Others attempt to specialize, such as investment banks and hedge funds. Regulations enacted in every country control what organizations can and cannot do in terms of providing financial services. Yet regardless of the restrictions, this vast industry has a major impact on economies. For example, 2008 U.S. commercial banking revenues, as one sector of financial services, were estimated to be $695 billion (IBIS World Industry Reports 2008).

Due to the worldwide economic situation, from September 2008 to early 2010 the world has witnessed massive subsidies given to financial services organizations, including mandated provision of funds to U.S. banks under the Troubled Asset Relief Program (TARP). Any commentary on financial services cannot ignore the tremendous power these organizations have on the world economies, as witnessed by their primary role in the various government bailouts during the economic recession (United States Government Accountability Office 2009). This early twenty-first-century crisis is clearly a collective failure of financial markets as well as of government policies and financial sector regulation and supervision.

The financial services industry has a tremendous impact on organizations by influencing personal wealth, access to education through loans, community viability, and even the ability of governments to implement policies. Given its size and its tremendous leverage on world economies, this industry must take a major role to improve the environment. These influences are magnified when loans are not available to fund innovations for decreasing a business's environmental footprint. This article addresses what is being done in the financial services industry related to environmental sustainability and the challenges the industry sector will face going forward.

Sustainable Practices and Innovations

Many different discourses occur around sustainability, making definition of the term difficult and the identification of relevant corporate practices equally difficult (Dryzek 2005; Gray 2006). The scholar Arieh Ullmann (1985), one of the first to analyze sustainability in financial services, concludes that social reporting, in general, is a confused state of varied theories, concepts, and inconsistent functional terms. More recent data and improved theory show a weak relationship between environmental performance and corporate disclosure sustainable practices (McCammon 1995). The relationship between market performance and social disclosure is far from conclusive, however (see Gray 2006 for a review of this literature).

Thus when we discuss the financial services industry performance as related to environmental sustainability, we should keep in mind the confused state of definitions and of relationships and the lack of incentives to invest in socially responsible activities. We cannot conclude that the industry is not interested or unwilling. We can conclude that the investment targets are far from clear. We can conclude that the more data that point to the industry's actual or perceived environmental impacts, the more corporate action will change. The demonstrable impacts will influence organizational reputation, perceived management competence, and risk management (Orlitsky and Benjamin 2001). In light of this confusion around theory and measurement, we can point to some directions that the industry is taking.

One way to phrase these discourses is to compare and contrast definitions of sustainability as the politics of constraint versus the politics of the possible:

> Environmentalism offered something profoundly important to America and the world. It inspired an appreciation for, and an awe of the beauty and majesty of, the nonhuman world. It focused our attention . . . but environmentalism has also saddled us with the albatross we call the politics of limits, which seeks to constrain human ambition, aspiration, and power rather than unleash and direct them. (Nordhaus and Shellenberger 2007, 16–17)

The politics of constraint expect certain actions to be taken that limit our use of resources and focus our attention on humans as the main cause of environmental degradation. Preservation, conservation, and a more radical "limits to growth" approach refer to a massive need to survive (Meadows, Randers, and Meadows 2004). Environmental groups combat the impacts of business organizations on our society, such as those in the financial services, and create an adversarial atmosphere among the various societal stakeholders. This type of discourse defines *sustainability* as preserving at least what we have today without further deterioration in our economy, our environment, and our society, a classic reference to the Brundtland Commission's commentary on sustainable development (United Nations World Commission on Environment and Development 1987).

This discourse contrasts with the rhetoric of ecological modernization and the green parties across the world. These other approaches emphasize positive actions that balance a triple bottom line approach, that is, a balance of outcomes in light of the inevitable growth our world faces. It approaches the issues of sustainability as the cooperative efforts that support human growth with innovation and new approaches to intractable problems. Extreme aspects of this discourse have been advocated by ecofeminists or ecospiritualists (Dryzek 2005).

These two discourses (or views) on the financial services industry define most approaches that have been taken to address environmental sustainability. Regardless of the approach the industry takes on environmental sustainability, both lead one to conclude that the precautionary principle is the prudent course of action. This principle specifies that regardless of the state of knowledge about environmental sustainability, we should act as if we need dramatic actions to offset the ill effects of environmental degradation (Gollier, Jullien, and Treich 2000). This principle demands that financial services organizations take deliberate actions to offset carbon emissions and act in a manner that increases beneficial outcomes for our environment.

Before proceeding, however, we must note that the discourse around sustainability is matched by a discourse on risk and the financial services industry. Many commentators on the recent financial turmoil point to the way in which financial markets affect peoples psychologically, and how peoples' reactions impact the industry. These impacts stem from citizens' insecurity about investments, the lack of trust of corporate managers, and the desire to have governments punish corporations for losing money, despite the fact that investing comes with risks and rewards. Thus the focus on sustainability, and whether or not the industry follows the politics of constraints or the politics of the possible, may be influenced by society's view of the financial services industry.

What Organizations Are Doing

The impact of the financial services sector on society and the environment derives mostly from the capital it employs—from financing infrastructure projects in developing nations to providing loans to businesses—with effects that can change the risk profiles of borrowers and lenders (PricewaterhouseCoopers 2009). The industry has a large built environment, as evidenced by branches of banks, large office towers, and a tremendous energy infrastructure to support trading and communication related to all sorts of markets and information exchange.

The industry faces, now as in the past, a myriad of challenges and opportunities to impact environmental sustainability. If one were to take a broad view of sustainability that includes environment and society, some of the major issues that financial services organizations face are brand and reputation management; environmental and social impacts of project financing; accessibility to services for underserved markets (Yunus 2003); environmental and social risk management in lending related to climate change (and the impact on borrowers, insurers, financial markets); socially responsible investment, lending, and marketing; compliance with regulatory requirements; and the environmental footprint of facilities.

Some authors state that financial services organizations—especially those in Europe—have a financial motivation to integrate sustainability into business (Russo and Fouts 1997). The scholar Olaf Weber (2005) maintains that integrating sustainability practices into the banking business is motivated by philosophical backgrounds, such as anthroposophy, or personal concerns, such as the agendas of public bank owners. These strategies lead to new sustainable products, such as venture capital funds and microcredit funds, or green mortgages, all of which are needed to foster sustainable development. Weber (2005) also found that financial institutions use five approaches (which he calls "models") to successfully integrate sustainability into the banking business: event related integration of sustainability, sustainability as a new banking strategy, sustainability as a value driver, sustainability as a public mission, and sustainability as a requirement of clients. Several of these challenges can be discussed under two headings: climate change initiatives, including those related to operations and the built environment, and environmental impact investing, including socially responsible investing and markets.

Climate Change Initiatives

The shift to a low-carbon economy is already under way, and businesses—especially energy, transport, and heavy manufacturers—are finding that they must get ready for it. Despite creating relatively low emissions as they conduct their work, financial services are not immune from a need to respond.

Changes in the global climate system during the twenty-first century are projected to have dramatic impacts on the world, including temperature increases, the rise in sea levels, dramatic precipitation and humidity changes, extreme wind and rain storms, and related events (Sussman and Freed 2008, 5).

If current climate science holds true and we take the average predictions, global greenhouse gas emission ideally should decrease by 90 percent from today's levels by 2050, containing global warming below 2°C (IPCC 2007). To reach this goal, the economy's carbon productivity would have to increase by 5 to 7 percent a year, compared to a historic rate of just 1 percent. Carbon productivity, which shows how emissions performance of an economy develops over time, is measured in gross domestic product (GDP) per unit of greenhouse gas emissions. This prescription decouples economic growth from emission growth (Enkvist, Nauclér, and Oppenheim 2008).

If humanity already possesses the fundamental scientific, technical, and industrial know-how to solve the carbon and climate problem for the next half century, then we would expect that the financial services industry has at its disposal a portfolio of technologies to meet the climate challenges we face. The financial services industry, unlike many industries, has shown surprisingly little evidence of activity in these areas. Some businesses take voluntary reductions in emissions, signing protocols such as the American College & University Presidents' Climate Commitment (2010). Buying carbon credits, investing in new technologies, and changing product designs are other carbon mitigation strategies. Few of these strategies are evident in the financial services industry (Hoffman 2006).

Many companies describe how climate change began as an endeavor within a functional area (such as environmental affairs) but diffused from the periphery to the core and, in the process, became an issue of strategic importance to the company. No such evidence exists in the financial services industry. In fact, by analogy, the finance and accounting functional areas were viewed as most resistant for climate-related strategies.

Swiss Re—the world's second largest reinsurer, providing insurance to insurance companies—was one of the first companies in the financial services industry to announce that it would eliminate or compensate for all of its greenhouse gas (GHG) emissions, with a goal of becoming carbon neutral by 2013. Swiss Re believes that reductions in global greenhouse gas emissions can be achieved through energy efficiency measures and by purchasing high-value emission certificates. It claimed to have reduced its own carbon dioxide emissions by more than 25 percent from 2003 to 2007 and offset the remaining emissions through certified emission reduction certificates, declaring to be a greenhouse gas neutral company since October 2003 (Swiss Re 2007).

Swiss Re is a classic example of using the precautionary principle. Swiss Re CEO Jacques Aigrain stated that "in the distribution of possible future outcomes of global warming, there is a significant tail representing very serious consequences. It is the prudent approach—a common practice in insurance and issues of financial stability—which requires us to take action today to mitigate global warming and to adapt to its consequences" (SEC 2007).

Industry views vary on whether or not climate change is significant. In a recent survey, Charles Schwab replied "N/A" to the question about physical risk of climate change, while Lehman Brothers stated that "physical risks pose a threat to the operations of all financial services firms and therefore the financial markets overall" (Sussman and Freed 2008, 10). Travelers, one of the largest providers of personal and commercial property and casualty insurance products in the United States, has taken several notable actions: using extensive risk modeling that includes climate change as a major risk factor, offering risk control services, and engaging in extensive community and government outreach to create greater awareness of this risk category.

Also in the United States, newresourcebank (2006) in the San Francisco Bay area offers extensive green resources. Some other efforts are made by Lloyd's Banking Group's sponsorship of the Corporate Leaders Group on Climate Change—part of the Prince of Wales's Business & the Environment Programme (2009), which is a collective business initiative to think about, challenge, and debate issues of corporate sustainability.

The financial services sector shows very little evidence of creating a positive impact on our environmental sustainability. This industry sector, unlike several others, does not have any coordinated effort to mitigate climate changes impacts, does not seem to have a systematic focus on climate change, and does not seem to put environmental sustainability at the forefront of its organizational strategies. Yet some progress has been made toward environmentally focused investing.

Environmentally Focused Investing

One place where the politics of possibility take concrete form is at the intersection of investment and innovation. Financial services organizations have modeled some of their investment strategies not on pollution control efforts but rather on past investments in infrastructure (such as railroads and highways) and innovative solutions for new businesses.

The financial sector began taking environmental risk into consideration by optimizing its own environmental performance (Weber 2005). There were two main reasons for this. First, banks wanted to decrease costs by reducing their use of energy, water, and materials (McCammon 1995). Second, they wanted to show their clients that "it pays to be green." As a next step, they introduced environmental risk management processes into credit management; some losses in the credit business caused by environmental risks justified such measures. At the same time, banks regarded the increase in environmental attitudes in society as a business opportunity. They subsequently created specialized credit products and mortgages as well as "green" or socially responsible funds, which invest in environmentally friendly or sustainable firms.

It has become increasingly difficult, however, to ascertain which kinds of measures or products labeled "green," "socially responsible," or "sustainable" have which kind of effect, both on banks and on sustainable development. Furthermore, it is difficult to determine which banks and financial institutions are the "sustainability leaders" in their sector.

One way the financial services industry has influenced sustainability efforts has been through the publication of information about companies' climate change efforts. These publications are aimed mainly at investors. Europeans had been the first to conduct this information exchange, such as Europe's utility sector sponsoring a publication with several new variables that made it possible to measure carbon emission against production and revenues. Goldman Sachs (2004) Energy Environmental and Social Index, a U.S. example of such a publication, is based on an analysis of thirty environmental and social metrics in eight categories.

The Carbon Disclosure Project (CDP) is a more ambitious effort. It is an independent not-for-profit organization that holds the largest database of corporate climate change information in the world. Based in the United Kingdom, it works with shareholders and corporations to disclose greenhouse gas emissions of major corporations. The CDP, which includes a group representing institutional investors that manages $10 trillion in assets, sent questionnaires to five hundred of the world's largest companies (mainly companies within the airline, automobile, retail, steel, power, insurance, and technology industries) asking them to explain their emissions policies and strategies. The project published the results for investors to note in their future investment decisions (CDP n.d.).

Since its formation in 2000, CDP has become a major standard for carbon disclosure methodology and process, providing to the global marketplace primary climate change data obtained from responses to CDP's annual information requests, issued on behalf of institutional investors, purchasing organizations, and government bodies.

Institutional investors (such as banks, pension funds, and insurance companies) who signed CDP's information requests are known as signatory investors. CDP currently has 475 signatory investors, including global investment/finance houses such as Banco do Brasil, Barclays, HSBC, Goldman Sachs, Merrill Lynch, Mitsubishi UFJ, Morgan Stanley, National Australia Bank, Nedbank, and Sumitomo Mitsui Financial Group. Of the signatory investors interviewed for a CDP study, approximately 60 percent methodically identified which companies in their portfolio were either not responding to CDP or were providing poor or trivial answers (Riddell and Chamberlin 2007). The investors then used this information to further engage with these companies on the issue of climate risk. Twenty-six percent then went on to support shareholder resolutions for better disclosure on climate risk from some companies not complying with CDP disclosure.

Of the signatory investors interviewed, 13 percent encouraged their investment bankers to use CDP data when making new lending decisions. One pension fund identified their inclusion of climate risk evaluation criteria in their request for proposals to fund managers, citing that those fund managers who were able to demonstrate their signatory status to CDP were more likely to be awarded the contract. All of the investors interviewed agreed that the CDP data is a valuable resource and incorporated it into their decision-making process at some level (CDP n.d.).

As corporations create internal infrastructure to better understand GHG emissions accounting, the quality of data is expected to improve. Reviewing the CDP responses over the past five years alone is evidence that corporations are listening to their investors and responding to the threat of climate change.

Calvert, a socially responsible investment company, demonstrated particularly progressive use of CDP data conducting the following best practices:

- A qualitative analysis using CDP data evaluates companies on a sector-by-sector basis. The utility sector is the main target, but additional areas of focus are the oil and gas, auto, financial, insurance, and manufacturing sectors.
- Calvert specifically looks for a company's public policy outlook, mitigation strategies, trajectory information, management opportunities, and level of qualitative information provided in a company's response to the CDP questionnaire.
- The information provided through CDP provides a platform for leaders and laggards, which is then incorporated into the decision-making process Calvert follows to invest in well-managed corporations.
- Calvert engages nonresponding corporations, which in some cases leads to shareholder resolutions and in others a change in response status to the CDP (n.d.).

Another effort that involved the financial services industries was the formation of the Equator Principles, a financial-industry benchmark for determining, assessing, and managing social and environmental risk in project financing (Equator Principles 2009).

Another comprehensive project has been the United Nations Environment Programme Finance Initiative (UNEP FI), a global network of signatories and partner organizations across the banking, insurance, and investment communities that focuses on the latest developments and emerging issues on finance and sustainability. UNEP FI works closely with over 170 financial institutions who are signatories to the UNEP FI Statements and a range of partner organizations to develop and promote linkages between the environment, sustainability, and financial performance. Through regional activities, a comprehensive work program, training programs, and research, UNEP FI carries out its mission to identify, promote, and realize the adoption of best environmental and sustainability practice at all levels of financial institution operations.

In the United States, the Coalition for Environmentally Responsible Economies (CERES, pronounced "series") is a national network of investors, environmental organizations, and other public interest groups working with companies and investors to address sustainability challenges such as global climate change. Its mission is to integrate sustainability into capital markets for the health of the planet and its people. CERES launched and directs the Investor Network on Climate Risk (INCR), a group of more than seventy leading institutional investors with collective assets of more than $7 trillion. Another effort is the Institutional Investors Group on Climate Change (IIGCC), a forum for collaboration between pension funds and other institutional investors on issues related to climate change. They seek to promote better understanding of the implications of climate change among members and other institutional investors; IIGCC also encourages companies and markets in which their members invest to address any material risks and opportunities to their businesses that are associated with climate change and to shift to a lower-carbon economy.

Swiss Re was ahead of the curve with its publication *Tackling Climate Change* in 1994. Swiss Re sought to bring climate change into policy and investment decisions, recognizing that it was more at risk from the physical impacts of climate change than many organizations. The insurance industry, in general, could experience dramatically increased costs due to growth of climate-related effects, including growth in natural disasters, disease, and mortality rates over the next ten years (UNEP FI 2002). In 2004, for example, the industry registered around $40 billion weather-related natural catastrophe losses, the largest amount in recorded history.

In 1996, Swiss Re started building up a sustainability portfolio of investments in companies supporting sustainable development, with particular emphasis on efficient resource utilization. Target investments focus primarily on alternative energy, water and waste management, and recycling. Investment clusters range from infrastructure / project finance–type investments to "CleanTech" venture capital. In 2006, the portfolio value grew substantially to CHF 376 million (CHF is the symbol for the Swiss franc). In April 2007, Swiss Re announced the successful close of the EUR 329 million European Clean Energy Fund, one of the largest funds of this type in Europe (Swiss Re 2007). The fund, a U.N.-accredited investment vehicle, provides capital to European clean energy projects that are environmentally beneficial and generate carbon credits or tradable renewable energy certificates. Swiss Re was the anchor investor in the fund and acts as carbon advisor for the selected projects (Swiss Re 2007). The fund was placed in Europe by Swiss Re's affiliate, Corning Research and Consulting. Other insurance companies have followed Swiss Re's lead, and many have been developing more accurate underwriting tools, such as catastrophe models, to establish appropriate exposure-based rates for insurance.

Some financial services companies have linked existing products to environmental sustainability, including complementary product offerings and emissions offsets (van Bellegem 2001). For example, GE's Money Earth Rewards Platinum MasterCard links purchases with offset products, similar to British Petroleum's Global Choice Program (Deutsch 2007). Barclay's offers the Barclaycard Breathe, from which .05 percent of what clients spend on the card goes to U.K.-based PURE, the Clean Planet Trust to fund government-approved environmental projects.

One small but interesting innovation occurred in Japan (Japan for Sustainability 2004). In 2003 three popular Japanese musicians—Takeshi Kobayashi, Kazutoshi Sakurai, and Ryuichi Sakamoto—established a bank in Japan, known as the AP Bank Co. (AP stands for "Artists' Power" and "alternative power"). It was based on the Mirai Bank (Future Bank), which was launched and headed by environmental activist and writer Yu Tanaka. The Mirai Bank accepts funds invested by citizens and offers low-interest loans for environmental projects or citizen-based activities that the bank wants to encourage. Thus inspired by the Mirai Bank, Kobayashi, Sakamoto, and Sakurai decided to establish a bank of their own to provide low-interest financing for activities related to renewable energy, energy conservation, and environmental protection.

Merrill Lynch (2009) has taken bold moves despite its financial difficulties. As a provider of capital, the company facilitated financing for renewable and clean energy investments. Merrill Lynch claims that as a proprietary investor it promoted investments in renewable and clean technologies, as a global wealth manager it provides solutions to integrate environmental investing into client portfolios, and through global research it publishes reports that highlight the risks and opportunities associated with the renewable and clean energy industry.

In the financing for Ulu Masen Ecosystem in Aceh, Indonesia, Merrill Lynch—in partnership with Carbon Conservation (working on behalf of the governor of Aceh)—came up with a deal that provides carbon financing for the world's first independently validated avoided deforestation project, which is compliant with Community, Climate, & Biodiversity Alliance (CCBA) standards (2008). CCBA is a partnership between leading companies, NGOs, and research institutes seeking to promote integrated solutions to land management around the world. The CCBA has developed voluntary standards to help design and identify land management projects that simultaneously minimize climate change, support sustainable development, and conserve biodiversity. It may not be the first avoided deforestation program, but it was one of the first to harness the power of an international investment bank and to link environmental benefits with companies' product offerings.

Merrill Lynch is using credits to create packaged products for institutional clients who want to offer ethical products to their retail customers. For example, a power company that wishes to offer a carbon-neutral electricity tariff, an airline offering carbon-neutral flights, or a car manufacturer who wants to carbon-neutralize its cars, would use Merrill's products.

Wells Fargo & Company (2008) announced that it has provided more than $3 billion in environmental financing—surpassing its goal to provide $1 billion in environmental finance commitments—two years ahead of schedule. Wells Fargo environmental financing included the provision of $2 billion in financing for building projects designed to meet U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification requirements; investing and committing more than $700 million to support solar and wind projects nationwide, enough to generate enough clean, renewable energy to power about 475,000 households; providing $500 million to support customers who have made environmental sustainability a key part of their missions; and providing $50 million to support nonprofit organizations that improve the environment in low- to moderate-income communities. Wells Fargo's $1 billion lending target was part of its ten-point environmental commitment aimed at helping to integrate environmental responsibility into its business practices (CSWire 2006).

Hewlett-Packard, PepsiCo, Procter & Gamble, and eight other global companies will measure their supply-chain emissions as part of their efforts to reduce greenhouse gases and to inform investors of their carbon footprint. The data will be fed to banks and funds, such as Goldman Sachs, Merrill Lynch, and HSBC Holdings, to help guide their lending and investment decisions (Morales 2008).

In 2007 Morgan Stanley partnered with Norwegian Det Norske Veritas (DNV), an independent risk-management and consulting foundation, to launch a Carbon Bank (Environmental Leader 2007). HSBC—the world's largest banking group—developed the Climate Confidence Index, which aimed to gauge public trends in attitudes about climate change and make them available to the public (HSBC 2007). The launch of the HSBC Climate Confidence Index is part of HSBC's broader strategy to contribute to tackling climate change. Other initiatives include the Global Environmental Efficiency Program, a $90 million commitment to reduce its own direct environmental impacts; the Carbon Finance Strategy to help clients respond to the challenges and opportunities of creating a low-carbon economy; and the HSBC Climate Partnership, a $100 million program involving four environmental groups and HSBC's employees to help reduce the impacts of climate change worldwide.

These projects provide a more hopeful look at what the industry is doing. Yet compared to other industries and the needs for environmental impact, the efforts are relatively meager. Unlike other sectors, the financial services industry has not focused on the challenges surrounding environmental sustainability and the need to play a major role in addressing these challenges. The next section addresses what the industry could do to address these challenges.

What Could the Industry Do?

If one were to consider only the short run, the outlook is bleak that the financial services industry will support and be part of environmental sustainability initiatives. The preoccupation with survival, the lack of evidence that their efforts have had any impact, and the lack of focus on environmental sustainability will contribute to a decrease in activity in this important area.

The financial services industry could have a major role to play, however. The industry could continue its development of investment metrics. A most important topic would be to verify the investment returns in those organizations that support and achieve climate reduction versus those that do not. For example, the efforts by HSBC, UNEP FI, Swiss Re, and others could have a major impact on the valuations of companies. If these financial services companies could produce data that investors trust, then substantial investments could be made to decrease the world's environmental footprint. In all likelihood, however, to produce these data the financial services organizations will need to partner with other organizations, such as the Global Reporting Initiative, or independent rating agencies, such as the Institute of Chartered Accountants in England and Wales or the Financial Accounting Standards Board in the United States (Gray 2006).

Banks should collectively adopt a set of principles in a code for responsible and sustainable banking that should be drafted in close consultation with national governments. According to Herman Mulder (2009), an independent advisor, the head of Group Risk Management at ABN AMRO from 1998 to 2006, and the initiator of the Equator Principles, such a code may include the following public commitments:

- incorporate and actively foster corporate social responsibility (CSR) and sustainable development (SD) in mainstream banking operations "in its own sphere of influence"; invest an explicit percentage of capital on an annual basis in SD business; set an explicit target for generating revenue from SD business; incorporate SD targets in business targets and performance appraisals; raise staff awareness and create active staff engagement by special programs;
- publish business principles, policies, analytics, risk management procedures, toolkits, performances in operations; define clear and consistent no-go interventions; offer an independent "grievance" procedure, allowing stakeholders to challenge the performance of an individual institution;
- incorporate SD issues in research, advisory, and lending operations with respect to its public and private sector clients; require similar, sector-specific disciplines from major clients, including the material contributors to the supply and distribution chains; emphasize the importance of verification and certification of products and services;

- require CSR and SD to be an explicit responsibility of a member of the European Managing Board or the United State's Boards of Directors; appoint a member in the European Supervisory Board or Boards of Directors in the United States with strong CSR and SD credentials; create an independent Advisory Council to the Board with focus on CSR and SD.

Another move the industry could make is to clean up its "own house" by enforcing high environmental standards for its buildings and workforce activities. Wachovia's major project in Charlotte, North Carolina, is exemplary (Charlotte Observer 2009). It plans to build its office tower according to Gold LEED certification standards and share space with Wake Forest University in an attempt to create a cultural campus that is both sustainable and efficient. Bank of America applied for Platinum certification for its New York office building in Bryant Park, yet another U.S. example of notable performance.

Bank of America, HSBC, Citigroup, and Swiss Re were once the sustainability leaders in the financial services sector, but their recent difficulties, especially Citigroup's, will curtail much of their efforts. Smaller, more versatile and less encumbered financial services organizations will likely lead the way for financing sustainability efforts. For example, in the United States, regional banks such as North Carolina-based BB&T could be leaders in financing renewable energy projects.

Banks manage and lend money. Most financial services organizations have capital requirements and offer incentives for people and companies to do business with them. Yet few have incorporated ways to monitor how clients implement and comply with environmental and social requirements built into agreements or transactions.

Further analyses will be necessary to measure the impact of integrating sustainable practices into the business strategies of the financial sector; initial approaches that can fulfill this necessity already exist. One example of such an approach is the sustainability balanced scorecard, which indicates the relation between the economic, environmental, and social performance of a firm (Figge et al. 2002).

Outlook

The financial services industry can help implement sustainable business practices by providing a market for climate exchange. This would involve facilitating markets that trade carbon credits, helping firms participate in the markets, and developing instruments that would provide financial security in such transactions. The aim of financial organizations such as the Chicago Climate Exchange, European Climate Exchange, Insurance Future Exchange, Montréal Climate Exchange, and Tianjin Climate Exchange is to apply financial innovation and incentives to advance social, environmental, and economic goals through cap and trade systems with global affiliates and projects worldwide; derivatives exchanges that offer standardized and cleared futures and options contracts on emission allowances and other environmental products are also planned. These financial institutions need to be supported and regulated, similar to other financial exchanges.

In sum, the industry will not, in the short run, make significant strides in the area of environmental sustainability. Yet with some political will and customer pressure, the industry could eventually increase its presence in support of environmental sustainability.

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See also Accounting; Climate Change Disclosure; CSR and CSR 2.0; Equator Principles; Green GDP; Investment, CleanTech; Investment, Socially Responsible; Risk Management; Social Enterprise; Sustainable Value Creation; Transparency; United Nations Global Compact

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Forest Management Industry

Forest depletion is a global problem with environmental and economic consequences, including loss of resources and local economies, extinction of plant and animal species, soil erosion, and increased greenhouse gas emissions. Certification programs, which identify resources from sustainable forests, are increasing their presence and impact worldwide, although Europe and North America have had the most success in addressing deforestation.

Forest sustainability and certification emerged as crucial global issues following the Earth Summit in 1992, with an original focus on tropical forests that quickly broadened to temperate and boreal forests. Today, several leading certification groups have a huge impact on forest industry and investment lands. Forest sustainability will be a fundamental issue impacting the forest industry over the next few decades, creating many related problems that will need to be addressed.

As human population increases, so does the demand for food, fuel, lumber, and other forest products. Increased food supply usually requires land clearing for crop production and livestock grazing. As harvested forests are not reforested, forest depletion occurs. This happened in ancient Greece and the Roman Empire, and in the United States during the late nineteenth century as timber was cut from region to region across the country. Today forest depletion is a global problem, especially in the tropical rainforest regions and even some boreal forests.

Forest depletion causes both ecological and economic problems. The vanishing forests supply timber and other products that serve as a foundation of many economies, provide habitat that support biological diversity, and function as regulators of global climate change. Deforestation leads to soil erosion problems and changes in the hydrologic cycle (ground water). Trees serve as a storehouse for carbon, and the loss of forest can result in more greenhouse gas emissions. Deforestation can even lead to animal and plant species extinction. Illegal logging and loss of forest cover in countries with a strong forest-industry economic sector can easily impact quality of life standards.

Sustained Yield

Forestry has a central underpinning of sustainability—the sustained yield concept—developed in eighteenth-century Europe to ensure a steady supply of wood, fuel, game, and other forest products. The owner of a castle might require his forest to generate annual revenue to support the estate, or a town might require a local forest to supply a steady supply of firewood. A timber famine could lead to social and economic disruptions, and forest regulation was developed to model growth, mortality, and harvest levels to produce a steady flow from the forest.

A nineteenth-century iron furnace provides a good example of sustained yield. A regular amount of charcoal was needed each year for fuel, say the charcoal from 9,000 cords of wood each year (32,621 cubic meters). Typically the surrounding forest might yield thirty cords (109 cubic meters) to the acre (4,047 square meters) at age thirty, which means 300 acres (1.2 square kilometers) of mature forest must be cut each year. After each harvest the hardwood forest is allowed to naturally regenerate, and thirty years later another thirty cords can be harvested from each of those acres. With 30 acres (0.12 square kilometers) harvested every year from a 9,000-acre (36.4 square kilometer) forest, over time the forest will develop into a patchwork of thirty stands, each one year older the other. Sustained yield produces the 9,000 necessary cords each year on a perpetual basis.

Sustained yield has been a hallmark of industrial and investment forest land management, guaranteeing a maximum, even flow of timber. Over the last quarter century the concept of forest sustainability has evolved to consider the forest as a naturally functioning ecosystem; ecosystem productivity maintenance depends on all of its components and natural processes. The concept came to be called "ecosystem management." Today, forest sustainability has a broad context that embraces more than the functioning of an ecosystem; ecological, economic, and social values are integrated to form the basis of sustainability.

Forest Sustainability

The United Nations Conference on Environment and Development held in 1992 in Rio de Janeiro (also called the Rio Conference or the Earth Summit) produced a Statement of Forest Principles; it is significant as the first global agreement on sustainable forest management. In 2000 the United Nations Forum on Forests was established to promote "the management, conservation, and sustainable development of all types of forests." The United Nations General Assembly adopted the "Forest Instrument" in 2007 as a global agreement on the framework for national action and international cooperation to advance sustainable forest management. A year after the Rio Conference, in 1993, an International Seminar of Experts on Sustainable Development of Boreal and Temperate Forests was held in Montréal; this led to the development of the Montréal Process, which identifies criteria and indicators for sustainable forest management.

The Montréal Process uses seven key criteria, and seven similar thematic areas are now considered fundamental to sustainable forestry. They provide a structure for systems that certify forest sustainability and are now generally accepted as an implicit definition of sustainable forest management. These seven thematic areas are:

- Extent of forest resources. This refers to having significant forest cover and growing stock reserves to support all dimensions of forestry, including reduction of deforestation, restoration of degraded forests, and storage of carbon to moderate global climate change.
- Biological diversity. This refers to conservation and management of biological diversity at the ecosystem, species, and genetic levels, including protection of fragile ecosystems and genetic improvement to increase forest productivity.
- Forest health and vitality. This refers to minimizing the risks and impacts of unwanted disturbances like wildfires, invasive species, insects, and diseases.
- Productive functions of forest resources. This refers to maintenance of a high and valuable supply of primary forest products, for both the present and future generations.
- Productive functions of forest resources. This refers to protection of soil, hydrologic, and aquatic systems. These systems provide clean water, healthy fish populations, reduced soil erosion, and conservation of ecosystems.
- Social and economic functions. This refers to the economic contribution of forest resources in terms of employment, processed forest products, and timber investments. Protection of cultural, spiritual, and recreational values is also important.
- Legal, policy, and institutional framework. This refers to the framework that supports the six themes above, including participatory decision making, governance and enforcement, monitoring and assessment, and broader social aspects like equitable use of forest resources.

Sustainable forest management is one of two approaches for the sustainable development of forest resources. The second is the ecosystem approach developed by the Convention on Biological Diversity (2008), which is defined as "a strategy for the integrated management of land, water, and living resources that promotes conservation and sustainable use in an equitable way." There are three objectives: conservation, sustainable use, and equitable sharing of benefits. Maintenance of fully functioning ecosystems leads to sustainable development. The crux of the ecosystem approach is to manage the range of demands placed on the forest. Adaptive management is a requirement, as ecosystems are not fully understood. A second requirement is that the forest ecosystem's intrinsic values and tangible benefits should be shared in a fair and equitable manner. These approaches promote practices that are environmentally, socially, and economically consistent.

Forest Sustainability Certification Programs

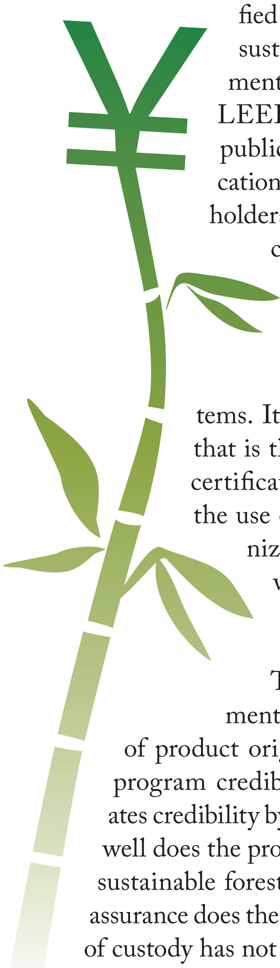
During the 1980s and 1990s, forest sustainability came to the forefront as a global problem. In particular, massive deforestation of tropical rainforests and the rapid loss of biodiversity caught the public's attention. In 1988 several environmental groups urged the International Tropical Timber Organization to develop a labeling program to identify tropical timber produced under sustainable forestry principles. The demand for "ecolabeling" increased; ecolabeling is a certification (or tag) attached to a product that indicates its environmental characteristics. Consumers can then identify environmentally friendly products and can direct their purchasing power to firms producing those products.

Forest certification is an ecolabeling process that identifies forest products that originated from sustainably managed forests. It is an attempt to use the marketplace, rather than government regulation, to ensure forest products are harvested using sustainability criteria. The concept is that consumers are willing to pay a premium for forest products that are produced using sustainable forestry practices.

Later an emphasis on market share or access was used as the rationale.

Europe, the United States, and Canada have substantial environmental regulations that cover both private and public forest lands. But not all consumers, especially those associated with environmental organizations, were confident that government regulation was effective. This provided an opportunity for environmental groups and forest-industry trade associations to develop programs that certify forest products meeting specified forest sustainability requirements. Forest certification assures customers that the timber that went into their products was managed correctly. Even logging organizations have set up certification programs to ensure that harvesting systems support sustainability objectives.

Some of the pressure to certify forest products develops from indirect demand for products like certified buildings. The U.S. Green Building Council has introduced Leadership in Energy and Environmental Design (LEED) to improve the environmental performance and economic return in buildings. The architectural design conditions of LEED recommend the use of recycled or local materials and forest products that have been certified to have been produced using sustainability criteria. Requirements such as this are often in LEED's bid requirements for public buildings. Forest certification must involve all the stakeholders to be effective, including consumers, retailers, producers, mills, environmental organizations, trade groups, professional societies, and certification systems. It involves a set of standards that is the basis of an assessment, a certification process that regulates the use of the "label," and an organization to manage the system, which is usually best handled by a third party or independent organization.



The integrity of the assessment and the assurance quality of product origin determine certification program credibility. The consumer evaluates credibility by asking questions like: How well does the program assesses the quality of sustainable forest management? How much assurance does the program offer that the chain of custody has not been broken (is the product in the store actually the one assessed in the forest)? Does a conflict of interest exist? Do all stakeholders feel the process fairly measures sustainability and effectively meet program objectives?

In the wake of the Rio Conference a number of environmental groups met to develop an independent global organization to certify forest products that were grown on a sustainable basis, and the Forest Stewardship Council (FSC) was formed in 1993 from this process. FSC does not certify forests themselves, but it accredits other organizations to do the actual on-the-ground certifications (called certification bodies). FSC certification covers over 100 million hectares of forest land in over eighty-two countries. (One hectare equals 10,000 square meters.) FSC certification standards are based on ten primary principles, and it has strong chain of custody procedures.

In 1999 the Program for the Endorsement of Forest Certification schemes (PEFC) was established as an independent, third-party umbrella organization that recognizes local forest certification schemes. Initially it had a European focus, but now it is global and covers 200 million hectares of forest land. A fundamental difference between FSC and PEFC is the stakeholders. While FSC was established mainly by environmental groups, PEFC had strong forest industry and trade groups among its founders.

The American Tree Farm System dates back to 1941 and is one of the oldest certifiers. It originally had a wood supply orientation, but it has always promoted sustainable forestry. Its certification is based on a set of standards and guidelines, and it offers a group certification for tracts under the same management. Most of these forests are small and owned by families and individuals. Currently about 10 million hectares are covered by the program.

In 1994 the American Forest and Paper Association, an industry trade organization, established the Sustainable Forestry Initiative to provide sustainable forestry certification for forest industry land. Today it is an independent organization that certifies about 70 million hectares of North American forest land. Participants are mainly forest industry firms or timber investment management organizations. Like the other certifiers, it operates with a set of sustainability standards.

The objectives, standards, and criteria used by the various certification groups tend to be similar. Differences tend to result from the focus of the founding groups. The American Tree Farm System, for example, was developed by people with a timber production focus and the certification system has that same focus. FSC, founded by environmental groups, stressed basic goals like minimizing forest conversion, respect of international workers rights, respect of human rights with particular attention to indigenous peoples, limited use of hazardous chemical, no corruption, and special protection for special cultural areas. FSC's ten principles illustrate the types of rules and policies that form all forest certification systems:

- Compliance with all applicable law and international treaties
- Demonstrated and uncontested land tenure and use rights
- Respect of indigenous peoples' rights
- Maintenance and enhancement of well-being of forest workers and local community
- Equitable use and sharing of forest benefits
- Minimization of logging's environmental impact and maintenance of ecological functions
- Appropriate and continuously updated management plan
- Appropriate monitoring and assessment activities on forest conditions and impacts
- Maintenance of high consecration forests that are significant or critical
- Reduction of natural forest use and restoration of natural forests

Around 10 percent of the world's forest area is now under some forest certification. This may seem like a small amount, but it represents tremendous progress. Increasing demands by environmental groups have resulted in major pressures on forest industry, and they have adapted via their own sustainability programs. One thing is certain: the role of forest sustainability will continue to grow in importance on forest industry and timber investment lands.

Outlook

Sustainable forest management and forest certification have gained wide acceptance since the 1990s. The acres managed under certified sustainable forestry have grown steadily, and the concept has found strong support from environmental groups, nongovernmental organizations, and even forest industry / timber investment groups. But the original impetus for increased forest sustainability and certification was tropical deforestation, and the majority of growth in management and certification has been in North America and Europe. Strong environmental pressure to gain forest certification in tropical forests is expected.

Environmental groups have taken their efforts to impact environmental sustainability on both public and private forest lands directly to the marketplace. They have applied pressure on retailers that sell forest products to limit their procurement to certified products, and many major corporate chains have agreed to the limitation. One of the primary means of strengthening forest certification will be via the marketplace, but consumers have not yet sent strong market signals to suppliers that they demand certified forest products with a willingness to pay a premium for certified wood. Most of the market pressure for certification has been on "buyer groups," like the home improvement chains.

All certification systems have costs. Forest management activities and plans must be changed, special inventories might be required, and tracking systems may be needed. Production costs can sometimes increase by up to 25 percent. Especially in developing countries, these costs can be prohibitive. Major net importers of forest products, like East Asia, would be most affected and could suffer. The cost of certification will continue to be a factor in its growth.

To date, most of the certified forests have been industrial and investment ownerships, but a significant portion of the world's forests are in small private holdings. These ownerships will need to be addressed as certification grows, and measures to assist these owners may be necessary.

Various certification schemes have developed from the desire of the forest industry and forest owners to control the certification system. Some certification systems will attain global acceptance in the future and some will likely fall by the wayside. The forest industry faces a risk that their certification systems may not attain long-term credibility. One way to avoid this problem is through some level of mutual recognition of systems, which has already occurred in some cases.

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See also Building Codes, Green; Development, Sustainable; Ecological Economics; Ecosystem Services; Facilities Management; Information and Communication Technologies (ICT); Packaging; Property and Construction Industry

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Free Trade

Free trade is the movement of goods, services, labor, and capital between countries, without government-imposed trade barriers. It also refers to the efforts of the World Trade Organization and various international agreements to liberalize, or reduce barriers to, trade. Free trade's effect on economic and environmental sustainability is unclear, and trade liberalization methods must balance the needs of developed and developing countries to achieve sustainability.

The term *free trade* refers generally to the free movement of goods, services, labor, and capital across national borders without the interference of government-imposed economic or regulatory barriers. Although it is often considered an antagonist to the goals of sustainability, many economists and policy makers view fully implemented free trade as the end goal of international economic relations. But free trade in the purest sense is far from a reality, especially on a global scale.

Free trade, more specifically, refers to the multilateral efforts at the World Trade Organization (WTO) to liberalize trade by reducing import taxes (tariffs) and removing nontariff barriers globally. It also refers to the bilateral and regional agreements that liberalize trade between trading partners. Some critics blame these concrete trade liberalization efforts for aggravating the inequalities between nations and putting additional strain on the environment through rapid industrialization (Stenzel 2002). Others claim that only free trade can promote worldwide sustainable growth and development.

Origins of Free Trade

The economist Adam Smith wrote in 1776 that "it is the maxim of every prudent master of a family never to attempt to make at home what it will cost him more to make than to buy. . . . What is prudence in the conduct of every private family can scarce be folly in that of a great kingdom" (Smith 1904, 2:11–12). This logic became the foundation for the nineteenth-century economist David Ricardo's theory of comparative advantage, which encouraged countries to specialize in certain products while trading for others. By the 1930s, economists began to embrace free trade as a way to promote both peace and prosperity (Bhagwati 2008).

After World War II, economists and policy makers rebuilding the global economic system proposed creating the International Trade Organization (ITO) to regulate trade between nations. Because the ITO was never founded, the interim General Agreement on Tariffs and Trade (GATT) became the "de facto institution" for governing international trade in the postwar era, until the WTO replaced it. (Bhagwati 2008, 8).

These early efforts at liberalizing trade sought to promote development and economic growth. They were reactions against the "beggar thy neighbor" economic policies that characterized the 1930s. During that time, countries devalued their currencies and increased import tariffs to give their goods a price advantage over other countries. Economists blame such protectionist policies, in part, for exacerbating the Great Depression and the resulting global economic downturn. Under the various negotiations of GATT, more countries began to liberalize trade in the latter half of the twentieth century.

In 1995, 123 countries formed the World Trade Organization. The WTO governs trade in services, goods, intellectual property, agriculture, textiles, and many other issues related to trade. In addition, the WTO established the Committee on Trade and the Environment (CTE) to examine the relationship between trade and environmental policies. The committee recommends modifications where trade liberalization measures do not promote sustainable development and protect the environment.

The Doha Round of WTO negotiations (named for Doha, Qatar, the location of the first meeting) marks the first time that environmental commitments were open for negotiation. The Doha Development Agenda (DDA) ambitiously advocates liberalizing trade in sensitive areas, such as agriculture and intellectual property, while promoting sustainable development and increasing incomes for less developed countries (WTO 2001). Although optimism surrounded the beginning of the Doha Round in 2001, many false starts have contributed to uncertainty about the future of the WTO as a forum for trade liberalization. Increasingly, countries are turning to bilateral and regional agreements to remove trade barriers.

Aims of Trade Liberalization

Since the 1980s, countries have been interested in the relationship between trade and sustainable development. Although the trade–sustainability relationship is largely indirect, the WTO argues that free trade leads to environmental sustainability through economic development, institutional stability and predictability, increasing innovation, more-efficient resource allocation, and increased incomes (WTO 2006). Trade liberalization, however, has not had a completely positive effect on environmental (or even economic and social) sustainability.

Since the mid-1990s, when bilateral and multilateral trade liberalization increased, the resulting industrialization often led to environmental degradation. The North American Free Trade Agreement (NAFTA), for example, worsened air and water pollution by encouraging the establishment of hundreds of export-focused *maquiladoras* (foreign-owned factories in Mexico that employ lower-paid workers; Stenzel 2002). Furthermore, gaps between rich and poor countries have actually widened since that time. Still, many policy makers view piecemeal bilateral and multilateral agreements as building blocks to attaining the promised benefits of fully implemented free trade.

Most countries see the market access provided by free trade as a benefit to their citizens. Market access includes access to goods, cross-border services, capital, and intellectual property (trademarks or patents, for example). Unfortunately, provisions that promote market access for one country may discourage it for another. Even fully implemented free trade cannot improve every person's or every country's welfare simultaneously. Instead, in theory, it would reallocate resources so that the "winners" would gain more than the "losers" would lose, thus leading to an overall average increase in global welfare.

Since no one country, sector, or industry wants to become the loser, each economic actor (i.e., seller, consumer, worker, or investor) has different goals for trade liberalization. Agricultural importers, for example, push for eliminating subsidies (governmental financial support) on developed countries' agricultural products in order to reduce the cost of imports. Members of the U.S. industrial sector seek to increase and harmonize regulatory health, safety, and environmental standards, in part so that competitive industries in the developing world cannot inexpensively create the same products. The pharmaceutical industry would like heightened protection for intellectual property (i.e., drug patents) so that it receives due compensation for the costs of research and development and is not immediately undersold by generics producers who reverse engineer the drugs.

Just as the interested economic actors prioritize certain items on the liberalization agenda, they remain wary of the priorities of others. Developing countries would like trade liberalization to eventually lead to more sustainable economic and social development, but they resist environmental commitments. The developed world, meanwhile, pushes for environmental protection but hesitates to allow flexibility for lesser developed countries, fearing the developed nations would be unable to compete with countries conforming to lower environmental standards.

Impacts on Sustainability

Economists accept that free trade generally has a positive impact on trade flows. One study shows that trade volumes were up 120 percent in 2000 alone, largely due to the WTO's trade liberalization. The same study indicates that, in manufacturing, where trade barriers came down, trade volumes increased, and where barriers remained high, trade volumes were little or even negatively affected. (Trade volume is measured by the number of goods and services traded in a given time period.) For example, trade in clothing, footwear, and agriculture has changed little in recent years because the developed world has maintained protection over those sectors (Subramanian and Wei 2007).

Although trade liberalization has led to increased trade volumes and economic growth in a few cases, the sustainability of that growth and its impact on the environment are unclear. After the signing of NAFTA, incomes and employment rose significantly in the northern part of Mexico. Likewise, exports in manufacturing increased quickly. But much of this improvement can be attributed to the *maquiladora* industry, which is largely disconnected from the rest of the Mexican economy (Salas 2001). Such economic gains may not last unless the free trade policies encourage the transfer of valuable technology and help build local economies through forward and backward economic linkages. (Forward linkages are distribution chains between the producer and its customers, and backward linkages are distribution chains between the producer and its suppliers.)

Economic sustainability is not the only concern. As trade flows increase so does the need to transport goods and services, depleting fossil fuels that are not sustainable over time. Thus environmental concerns have begun to play a more central role in international trade negotiations. In addition to the CTE's work, the WTO is engaged in the issues that concern environmental interest groups. The WTO maintains that its role is to continue to liberalize trade, while ensuring that environmental protection does not interfere with trade and that trade rules do not interfere with domestic environmental provisions (WTO 2006, 6).

In addition to the WTO, bilateral and regional agreements have addressed the role of environmental protection in trade liberalization. NAFTA was the first "significant trade agreement" to include environmental provisions—in a side letter to the agreement. Other agreements that have more enforceable provisions followed (Gallagher 2009).

Balancing Economic and Environmental Sustainability

The principle of sustainable development has become a priority in global trade negotiations. Differences of opinion remain, however, over the specific methods of promoting such development and which pillar of sustainability should take precedence. The primary controversy concerns the capabilities of developing nations to conform to the environmental commitments demanded by the developed world.

Many argue that while the developing world needs market access to enter the world economy, it also needs specific policies that build up domestic industries and institutions in order to be globally competitive. These policies could provide developing countries with the flexibility to control the movement of capital, encourage technology transfer, and "generate the resources they need to protect the environment" (WTO 2006, 7). For low-income nations, reducing poverty is the main priority. But the developed world, responding to the pressures of environmental interest groups, maintains that environmental protection must accompany poverty reduction and economic development. Some WTO members recognize that environmental commitments must consider developing countries' capacity to embrace and enforce those commitments. Outside multilateral trade negotiations, however, developing countries often must acquiesce to the demands of their developed trade partners in order to acquire market access.

Growth and Change

The theory behind trade liberalization, when combined with environmental awareness, shows promise despite the antagonistic relationship between free trade and sustainability. As countries continue to remove trade barriers, global competition in all sectors should increase. The result should be more-efficient markets and more opportunities for technological and economic development in the developing world. Efficient markets could allow environmentally friendly technology to transfer across borders. Since poverty has been identified as a primary cause of environmental destruction, true economic development from free trade could have a positive effect on the environment in the future.

A main critique of trade liberalization methods such as the WTO and regional or bilateral agreements is that the developed world demands liberalization from lesser developed countries without removing its own trade-distorting barriers. For example, the developing world must reduce tariffs on textiles and sensitive agricultural products, but the United States and the European Union maintain substantial subsidies on agriculture (World Bank 2007, 40). Thus, many argue that we will not achieve global sustainability until we remove such barriers and approach fully implemented free trade.

Many people doubt the fundamental principles of free trade. The financial crisis that began in late 2007 has highlighted market flaws, leading people to question whether markets should remain free of government intervention. Countries have reintroduced protectionist measures to guard their economies from a deeper recession. The DDA has been stalled almost since its inception, and many countries' negotiators no longer anticipate achieving multilateral trade liberalization via the WTO. Meanwhile, small-scale trade agreements proliferate as countries form bilateral and regional trading blocs to gain market access.

As applied, free trade has not had a definitive positive impact on sustainable development. Growing trade volumes have increased global transportation, worsening air and water pollution and depleting natural resources. Rapid industrialization in places such as Mexico and China has taken its toll on the environment. Economically, trade liberalization has lifted some out of poverty but overall has not been able to shrink the gap between rich and poor.

Still, sustainability concerns have gained importance significantly since the U.N.'s Earth Summit in 1992. Trade agreements, bilateral or multilateral, can no longer ignore issues of sustainable economic and environmental development. If the growing network of bilateral and regional agreements acts as a set of building blocks toward global free trade, and those agreements contain flexible provisions for environmental protection and economic development, then free trade in the future may prove sustainable after all.

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See also Agriculture; Base of the Pyramid (BOP); Consumer Behavior; Development, Sustainable; Equator Principles; Financial Services Industry; Global Reporting Initiative (GRI); Information and Communication Technologies (ICT); Poverty; True Cost Economics; United Nations Global Compact

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G

Global Reporting Initiative (GRI)

Attention to corporate social responsibility and company sustainability reporting requires a means of evaluating and monitoring an organization's business activities. Although several metrics have been developed since the late 1990s, the Global Reporting Initiative is the most widely used voluntary reporting protocol in the world. It consists of universally accepted standards that measure a business's "triple bottom line."

In an era of exposed corporate greed and resultant stakeholder demand for more comprehensive and pervasive accountability, standard concepts of business ethics and environmental stewardship have evolved into more powerful markers of corporate social responsibility and company sustainability reporting (both known as CSR). Universal guidelines have been developed and periodically updated and refined to promote increased operational transparency and to level informational reporting asymmetries. The demands and expectations of investors and other entities affected by a business's operations have served as a catalyst for the development and implementation of universally accepted standards to benchmark an organization's performance. These monitoring systems are used to measure ethical, social, and environmental performance—better known as the "triple bottom line," a form of business reporting that accounts not only for return on investment (the traditional reporting model) but also for environmental and social values. They also aid the potential investor in his or her investment decision making.

One such example of a voluntary reporting protocol—and the one most widely used internationally—is the Global Reporting Initiative (GRI) G3 Guidelines. These guidelines consist of an independent group of standards that offer a universal method of sustainability reporting. Businesses that present themselves to such scrutiny integrate their financial, environmental, and social performance reports into a single publication available to the public for open review.

Evolution of GRI Reporting

GRI was first developed in 1997—partially in response to the 1989 Exxon Valdez offshore oil spill in Alaska—by the Boston-based Coalition for Environmentally Responsible Economies (CERES) and quickly evolved into a separate division (Buchanan, Herremans, and Westwood 2008). In 2002, the United Nations Environment Programme (UNEP) bolstered the international credibility of GRI, which incorporated as a nonprofit organization and relocated its headquarters to Amsterdam. Precipitated by multistakeholder input, numerous changes to GRI measurement standards resulted in the third version of the guidelines, or G3, launched in October 2006. Currently, GRI is regarded as one of the most adopted and well-recognized methods of sustainability reporting, and it has been implemented by more than 60 percent of the Global 1000 corporations; a plethora of nongovernmental organizations (NGOs), including the United Nations; and thousands of small and medium enterprises (SMEs).

The GRI Reporting System

The GRI reporting framework consists of guidelines or queries regarding the reporting entity's operations. These measurement standards have been developed through continuous interaction with individuals representing academe, business, industry, civic organizations, labor unions, and public and governmental offices emanating from over sixty countries.

The guidelines provide core content for organizations of all sizes, geographical locations, and types. They include several terms: *indicators* measures performance; *protocols* explain the methodologies of indicators; and *sector supplements* augment the guidelines by adding content unique to certain segments of a particular industry. More specifically, the indicators contain queries pertaining to how a company's operations affect economic, environmental, human rights, labor, product responsibility, and societal issues. The protocols support each indicator by providing definitions for key terms used by each indicator and explaining the indicator's intended scope. As the "recipe" for the indicators, the protocols reflect the way in which reporting should be addressed. Sector supplements basically provide a customized version of the reporting guidelines. Several examples of industries addressed by specific sector supplements include automotive, construction and real estate, electric utilities, logistics and media, NGOs, oil and gas, and telecommunications.

G3 reporting elements are grouped into categories of economic (EC), environmental (EN), and social responsibility (SR) factors. Each of these categories is then further subdivided into individual metrics identified as "Core," or essential components, and "Additional," or supplemental components. The designation of a letter rating from *A* to *C* depends upon the number of metrics addressed and the quality and correctness of the material provided. Essentially, the measurement metrics could be identified as *how* the report is presented (for example, its clarity, level of assurances, and timeliness); *what* the report should contain as outlined by GRI's economic, environmental, and social indicators; and *whom* the submitted material affects (a designation of that entity's stakeholders). Therefore, the desired reporting outcome is to relay the extent by which company practices have impacted the Earth, people, and economies. Comprehensive, transparent reporting allows the company to reassess its strategies, provide information affecting market relations, benchmark and/or demonstrate sustainable practices, and compare its performance with other reporting companies over time. The reporting organization may self-declare its report without further assessment, elect to be audited by internal GRI personnel, or employ the assurances services of a private third-party auditor.

In addition to letter ratings, GRI offers "pluses," with *A*+ ostensibly representing the ultimate rating of integrated performance. Juxtaposed to comprehensive CSR (qualitative reporting), it is less difficult to audit financial records since numbers (quantitative reporting) are less subject to multiple interpretations. These independent audits, also known as assurance reports, must be specifically requested by the reporting company when it determines its application level. If the company indicates in its report that a third party audit was conducted, that assurance report will typically accompany the company's submission. GRI will not examine the veracity of a third-party audit. Alternatively, the reporting entity may specifically request GRI (through its network of Directors, Secretariat team, and Technical Advisory Committee) to perform this assurance process. While GRI's assessment ensures that sample research on the company's standard disclosures has been conducted and that the guidelines were used appropriately, its conclusions do not measure the quality or value of the report's content. If an independent auditor is used, GRI only checks for the presence of an external assurance statement.

Shareholder vs. Stakeholder

At a time when businesses and governments are facing conflicts that far exceed acts of internal fraud or malfeasance, and as the domestic market continues to morph internationally, there has been a transfer of focus from the individual "shareholder" to the varied and multifaceted "stakeholder." GRI has recognized this transition: the identification of a company's stakeholders is critical in achieving the highest level of transparency in reporting. In current literature, the stakeholder has been defined to include "any individual or group who can affect or is affected by the actions, decisions, policies, practices, or goals of the organization" (Carroll and Bucholtz 2006, 67). Therefore, under this broadened term, the stakeholder would represent a company's other critical constituents, including its employee pool, union representatives, the media, political units, geographic areas affected by the presence of the product manufactured or service rendered, related markets, underdeveloped and developing countries, the larger ecosystem, and ostensibly the consumer. GRI has addressed each of these stakeholders in formulating its guidelines.

Shareholders, by common definition and historical development, have encompassed persons who invest in companies, acquiring tangible evidence of their respective investments—usually in the form of stock certificates—and who expect quick, favorable financial returns. With worldwide market symbiosis, the individual concern has had to defer to more defined collective consequences. With the realities of carbon dioxide emissions threatening the ecological balance and dangerously placing all life forms in serious peril, transparent reporting and comprehensive accountability have risen to the forefront in the search for remedial answers. Therefore, the manufacture of products and creation of services must now be measured against the effects and impact upon the "stakeholder." GRI, through its G3 Guidelines, provides a comprehensive method of measuring such impact.

International Reporting Guidelines

The GRI sustainability guidelines are recognized as the most integrated framework for disclosure of a business's social and environmental performance, incorporating a broad range of performance metrics. Other social reporting systems include the ISO 14000 series (International Organization for Standardization), an internationally recognized environmental certification process regarded as more inclusive of all societal and environmental stakeholders that moves beyond mere compliance to developing policies of continuous improvement; ISEA Standard AA1000 (Institute of Social and Ethical Accountability), which focuses primarily on social and ethical accounting; the Copenhagen Charter, an international standard involving stakeholder communications and the commitment of key management figures to open dialogue with certain identifiable stakeholders; SAI 8000 (Social Accountability International), a system of accounting that concentrates primarily on the organization's labor practices; and EMAS (European Management Audit System), measurement indicators primarily targeted to European Union–based companies espousing environmental policies.

Inherent Deficiencies in Voluntary Reporting

Ostensibly, there will always be deficiencies in any type of reporting that involves any degree of subjectivity. And without mandatory reporting, how truly effective is reporting on a voluntary basis? Without a universal mandate for CSR, certain queries are inevitable. For instance, how truly comprehensive is a company's voluntary effort to reveal its strengths and deficiencies as well as define the overall ramifications of its business operations on its stakeholders? What are the organization's checks and balances and are they implemented on a temporary or permanent basis? What safeguards are in place to separate rhetoric from reality?

One would naturally expect there to be a certain amount of "greenwashing" and sugarcoating of facts within the report in order to lure the would-be investor and repel the investigating consumer advocate or inquiring politician. If the stakeholder is being given an increased role in dialoging with the reporting company, should not the stakeholder then participate in that business's development of its organizational scheme, its growth and business goals, and its particular mission? Reporting *to* or *about* nontraditional stakeholders would logically presuppose that these interested parties are in continual discourse with the reporting entity.

Self-reporting assumes that the reporter is speaking the truth, and it is not always possible to confirm the substance of the information disseminated. It is usually a chief officer who selects the information to be released, material that might be technically correct but present a distorted image of the business's operations. Trade secrets—encompassing everything from a product recipe to a customer list—are given special exemption protection, but such absence of information may undercut the goal of comprehensive transparent and sustainability reporting.

While GRI identifies detailed reporting standards, it is still the prerogative of the reporting entity to define its particular stakeholders.

The Future of GRI

GRI is a dynamic organization, continuously responding to rapidly developing technologies and feedback for additional, modified, or deleted guideline queries to respond to the needs of business and its many stakeholders. Assurance reporting, guideline categorization, and digitalizing its reporting "language" are key examples of GRI's commitment to providing the best methods of comprehensive, transparent reporting.

Sector Supplements

As all industries cannot be adequately evaluated by a "one size fits all" set of metrics, GRI has created individual categories for certain types of businesses as mentioned previously, formulating indicators unique to such industries. GRI has determined that these sectors require specialized guidance to complement, not substitute for, the Guidelines.

Matchmaker Program

The GRI organization inaugurated a "matchmaker" program with the launching of the G3 protocol to offer institutions of higher learning an opportunity to become part of a three-tiered process of reporting, verification, and critique.

Business entities voluntarily submit information concerning their operations, nature, and composition of products produced, scope of business influence and dealings, and details of labor and management interaction (the reporting element). The information disseminated is then audited by an independent entity that is allowed access to the company for verification, follow-up, and substantiation of information provided (the audit/verification element). Finally, as an affirmation of the auditing process, an institution of higher learning is invited to review and assess the reports prepared by both entities (the critique element). The findings of all three organizations are then summarized and the company is then rated. This rating and the G3 Protocol conclusions are stored online with GRI, offering the public additional details regarding stakeholder effect.

Universal Labeling

In an attempt to uniformly segregate and identify the components, characteristics, and effects of a business's operations as well as to facilitate the electronic communication of business and financial reporting, GRI is participating in the development of "eXtensible (sic) Business Reporting Language" (XBRL) and moving toward global uniform reporting and the configuration of data in a digital format compatible with financial reporting requirements. This method of organization is accomplished by placing a "tag" on certain numbers and qualitative material that can be recognized by computers and downloaded, analyzed, and stored. This process essentially filters variables and labels, helping both investors to base decisions upon sustainability information and researchers to import desired information into their data systems. For example, "GHG" would represent greenhouse gases and alert the researcher or potential investor to that particular data. In this manner, a comprehensive taxonomy list may be developed for worldwide usage.

National Annexes

As specific regions and countries pose unique features, GRI is attempting to modify its guidelines to reflect how these differences might impact the reporting process. Cultural distinctions endemic to specific countries and regions often produce a different perspective as to how the reporting entity's operations impact their respective communities. In this manner, GRI faces the challenge of identifying and labeling these indicators of community impact and assessing compliance with suggested practices.

GRI has undoubtedly pioneered the world's most extensive and widely used sustainability reporting protocol. As the framework continues to respond to changing global dynamics, GRI strives to respond accordingly through its consensus-seeking process that draws in contributors globally, representing industry, governance, labor, and professional institutions. Acknowledging the flaws of trade secret protection and potentially inaccurate self-assessment, GRI remains committed to continuous improvement to effect the highest level of transparency in sustainability reporting.

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See also Accounting; CSR and CSR 2.0; Ecolabeling; Equator Principles; Performance Metrics; Stakeholder Theory; Transparency; Triple Bottom Line

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Green GDP

Traditional measurements of performance, such as gross domestic product (GDP), account for economic development but do not accurately reflect human or environmental well-being. Since the 1990s several new metrics have been proposed, including green GDP, which attempts to provide a more accurate accounting that considers both the positive transactions that benefit well-being and the negative economic activities that diminish it.

The concept of "green GDP" arose in the early 1990s in reaction to the deficiencies of the traditional gross domestic product (GDP) to account for the economic costs of depleted natural resources and incurred pollution, which in turn affect human welfare. GDP is usually defined as the total market value of all final goods and services produced within a territory in a given period of time (usually a year), including exports minus imports (net exports). It has been used as a standard measure of the size of an economy in national accounting and is often mistakenly regarded as a proxy for progress in the public discourse. A closely related term is *gross national product* (GNP), which is GDP plus international income transfers. The term *gross* means the exclusion of capital depreciation from the accounting. Infrastructural wear and tear, for instance, do not make their way into the GDP. When such considerations are taken into account, *net domestic product* (NDP) and *net national product* (NNP) are used.

Limits of Traditional GDP

Ecosystem services such as climate regulation, carbon sequestration, and nutrient cycling, while indispensable for human survival, are not part of traditional economic accounting. Some have estimated the economic value of the world's ecosystem services to be US$33 trillion per year on average, mostly outside the market and almost twice as much as the global GDP total (Costanza et al. 1997). Valuing ecosystem services, however, has been controversial to some economists and ecologists for methodological and other reasons. GDP omits many of the important goods and services that we derive from nature because its scope is delimited completely by the market. Thus, despite its prominent position in economic analysis and public policy, GDP has become the target of increasing criticism in recent decades. In GDP accounting, no distinction is made between activities that contribute to well-being and those that detract from it. A classic example is an oil spill, which is counted as a positive addition to the GDP because it warrants expenditure on cleanup. In this way, many environmental damages are vindicated as contributions to economic progress. For the environmentally conscious, this is an affront to both intuition and ethics as pollution (especially of such a magnitude) is detrimental to both human and environmental health.

Also, GDP does a poor job of reflecting actual human well-being because it neither accounts for social sustainability nor future consequences of present consumptions. In fact, recent studies suggest that, for a number of countries, the positive correlation between human well-being and GDP breaks down after GDP values reach a certain threshold—known as the "threshold hypothesis" (Max-Neef 1995). A rising GDP merely signals an increasing level of market transactions, without regard for whether these activities are beneficial to humans and nature in the long run. Thus, a fixation on the temporally narrow scope of traditional economic accounting can lead to dangerously myopic policies. The absence of ecosystem services and environmental damages (known as "externalities" in economic parlance) from monetary valuation potentiates the vicious cycle of economic shortsightedness and environmental misuse. It is widely accepted now that GDP significantly undervalues the contributions of nature to human well-being and is ill-suited for measuring sustainable development. Green GDP (also green NNP), therefore, has been proposed to explicitly estimate these missing costs by subtracting the economic penalties imposed by natural resource depletion and pollution from national accounting. As a result, the green GDP is meant to advance a more inclusive view of "natural capital" and promote more sustainable management practices.

Alternatives to GDP

The notion of "greening" GDP has gained some momentum in both academia and public policy since the early 1990s. One of the most noteworthy attempts to implement the concept was carried out by the People's Republic of China. In 2006, the Chinese government released its environmentally adjusted GDP—its green GDP, prepared jointly by the State Environmental Protection Agency and the National Bureau of Statistics (SEPA and NBS 2006). Included in the calculation were assessments of air, water, and solid-waste pollution as well as the costs of depleting various natural resources. The report concluded that the economic loss of environmental damages amounted to 3 percent of the country's GDP in 2004. Nearly as soon as the figures were released, however, it became clear that there still remained major defects in the accounting procedures. A large number of concerns were not factored into the analysis, and there were also myriad methodological obstacles that impeded a thorough economic analysis of environmental damages. For instance, only half of potentially more than twenty pollution costs were estimated in China's green GDP report. Concerns such as soil and groundwater contamination, as well as the entire categories of natural resource depletion and ecological damage, were not included in the accounting. Thus, the 3 percent diminution fell short of what many analysts believed the actual costs were. It is now evident that green GDP, for China and elsewhere, is still theoretically appealing but practically formidable.

In addition, several other development metrics similar to green GDP have also been developed as a part of a larger group of sustainable development indicators. For example, the Index of Sustainable Economic Welfare (ISEW) was developed in the late 1980s to address the flaws in GDP. ISEW accounts for both conventional economic transactions and nonmarket natural and social benefits, and its value is determined by the balance between positive transactions that benefit human well-being and negative economic activities that diminish it. Genuine Progress Indicator (GPI), developed later in 1994 by Redefining Progress (a nongovernmental organization focused on public policy), includes essentially the same measures as ISEW. The main differences between the two are related mostly to data availability and users' preferences for valuation methods. ISEW and GPI have widely been used by international organizations, governmental agencies, and academic researchers. Another common development metric is Genuine Savings (GS), proposed by the World Bank in 1999. Taking into account both natural and human capital, GS estimates the domestic savings less the value of resource depletion and environmental degradation. A relatively new metric, Happy Planet Index (HPI), was introduced by the New Economics Foundation (NEF) in 2006. HPI bypasses traditional monetary approaches and focuses on the efficiency with which countries translate natural resource use into human and societal well-being. Specifically, HPI is the ratio of happy life years (the product of life satisfaction and life expectancy) to environmental impact (measured by ecological footprint).

The Future of Green GDP

Despite the mounting criticisms of its irrelevance and the emergence of alternatives, GDP's deeply entrenched position in the mainstream discourse will likely ensure its continued prominence in both economics and public perception. It is important, therefore, to clearly understand what GDP measures and what it does not. Meanwhile, efforts for valuating the depletion of natural resources and the impacts and mitigations of pollution will continue. The environment must be part of national accounting. The United Nations has published a set of accounting guidelines in the *Handbook of National Accounting: Integrated Environmental and Economic Accounting* (known as SEEA 1993 and SEEA 2003), which provide a common framework for valuating environmental contributions to economies and economic impacts on the environment. Such efforts promote methodological standardization that in turn facilitates applications and cross-country comparisons. They also represent a continued operationalization (the process of strictly defining variables into measurable factors) of the ideas behind green GDP. Although it remains implausible that GDP will soon be displaced as the hallmark indicator of economic fitness, attempts to "green" it, despite various shortcomings, constitute a positive movement in the direction of environmental consciousness. Complementary indicators and indices are also needed if we are to adequately measure our true economic wealth and health: the sustainability of human–environmental systems.

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See also Development, Sustainable; Ecological Economics; Ecosystem Services; Natural Capitalism; True Cost Economics

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Green-Collar Jobs

The promise of an economy that creates good jobs while protecting and restoring the natural world is an alluring one. Depending on society's commitment to sustainability, between 8 and 40 million green-collar jobs—loosely defined as employment that contributes to environmental quality—could be created in the U.S. alone by the year 2030.

As more people recognize the need to address the multitude of threats to our environment, businesses are rethinking their core business models to reflect the shift in consumer preferences toward products that are less harmful to the environment. Likewise, entrepreneurs are rushing to develop new green products and services. Besides climate change, critical environmental issues facing business today include energy, water, biodiversity and land use, chemicals, toxics, heavy metals, air pollution, waste management, ozone layer depletion, oceans and fisheries, and deforestation (Esty and Winston 2009). The demand for innovative solutions to address these challenges has led many commentators to conclude that we are on the cusp of a "green wave" in terms of job growth and economic opportunity. Millions of new green jobs will be created, so the theory goes, ranging from renewable energy installers to mass transit employees, from sustainability analysts to water resource technicians. Because many of the jobs are blue-collar in nature, they may provide pathways out of poverty for low-skilled, low-income earners (Jones 2008).

Beyond job creation, the green economy promises to provide additional economic benefits. For example, households, businesses, and governments save money as they become more energy efficient. These savings are recycled into the local economy, creating opportunities for local businesses to grow. New markets for greener products and services also support new industries, potentially expanding the local tax base. A greener economy, with its emphasis on green buildings, also promises to improve worker productivity by creating healthier work environments where employees have greater access to fresh air, sunlight, and less exposure to toxins.

In addition to the economic benefits, the green economy will improve environmental quality as greener products and services are brought to market. Electric cars have lower carbon emissions. Green buildings use less water. Mass transit promotes denser development patterns lessening pressure to convert productive farm and forestlands.

Green-collar jobs provide communities with the opportunity to both strengthen the local economy and improve the health of the environment. As green-collar jobs become as commonplace as white- and blue-collar ones, we will be forced to rethink our current approach to economic development with its focus on unbridled growth and lack of concern for the environment. In a green economy, economic development and environmental quality go hand in hand. Businesses become much more efficient and waste as we know it is practically eliminated. Decision making is driven by the recognition that only a healthy environment can support a long-term, sustainable economy (Hawken, Lovins, and Lovins 1999).

Defining Green-Collar Jobs

There is no consensus in the literature on how to define green-collar jobs. A broad interpretation of green jobs includes all existing and new jobs that contribute to environmental quality. Probably the most concise, general definition is "well-paid, career track jobs that contribute directly to preserving or enhancing environmental quality" (Apollo Alliance 2008, 3). This definition suggests that green-collar jobs directly contribute to improving environmental quality, but would not include low-wage jobs that provide little job mobility. Most discussions of green-collar jobs do not refer to positions that require a college degree but to positions that typically involve training beyond high school. Many positions are similar to those held by skilled, blue-collar workers such as electricians, welders, and carpenters. Examples of green industries employing worker with such skills include smart-grid construction; expansion of freight and passenger rail; wind, solar, and biofuel production; and energy efficiency industries.

Estimating the number of existing and potential green-collar jobs is equally as difficult as defining exactly what a green job is. Thus far, research documenting the number of green-collar jobs has been quite varied. Conservative estimates that include only renewable-energy and energy-efficiency industries suggest about 8.5 million jobs in the United States. These estimates focus on specific activities rather than traditional job or industry characteristics (Pinderhughes 2007). According to the American Solar Energy Society, this figure could grow by as many as 40 million by 2030.

Differences in estimates of the number of green-collar jobs can be attributed to several issues. First, a few analyses include all jobs related to promote a green economy. Thus, they would include workers in the plastics and steel industry, for example, because these materials are used to construct products like wind turbines and solar panels. These reports tend to overestimate the number of green-collar jobs because most of these jobs would not be considered green. Second, even if these related jobs are considered, they probably should not be considered as full-time equivalents because much of their output, in most cases, may not go to green activities. A more accurate accounting method might try to take into consideration the proportion of their product that is used to promote environmental quality. Third, some analyses attempt to consider the multiplier effect of the green economy. These analyses assess the direct and indirect impacts on a regional economy by estimating the number of jobs and income that are created through investments in green-collar jobs (Pollin and Wicks-Lim 2008). These estimates typically include service-sector jobs that most people would not consider career-track jobs. Finally, data collected through the Census Bureau and other official sources do not collect information in a manner that would allow researchers to identify green-collar jobs.

Strategies for Promoting Green-Collar Jobs

Communities seeking to promote green-collar jobs first need to identify their goals. This does not have to be an extensive process, but it is essential to build on local strengths and opportunities (Green and Haines 2007). Next, localities need to identify appropriate public policies that will allow them to achieve their goals. Concurrently, it is essential to prepare the workforce for green-collar jobs. Programs should be linked to local opportunities and provide workers with skills that will allow them to move up the career-track (Apollo Alliance 2008). Finally, communities should monitor and evaluate their progress toward growing green jobs. Given the current economy and evolving technologies, it is likely that significant course corrections will be necessary as the green economy continues to take shape. By linking green job policies with environmental goals, communities may find broad-based support for the types of strategies discussed below.

Many of the green job strategies outlined are demand-driven. These types of strategies are seen as crucial to the successful development of the green economy because they provide a stable, secure funding environment in which companies can take root and grow. There are probably many more strategies than are discussed here, but these are the core considerations for most communities.

Energy Efficiency and Green Buildings

A report by The American Council for an Energy Efficient Economy (ACEEE) found that significant energy efficiency potential remains available in the United States. For example, across all sectors, studies show a median technical potential of 33 percent for electricity (Nadel, Shipley, and Elliot 2004). In addition, approximately 40 percent of our energy use is associated with buildings. Energy efficiency is seen as a powerful strategy to grow green-collar jobs because of the potential demand for energy audits and retrofits that exists in neighborhoods, schools, and businesses across the entire United States. Communities can drive green-collar job creation that is tied to efficiency and green building by crafting policies to improve their own facilities. The jobs related to energy efficiency are often concentrated in traditional building trades and construction industries. The jobs related to green buildings not only include green construction jobs but sustainability analysts, urban planners specializing in brownfield redevelopment, and other development professionals with experience in green design. Estimates suggest that about ten jobs are created per $1 million investments in high-performance buildings (Center on Wisconsin Strategy 2007). Jobs are created through the economic activity associated with retrofitting buildings and green construction, and also through the energy savings that result from these activities (Goldstein 2007).

Renewable Energy

Renewable energy is growing rapidly as an alternative to fossil fuel usage. It is seen as a significant generator of green-collar jobs both in terms of manufacturing and in terms of design, installation, and servicing of the systems themselves. Communities can promote renewable energy development through conventional means such as offering tax incentives, credits, and other mechanisms to encourage renewable energy manufacturing in their own backyards. They can also develop creative financing mechanisms that incentivize homeowners and businesses to deploy renewable energy on site. Many countries, states, and even some cities are effectively mandating renewable energy development by passing renewable energy portfolio standards (RPS) requiring that a certain percent of energy purchased be derived from renewable sources. Worldwide, the largest number of jobs in this sector is in biomass. Three countries (Brazil, the United States, and China) account for the vast majority of jobs in biomass. Jobs in solar industries are the second highest, with most of those jobs located in China. Overall, renewable energy sources are growing rapidly, especially in developed countries (Renner, Sweeney, and Kubit 2008). Varied job opportunities appear throughout the renewable energy industry including biomass, solar thermal, wind, solar panels, hydropower, and geothermal. A few of the renewable-energy job types include electrical and mechanical engineers to design solar components, solar installers, and geothermal and heat pump system engineers, installers, and operators.

Transportation

Transportation accounts for about one-fourth of the world's energy use. Green-collar jobs in this sector are most often associated with fuel efficiency and public transportation. There are few reliable estimates of the number of jobs in the transportation sector. The discussion tends to focus on improvements made through green vehicle manufacturing and through public transportation. Green vehicles include electric hybrids, compressed natural gas, low sulfur diesel vehicles, and vehicles capable of running on various biofuel blends. As of 2009 the number of jobs in manufacturing green vehicles is relatively small, with most of the jobs concentrated in Europe. Public transportation, however, is a significant employer in many developed countries. Many of these counts, however, include employment with traditional petroleum-based bus systems.

Smart Grid

The current electrical grid is widely seen as a barrier to achieving significant improvements in both energy efficiency and renewable energy growth. The system prevents the full deployment of wind, for example, because the transmission lines simply do not exist to connect our nation's largely rural high-plains wind resource to our urban population centers. The grid is also highly localized and disjointed, which prevents the effective movement of power throughout the country when demand exceeds supply in a given region. A newer, more modern smart grid can take advantage of recent improvements in information technologies to better manage electrical loads. An industry estimate of jobs associated with investments in a smart-grid system for the United States claim that 280,000 jobs potentially could be created (The Gridwise Alliance 2009). These jobs would likely encompass a broad range of occupations including system designers, project developers, marketers, public relations, supply chain managers, and several types of field technicians.

Environmental Management

This strategy is often not equated with green-collar jobs but it is so broad that it has tremendous potential to grow them. Included in this category would be many technologies that directly benefit the natural environment, including water, solid and hazardous waste, and air quality technologies among others. We are reluctant to include the recycling industry, although many states and localities have been very successful in promoting recycling programs. Most of the jobs in this sector, however, are low-wage positions with few opportunities for mobility. Recycling markets also appear to be quite sensitive to economic conditions. One of the lessons learned is that green industries will still be market-driven and may experience many swings as they mature. It also shows that not all green industries will produce good jobs for workers. It is difficult to estimate the number of green-collar jobs in this area because the category is so broad. Job types might include air quality specialists, greenhouse gas managers and accountants, and water resource specialists (Lewellyn, Hendrix, and Golden 2008).

By adoption of these broad strategies, communities may be able to achieve multiple goals including environmental quality and green job creation. Many of these strategies are particularly appealing because they are demand driven, meaning locally elected officials can create the demand for green industry by simply shifting their regulatory and purchasing policies to achieve their green job and environmental goals. Communities that can weave together a policy framework with broad-based support will likely be at a significant advantage in terms of creating a business environment that encourages green industry development.

Challenges and Solutions

There are many challenges to green-collar job creation including workforce development, policy development, technological barriers, geography, environmental issues, and financial constraints. Many of the solutions to the challenges facing green job growth are policy related. For example the lack of a coherent federal policy has led to a very chaotic growth in the wind industry. Tax credits that make wind financially competitive have only been reauthorized for two years at a time. Thus the industry is in a constant state of flux between rapid project growth and dramatic reductions in investments depending on the biennial whims of federal policy makers. The challenge for local governments is to focus on those areas over which they have control while seeking to minimize the negative impacts of state and federal policies over which they have little control.

Workforce development is a key challenge. Many green-collar jobs do not require major changes in training programs because they can build on programs in the trades and advanced manufacturing industries. These programs still face some of the same obstacles that workforce development efforts have experienced in the past. It is difficult to recruit youth into these programs even though they tend to be good-paying jobs with opportunities for income mobility. In addition, it may be too costly for small communities to develop specialized training programs for emerging green-collar jobs. A more likely strategy is that green-collar jobs will require more intensive use of apprenticeships and school-to-work programs to provide on-the-job training. Another solution may be to develop green entrepreneurship programs for youth.

Many jobs in the renewable energy sector will be tied in the short run to geographical regions that have considerable sources of renewable energy, such as biomass, wind, and even solar. For example, the Midwest has a large concentration of biomass that could be used for biofuels; over 80 percent of biofuel facilities currently are located in the Midwest. Many coastal communities can harness wind energy. The Southwest has a significant potential for solar energy. These regions are likely candidates for renewable energy production and manufacturing. But geography need not be a constraint for communities pursuing renewable energy job creation. A very strong predictor of green-collar job growth is local renewable energy policy. Those states with strong incentives, including New Jersey and California, have leapt to the lead in renewable energy deployment. Not surprisingly, they have also benefited from new green industry creation, especially in sales, servicing, and installation of renewable systems. Communities can enact policies that increase demand for residential, business, and government renewable energy projects.

There are several technical challenges to green-collar job creation. For many reasons, it is likely that the renewable energy sector will be more decentralized and based in smaller units than our current system is. This technical challenge will likely be overcome through development of a smart-grid system that will create many more opportunities to develop locally distributed renewable energy resources that can feed into the grid. Overcoming this challenge will take considerable public and private investment and will not happen overnight.

Financial constraints are another challenge to green job creation. For example, green buildings include both energy efficiency and renewable energies. There is general agreement that retrofitting existing buildings and improving energy efficiency offer the greatest potential for the environment and jobs, at least in the short run. Yet this may be the most challenging sector with which to grow jobs. The cost of retrofitting will be prohibitive for low-income residents in most countries and will require substantial government subsidies (Jones 2008). Cost is also a major challenge for individuals to install renewable energy at their home including solar PV (photovoltaic), hot water, and solar space heating. Americans are extremely mobile and may be reluctant to pay for these technologies because they are concerned they will not get their investment back before they sell their homes. One solution to this problem is being adopted in communities across the country: Local governments are bonding and then using the funds to lend to homeowners at very low interest rates for installation of renewable energy systems. These systems are then paid off over a ten- to twenty-year period through the property tax bill. If the homeowner moves, the payment stays with the home and the new homeowner continues payment.

Green vehicles continue to draw a great deal of interest among environmentalists. Only a very small percentage of the workforce, however, is now employed in automobile manufacturing that would be considered green. There have been important breakthroughs in automotive technology that may significantly increase the potential for green vehicles. Moving this new technology to mass production, however, could take many years and significant capital investment. A major hurdle to green vehicle growth is battery technology: Without adequate storage, the concept of plug-in vehicles is limited. Efforts are underway to reduce the size of battery storage. With improved batteries, green vehicles may be charged at night to take advantage of lower electricity rates; the batteries' energy then is used during the day for driving or for powering household appliances. When combined with renewable energy sources, such as solar power, green vehicles could have a significant impact on carbon emissions.

Finally, there are a number of environmental issues that may constrain green-collar job growth in areas such as biofuels. Much of the current literature focuses on the dilemmas associated with corn ethanol (i.e., trade-offs between food costs and fuel costs). Research focusing on cellulosic ethanol offers the potential of avoiding the trade-off between food and fuel and overcoming many of the economic and environmental costs associated with corn ethanol. Other solutions include the development of algae as a biofuel and utilizing other types of nonfood feedstock for biofuel production.

The Future

Green-collar job growth will be dependent on sustained societal commitment to addressing climate change and other threats to the environment. If commitment is long-lasting, then our current economic system will have to be transformed in a way that puts focus on other metrics (i.e., measurements) beyond just gross domestic product and unbridled growth. Environmental factors will need to be considered as well. This will create a huge opportunity across all sectors of the economy as new and existing businesses look for ways to become greener in terms of product and service delivery. The transition toward a green economy will be difficult for many regions. Promoting green industries will lead to job loss in some traditional industries. It will require more investment in workforce development to help workers make this transition.

In summary, green-collar jobs are expanding, but not rapidly enough. Worldwide, green jobs tend to be concentrated in a few developed countries. The United States has not invested as much in research and development in the green sector as many western European countries. Investments in research will be critical to the growth of green-collar jobs over the next decade. Government support for the public and private sector to adopt new technology will also be an essential factor in the transition to this new economy. Finally, educational programs have been proven to be an important element in increasing the public's awareness of environmental issues and in changing attitudes and behavior.

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See also Education, Business; Education, Higher; Energy Industries—Overview of Renewables; Investment, CleanTech; Natural Capitalism; Social Enterprise

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Greenwashing

Although not always used intentionally, greenwashing refers to deceptive public relations or marketing claims about so-called environmentally friendly products. It is a prominent practice; an overwhelming majority of green goods are the focus of some type of greenwashing. These misrepresentations result in consumer distrust, which threatens the survival of the developing market for green products.

The green marketplace is an increasingly attractive one for the business world. Recent surveys indicate that over 90 percent of consumers in the United States say that they participate in the world of sustainability (Hartman Group 2007), and a large segment (37 percent) feel highly concerned about the environment (California Green Solutions 2007). U.S. consumers are expected to increase spending on green products (products that are organic, natural, or are otherwise environmentally friendly) to $420 billion in 2010 (Mooth 2009).

Unfortunately not all signs are encouraging. Consumers in many cases still have not bought into the benefits of going green. While 49 percent say that a company's environmental record is important, only 21 percent say it has driven their choice (Wasserman 2008). Many consumers not only continue to question whether the price premium for green products is justified, but they are also skeptical of the product's environmental claims; very few—only 10 percent—trust the environmental information they get from business and the government (Futerra 2009, 1). Charges of greenwashing are consistently made by consumers, government agencies, and consumer advocacy groups.

What Is Greenwashing?

Greenwashing typically refers to advertising, public relations, or product package claims that inadvertently, or in some cases deliberately, mislead consumers about the environmental benefits of a company, product, or service. Some groups broadly apply the term to any company that promotes any aspect of environmental benefit while ignoring other damaging impacts of their company operations. For example, Shell recently withdrew its sponsorship of a wildlife exhibit after complaints that it was using this tactic to greenwash its environmental credentials. Others have tried to offer guidance by providing greenwashing categories. Notable amongst them is the company TerraChoice Environmental Marketing (2009), which recently found that over 98 percent of green products committed at least one of their "seven sins of greenwashing":

1. Hidden Trade-off. Seventy-three percent of companies were guilty of focusing on a narrow set of attributes while ignoring other environmental issues. A washing machine that promotes its energy savings while using large quantities of water would be an example.
2. No Proof. A paper-towel company that stated its products contained 80 percent postconsumer recycled content would be an example of this sin. Committed by 59

percent of companies, it refers to claims that "cannot be substantiated by easily accessible supporting information or by a reliable third-party certification."

3. Vagueness. *Good for the Earth and environmentally friendly* are general terms that are not easily interpreted. Fifty-six percent of products surveyed committed this sin.
4. False Labels. Many companies use legitimate third-party organizations (for example, Energy Star in the United States and European Union) to test and provide certification regarding their green claims. A company that uses its own in-house certification without additional explanation is an example of the 24 percent of companies that use false labels that mislead consumers.
5. Irrelevance. A number of claims are truthful but irrelevant. Some paper towels are advertised as 100 percent cellulose. This is true, but all paper towels are made out of cellulose. Eight percent commit this sin.
6. Lesser of Two Evils. Environmentally friendly pesticides are an example of this sin. These claims distract consumers from the potentially larger environmental impact of the product. Only 4 percent of companies committed this.
7. Fibbing. Outright deceit was committed by less than 1 percent of products. Claiming a particular certification (such as USDA organic) would be an example.

Greenwashing Versus Spin

The "seven sins" reveal that most greenwashing is not a malicious intent to deceive consumers. Particularly for new categories, consumers rely extensively on product communication to inform their decision making. Misleading communications hurt consumers and also disadvantage those companies with legitimate green attributes. Consumers may end up supporting companies with few actual green features. If consumers can't trust the green information provided, they will no longer base their purchases on this attribute, and companies no longer have an incentive to develop safe green products. The market will die before it has an opportunity to grow.

Growing consumer interest and demand for green products makes an inviting target for companies to highlight any green aspect they can find in their company or product. This has led to an increase in consumer complaints against many environmental claims; a fivefold increase has occurred in the United Kingdom since 2006 (Wilson 2008, 1). Some categories are more prone to greenwashing than others. For example, in the United Kingdom greenwashing most commonly was found in the travel and automotive industries, while in the United States it is most prevalent in toys, cleansers, and cosmetics (Futerra 2009).

Avoiding Greenwashing

Although the global standards developed by the International Organization for Standardization (ISO) provide a comprehensive list of guidelines for environmental labeling, many countries have adopted their own due to varying consumer knowledge and cultural specifics. Countries including the United Kingdom, France, and the United States are beginning to revisit guidelines that were originally developed before words such as *renewable energy, sustainability*, and *carbon offset* were introduced. Consumer advocacy groups such as Greenpeace and Co-op America consistently investigate and report corporate greenwashing instances, and websites such as greenwashingindex.com allow consumers to seek out and report greenwashing activities.

Over 60 percent of consumers view sustainability campaigns as just another marketing tool. This creates a strong barrier that companies marketing green products must overcome. Although there is no such thing as a completely green product, companies can help grow the green market by using guides such as the seven sins or the ten signs of greenwashing (Futerra 2009).

Similar to any product category, consumers need to be educated customers. They need to be wary of unsubstantiated claims and carefully examine symbols and logos. Look beyond the pretty art and lofty words. Finally, if the green product industry is to survive, consumers must be willing to support legitimate offerings through their purchasing decisions.

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See also Consumer Behavior; Ecolabeling; Marketing; Packaging

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Health Care Industry

Despite the importance of the environment to our health, the health care industry has lagged behind in its commitment to environmental sustainability. The trend is changing as the health care sector assesses environmental costs, such as energy consumption and the disposal of toxic substances. To spur more rapid progress, health care organizations need to take on environmental concern as a central mission, rather than simply a cost-saving measure.

Every society maintains a health care sector whose activities reflect, for good or ill, the culture, priorities, resources, and values of that historically and geographically defined group. Nation-states develop systems of care and organize them in diverse ways, assigning different responsibilities to agents at local, regional, and national levels. In many communities the health care system is considered an industry with its components organized in a complex web of for-profit and nonprofit enterprises. Governments and nongovernmental organizations (NGOs) invariably play important and complicated roles as providers, funders, and regulators. In general, health systems include facilities that provide acute care, such as hospitals and outpatient clinics, and those that provide chronic care, such as nursing homes and hospice programs.

The concept of health varies by culture. Health can mean the absence of disease, the maintenance of physical, mental, and social well-being, and/or the ability to adapt to changes in society and environment. Health care systems can be shaped by regional perspectives on the degree to which biological, psychological, and social factors affect health; beliefs that health has a spiritual aspect; and opinions about who should administer health care and whether it should be managed publicly or privately. Who should bear the primary responsibility for health care—individual, healer, local community, or larger society—is also important. Communities also vary in their awareness and sense of responsibility for the environmental costs of health care and their degree of commitment to social justice. The result of all these factors is health care systems that may or may not be sustainable ecologically, socially, or financially.

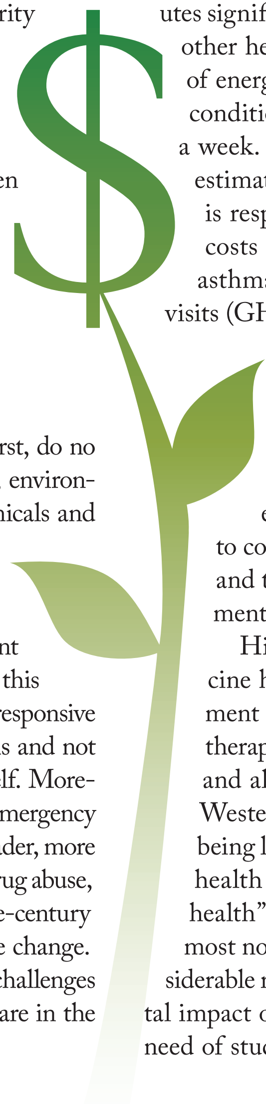
Since the mid-1970s, broadscale social trends, such as global overpopulation, have increasingly challenged health care systems. Elders, whose numbers are rising, incur the most health care costs per capita, while people of reproductive age add children to the burgeoning population. Growing numbers of people increase levels of consumption, the burning of fossil fuels, and industrial activities that hasten climate change, which in turn affects disease distribution. Floods, droughts, poor water quality, and instability over food supplies brought on by climate change will continue to affect the patterns and severity of human disease dramatically.

Economic, as well as ecological, forces are also changing health care. In many countries economic trends are driving nonprofit health organizations to act more like businesses. Clinical outcomes are expected to be measured and tied to reimbursement. (This trend in health care, which is also evolving in education and other fields, is known as "pay for performance.") A major problem is creating financial incentives designed to improve health services rather than the bottom line of health care providers. Insurance companies tend to reimburse hospitals and doctors at higher rates for acute care services than they do for chronic care, even though a growing elderly population means more and more people require chronic care.

In addition, health care systems generally do not function at optimal efficiency in part due to administrative waste and information-system deficiencies. Complex administrative procedures create confusing billing systems that perplex providers and patients. A study published in 2003 found that in the United States in 1999, an estimated 31 percent of health care expenditures went to administrative costs, compared to 16 percent in Canada; this represented $1,059 and $307 per capita, respectively (Woolhandler et al. 2003, 768).

Education and wealth dramatically affect health and quality of life. Social inequities reduce the availability of health care and lower average levels of population health. Spending more money on health care, however, does not always guarantee better outcomes. For instance, the United States spent about 16 percent of its gross domestic product (GDP) on health care in 2008; this was roughly 40 percent of all the money spent in the world on health care (WHO 2007). Yet, despite health care expenses that are among the highest in the world, U.S. infant mortality rates compare poorly with many countries, ranking 30th in 2005 (CDC 2009). At the same time, life expectancy was more or less the same in 2007 than in many countries that spent comparatively little on health care, such as Costa Rica ($779 per person), Chile ($689), and Cuba ($674) (WHOSIS 2009; dollar figures are in purchasing power parity (PPP) from 2006).

While high financial costs burden some of the most effective and accessible health care systems of developed countries, poor countries often cannot provide what is necessary to maintain even minimum health care standards (WHO 2003). Historically, environmental costs have been excluded from health care budgets, so including them portends even higher costs to consumers.



Environmental Aspects

The Hippocratic maxim for medical practice—"First, do no harm"—mirrors the important, but often ignored, environmental precautionary principle: the safety of chemicals and biological products should not be assumed before they are released into the environment. It might seem intuitive that the world's health care providers should be leading efforts to protect the environment and preserve the viability of the human species, but this is not so. Health care has often been regarded as a responsive solution to environmentally caused health problems and not widely perceived as an environmental problem itself. Moreover, the emotional power of life-saving acute and emergency care tends to detract society from responding to broader, more complex chronic concerns such as teen pregnancy, drug abuse, and increasing antibiotic resistance, as well as the late-century population health problems associated with climate change. It also tends to diminish attention to the growing challenges of providing environmentally responsible chronic care in the community and at long-term care institutions.

Nevertheless, when compared to public health measures such as improved nutrition and smoking-cessation programs, hospital-based medical services have much higher costs. For instance, the health care costs for an overweight individual who requires a heart bypass operation would be greater than the costs for someone who lives a healthier lifestyle, thereby reducing the likelihood of a need for expensive acute treatment.

The vision of modern medicine is framed on one side by progressive utilitarian philosophies (cost efficiency) and on the other by scientific achievement (research, curing disease), so it does not easily incorporate costs to the environment. The health care popularly perceived as "best" is often the most visible in the media and marketplace, which means health care systems that use technology and pharmaceuticals most aggressively. Culturally and psychologically, modern medicine seems most powerful when it is most environmentally costly.

The pharmaceutical industry, from manufacture all the way through the supply chain to disposal, contributes significant toxins to the environment. Hospitals and other health system components consume high levels of energy for lighting, heating, and air filtration and conditioning all hours of day and night, seven days a week. The U.S. Environmental Protection Agency estimates that the health care sector's electricity usage is responsible for $600 million in increased health costs annually, including increased incidences of asthma, respiratory illnesses, and emergency room visits (GHSI, Practice Greenhealth, and Health Care Without Harm 2009, 2). Patients and providers, including NGO donors, are enamored with the newest genetic therapies and expensive diagnostic equipment. By focusing on the bright lights and newest gadgets, societies tend to neglect community health and fail to consider environmental contributions to disease, and the environmental costs of therapies and treatments themselves.

Historically and regionally, some forms of medicine have given more consideration to the environment and have had less negative impact on it. These therapies are often termed CAM, for "complementary and alternative medicine" in contrast to traditional, Western allopathic medicine. They increasingly are being labeled "integrative medicine," as fusion among health care models occurs; "wellness" and "holistic health" are other common terms. Around the world, most notably in China and India, people commit considerable resources to holistic therapies. The environmental impact of integrative medicine is a field that is still in need of study, however; the focus of this article is on the environmental impact of allopathic health care, which has been subjected to more research.

Health care systems incur varying environmental costs related to everything from facilities, transportation, and food to energy consumption and waste. Moreover, they employ large numbers of people whose own health, lifestyles, and attitudes about sustainability are critical to their communities.

Ecological Footprint

A concept that holds promise to reframe health care practices is the "ecological footprint." In their seminal work *Our Ecological Footprint: Reducing Human Impact on the Earth* (1996), William Rees and Mathis Wackernagel of the University of British Columbia created a paradigm to help move humanity out of the red zone of overconsumption and into the green zone of sustainability.

The ecological footprint is an accounting method for determining approximately how much of the Earth a particular activity is using in terms of the Earth's regenerative power. The footprint measures the annual per capita rate of the use of such sectors as grain and meat production, fishing, fossil fuels, and land for buildings and roads. According to the Global Footprint Network (2009), humanity uses the carrying capacity of about 1.4 planets each year to produce goods and absorb waste. The network has defined "Earth Overshoot Day" as the day each year that humanity "begins living beyond its ecological means." In 2009, Earth Overshoot Day occurred on 25 September.

Can the ecological footprint be applied to health care? The Global Health and Safety Initiative (GHSI)—a diverse group of health care stakeholders whose goal is to improve patient and worker safety and environmental sustainability—developed *The Eco-Health Footprint Guide* to help health care organizations apply the concept to their facilities (GHSI 2009). This document was one of the first to customize the broad concepts involved in applying ecological footprint to the health care industry. Dartmouth-Hitchcock Medical Center in Lebanon, New Hampshire, developed an accounting tool that can be used to measure relevant parameters, such as carbon footprint, waste generation, and energy usage. The governing principle is that anything that can be measured can be managed.

Environmental Responsibility

The International Federation of Accountants published a "Sustainability Framework" (2008) to encourage its members to embrace sustainability and develop metrics to assist clients in understanding the concept and begin conducting business in a manner that encompasses environmental costs. These methods are becoming increasingly available to those in health care working to "green" their practices. In so doing, they can align themselves with the chief financial officers of their organizations and help them expand accountability.

The health care industry needs to continue to develop metrics similar to the ecological footprint to measure work practices and materials. For example, how does the cost of manufacturing, purchasing, and laundering linens made of natural fibers compare with the cost of manufacturing, discarding, and disposing of synthetic fibers? How do these costs compare to single-use paper gowns and bed linens? How should those costs best be measured in terms that reflect actual environmental costs?

There are several reasons why something more than the ecological footprint is needed to gauge the environmental costs of health care. Compared to a hospital's total ecological footprint—daily consumption of food, plus energy, transportation, and so forth—the portion of environmental costs from health care services is relatively small. Moreover, the ecological footprint, as originally defined, fails to consider factors such as the use of toxic chemicals. It also does not directly measure the environmental costs of using nonrenewable fossil fuels, and, compared to many industries, health care is a heavy consumer of fossil fuels. Toxic chemicals and biological products are a significant environmental problem for the health care industry, so the footprint concept has to be adapted to address these failings.

A growing consciousness about health care's environmental impact has emerged, largely due to the efforts of environmentally active groups such as Health Care Without Harm. Through their efforts and those of the U.S. Environmental Protection Agency, the American Hospital Association, and the American Nurses Association, a memorandum of understanding was developed in 1998 to form Hospitals for a Healthy Environment, a nonprofit whose original mission encompassed a number of environmental goals, including a 50 percent reduction in total hospital waste by 2010 and the virtual elimination of mercury in hospitals by 2005. Through the efforts of this organization, which became self-supporting in 2007 under the name Practice Greenhealth, hundreds of hospitals began looking seriously at their operations and began the process of reducing environmentally costly practices. A number of group purchasing organizations, suppliers, and corporate health systems became enthusiastic supporters of these efforts and of CleanMed, a related nonprofit arm of Health Care Without Harm, which sponsors an annual conference on sustainability in health care.

Waste Management

One of the most visible conservation efforts is the management of "postconsumer" goods, that is, waste. Managing waste streams in health care is a new frontier and an object of much attention. Websites such as Practice Greenhealth and the EPA-funded Healthcare Environmental Resource Center (HERC) divide health care waste streams into such categories as solid waste, regulated medical waste, pharmaceutical waste (hazardous and nonhazardous), laboratory waste (hazardous and regulated medical), radiological waste, and construction and demolition waste. Increasing emphasis is being placed on reusing and recycling products, and the concept of purchasing single-use disposables, such as paper gowns, is being reevaluated.

An emerging area of health care waste management with implications beyond hospital walls is waste pharmaceuticals. Previous disposal methods of "crushing and flushing" or using a landfill are recognized as environmentally detrimental. Health care professionals generally had been unaware of thirty-year-old EPA regulations that designate common drugs such as warfarin, an anticoagulant also used in rat poison, as hazardous waste. Inappropriate disposal of these drugs can incur significant fines as the EPA and state environmental agencies have stepped up inspections and enforcement. In addition to financial risks, exposure to drugs meant for humans can have unexpected consequences in the animal kingdom: compounds containing estrogen can cause the feminization of fish, while antidepressants can disrupt amphibian metamorphosis (Orlando et al. 2004). These and similar discoveries have triggered a movement to stop drain disposal of all drugs.

On the consumer side of health care, increased abuse of prescription medication by young people, along with environmental concerns, has resulted in a number of medication take-back schemes, including community collection events, mail-back programs, and drop-off opportunities at pharmacies. A central data repository for tracking these practices has been developed by the Community Medical Foundation for Patient Safety to reduce the amount of drugs being wasted. Such efforts are having an impact: in August 2009, MaineCare decided to restrict initial prescriptions to a fifteen-day supply, instead of the usual ninety days, based on an analysis of consumer drug returns.

Potentially more significant in promoting health care sustainability is pollution prevention—avoiding and reducing the production of waste in the first place. The most environmentally desirable health care services are obviously those that generate zero waste. Some of the integrative medicine therapies noted earlier would fall into this category: physical therapy, chiropractic care, massage, Reiki, acupressure, and even acupuncture (although a small amount of regulated medical waste is generated by the needles). Talk and story-based therapies, such as hypnosis, counseling, coaching, and patient education, count as well. But no form of therapy is truly environmentally cost free; all of these incur the environmental costs of the buildings that house their activities, the training of staff, towels, lighting, educational pamphlets, and so on.

Expensive, chronic care, such as is provided in nursing homes, has a lower ecological footprint than acute care because of the less technological nature of the care. But from a quality-of-life perspective, supporting elders to remain in their own homes and communities is better yet. There are also cultural movements, such as the Eden Alternative and other "green" nursing homes, that that introduce residents to more natural alternatives, such as animals and plants, daylighting, healthy local foods, and gardening. A second realm of pollution prevention seeks to reduce what is called "upstream" waste, that is, waste produced in manufacturing, packaging, and transporting health care materials, tools, and equipment. In the industry in general, the environmental costs of upstream waste are many times greater than the environmental costs for the end user. For complex equipment, the environmental costs of upstream waste can be hundreds or thousands of times greater than the environmental costs of the clinical application of those materials and tools (Layke et al. 2000). For example, the electronic thermometers that have replaced mercury thermometers have complex origins that include the manufacturing of metals, plastics, and silicates. Add to these the environmental costs of packaging and transporting the thermometers and the disposal of billions of the tiny plastic tips that go with them. These costs show up in the environment as increased energy consumption from complex processing and thus play a role in speeding climate change.

Pharmaceuticals likewise have upstream costs. Purification, for example, requires repeated use of volatile organic solvents and energy. Many steps in chemical synthesis are speeded by toxic catalysts. Equipment for processing may require controlled temperature levels and vats of rare and expensive alloys. This is just one reason those interested in integrative medicine prefer more "natural" medicines that are raw and unprocessed. But even here, one must be careful to appreciate the environmental impact of medications and not make general assumptions. For instance, one of the best and most common medications, aspirin, is fairly simple to produce from a fossil fuel–derived chemical base. But in order to provide similar amounts of the naturally occurring painkiller, the needed trees and bushes would have to be grown over vast acreages, and then stripped, harvested, dried, stored, packaged, and transported.

But what about major, high-tech interventions, such as surgery and chemotherapy? Although the equipment involved in these is costly, as are the accompanying services such as ventilation, recovery rooms, sophisticated materials, unique prosthetics, and extensive laboratory tests, reductions in environmental costs can be found in these areas as well. One example is the movement in radiology from silver-based films and developing chemicals to digital imaging. The professional associations of laboratory chemists have been leaders in reducing laboratory costs by such measures as reducing the use of mercury-based contrast agents and using more sensitive tests to reduce the amount of tissue and reagents needed.

The mystique of the operating room has made it particularly resistant to waste-reduction efforts. But pioneering attempts have shown that, with careful planning and training, excess packaging can be reduced or recycled, unused instruments can be re-sterilized instead of thrown away, and drugs can be limited. Efforts are under way at a number of hospitals to classify unused chemotherapy drugs and other pharmaceuticals as hazardous waste, thereby ensuring their destruction through the best available technology.

A number of items used in health care are being considered for recycling, for example, disposable batteries can be replaced with rechargeable ones. Recycling common materials such as glass, paper, aluminum, and construction and demolition materials has begun. A growing movement in health care facilities includes using organic, locally grown whole foods and composting food waste (Kulick 2005). Disposables, once so popular, contribute significantly to a health care facility's ecological footprint. A return to reusable items such as linens and surgical supplies is being evaluated. Other single-use items are also being increasingly reprocessed and reused.

Those hospitals involved with developing metrics around the ecological footprint are examining all areas to ensure minimal waste generation. The increased use of computer-based information systems, which have lagged in health care compared to other industries, can help improve waste management.

While waste reduction appears to be the most obvious area for attention in health care sustainability efforts, it may be least responsible for the size of the organization's footprint. Based on the efforts of Dartmouth-Hitchcock Medical Center, an ecological footprint pioneer, the following areas contributed to their calculated ecological footprint, which was roughly two hundred times its physical footprint in global acreage (GHSI 2009):

- Products (40 percent)
- Transportation (31 percent)
- Energy (22 percent)
- Food (6 percent)
- Built Land (0.5 percent)
- Waste (0.2 percent)
- Water (0.1 percent)

The value of this process becomes readily apparent since products (including manufacturing), transportation (of patients, employees, products, etc.) and energy comprise 93 percent of the ecological footprint. This data can inform efforts to institute environmentally preferable purchasing, including sourcing products locally and regionally; encourage carpooling and mass-transit use by employees; and convert to energy-saving heating and air-conditioning systems. With this type of data, health care organizations can focus attention on the areas that provide the highest return on investment.

A balance must be struck, however, between reducing the overall footprint while ensuring compliance with state and federal regulations in the areas of the Health Insurance Portability and Accountability Act (HIPAA), hazardous waste disposal, fire regulations, construction codes, contractor practices, and so on. Meanwhile, the issue of paramount importance remains the quality and efficacy of care, patient satisfaction, and, especially, staff and patient safety. A truly sustainable health care system will enhance the quality of life of the people it serves.

Architecture

Regulation of medical waste and supply chain activism were already in place in 2003 when Boulder Community Foothills Hospital in Boulder, Colorado, was dedicated as the first hospital certified by a national green building program called Leadership in Energy and Environmental Design (LEED). About half of all the environmental costs of health care are associated with buildings and their maintenance. Thus a well-designed green building can do as much to reduce the ecological footprint of health care as changes in clinical practices. Architectural improvements include: constructing buildings in ways that minimize disruption of green areas and watersheds (preserving the habitat for native plants and animals), reducing parking areas and including connections to public transit systems, using new materials that create pervious paved surfaces, and installing high-performance insulation and low-energy heating, cooling, and filtration systems. Recycling and reusing old building materials is helpful, although residual toxicity, such as mercury and lead, can be problematic. Green retrofitting and remodeling are also proceeding. The U.S. Green Building Council (2009) maintains LEED criteria that are being increasingly applied to health care buildings. The Green Guide for Health Care (2009) provides a similar standard.

Planning efforts to develop new green health care buildings are increasing rapidly. One unexpected benefit of the new green buildings, according to a survey, is that the hospital staff feels supported in its idealism and undertakes new green initiatives (Guenther, Vittori, and Attwood 2006).

Culture and Behavior

The design tasks for architects of green health care facilities could be made easier by carefully considering when health care interventions are necessary and to what extent. For instance, most infectious diseases, especially viral illnesses, are self-limited and pass after a short time, requiring only bedside observation and minimal medications rather than considerable equipment and expensive antibiotics. Extending the natural end-of-life process through technology has often been criticized on economic grounds (the great expense does not greatly improve the quality of remaining life); concern for the environment adds power to the concept of "green dying." A project similar to the Oregon Plan, which was designed to cut the costs of care for the poor, could be developed to outline a range of health care interventions that balance patient care needs with environmental costs and become the standard for all health care (Bodenheimer 1997a, 1997b; Pierce and Jameton 2004).

Public acceptance and behavioral change are central to the success of green reforms in health care. These require modest expectations of what health care can offer and widespread choices and decisions to lead healthy lives. Nutritional counseling and changes in diet and exercise habits are known to promote health and wellness.

But no major changes can be made without addressing issues of cultural values, institutional change, regulation, and economics. For instance, patient consent has been a key moral theme of health care ethics in the last few decades. But if families of patients in acute care were to make the decisions about whether to use green products or the more standard ones, the costs of the supply chain costs would rise steeply (both types of materials would need to be supplied) and environmental savings would not be achieved. Most "greening" decisions need to be made by the institution, not the patient. Ideally, clinicians would educate patients about healthy ways to conserve resources. This role suggests that doctors, nurses, and administrators should live close to work, drive short distances or use public transportation, live in small homes, and so on. Otherwise clinicians would fail to set an example and would thereby violate the second principle of health care after "Do no harm," which is, "Doctor, heal thyself."

Outlook for the Future

Health care systems are facing a huge challenge in greening themselves and encouraging others to reduce their ecological footprints. Environmental pollution and disasters related to climate change are becoming more common, and the ability of the environment to service the needs of humans and other living creatures by improving water quality through natural cycles, for example, is diminishing. Meanwhile, world population continues to grow. The need for basic health care as well as environmental disaster–related emergency services will increase while the resources for these will decline. Consider, for example, early twenty-first-century efforts to reform the U.S. health care system: the word *greening* is almost never voiced in official discourse.

Still many avenues are open to improving the sustainability in the health care industry. First, the technologies, philosophies, and practices of health care systems tend to depend on the basic features of the regions and economies in which they exist. To the extent that industry at large becomes greener, so will health care.

Second, progressive environmental movements are greening neighborhoods, communities, and towns. We can expect that these movements will soon adapt health care to their visions, and new models and innovative solutions might be found.

Third, the most powerful innovations in health care often arise out of basic research. Indeed the culture and ethics of health care tend to follow, not lead, technological innovation in health care. For the most part, the basic science of health care is funded with an aim of saving lives and improving health. If the aim of basic research were tweaked to save (and even enhance) lives (individually and collectively) at *minimal environmental cost*, fruitful new directions might be found in health care technology. This could also inspire a health-oriented ecotechnology as well as traditional biotechnology.

Fourth, public health programs, which impact health much more than health care, need reform. About half of public health efforts are directed toward getting the patient to see a doctor. Another substantial portion is involved in educating communities but does not build significant relationships with industries. If public health initiatives pushed for more fundamental changes, a healthier population could help create an affordable and green health care system. This would involve challenging income inequality regionally and globally—an immense task. Also, environmental reforms would be needed in non-health sectors, such as agriculture, transportation, and power production. One reason to be hopeful is that many of the changes needed to green health care and improve human health are harmonious in their aims, values, and technologies.

What would a more sustainable health care system look like? As in any healthy organization, expectations and goals would be clear, limitations appreciated, and shared responsibilities outlined. Outcomes would be measured and reimbursement would reflect the attainment of calculable goals. Money, however, would not be the only measure of costs. Individuals would take better care of their own health, supported by educational programs that enlighten and motivate them. Resources would be allocated to provide care to the frail, especially children and elders, as well the poor. Communities would be (re) designed to be healthier by encouraging walking and development of local food production, for example. No system or community would be perfect, but an environmentally sustainable system could garner substantial public support.

Societies have historically supported health care systems that reflect their values. Too many modern systems are driven by individualism, anxiety, consumerism, technological imperatives, profit, and material growth. To become sustainable, health care systems will need to adopt a thorough appreciation of present environmental perils and understand that health care must be limited if it is to serve future generations. "Rationing" is a politically sensitive word, but service limits exist today in every country to one degree or another. Such decisions to limit the range of services and types of materials offered to patients should be based on scientific evidence of efficacy and a moral sensibility that supports compassion over unrealistic curative attempts. Ultimately health resides in the community, not in the individual. Health care and its environmental impact must be measured in concrete ways that reflect quality of life, not just quantity. Good business practice in health care requires that it not undermine, by excessive environmental and financial costs, the sustainability of other businesses, and that, like other businesses, it use progressive concepts of natural capitalism to invest in the future of health.

Health care systems are lagging behind other industries in their consciousness of environmental health issues. If human civilization is to thrive, health care providers and systems must come to the forefront of change.

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See also Biotechnology Industry; Building Standards, Green; Chemistry, Green; Facilities Management; Health, Public and Environmental; Information and Communication Technologies (ICT); Pharmaceutical Industry; Supply Chain Management; Water Use and Rights; Zero Waste

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Health, Public and Environmental

The public's health and health care systems will be critical issues for sustainable businesses of the twenty-first century. Many of today's illnesses and diseases are direct results of an unhealthy terrestrial environment, and the health of every individual—customer, employee, or stakeholder—contributes to a business's ability to succeed.

Health is more than the mere absence of disease. The World Health Organization (WHO) defines it as a broad concept (integrating biological, psychological, and social factors) related to individual and community well-being. Health should be viewed as a holistic or integrative function that allows adaptation to environmental and social changes. The individual health of participants in the business process—whether they be customers, employees, or stakeholders—clearly plays a role in the success of any business. Therefore, public health also is a clear contributor to the sustainability of businesses.

The world's ecosystems are deteriorating as a result of global climate change, and related problems with water quality and distribution, the presence of various toxins in our environment, and the emergence of new forms and distributions of infectious agents also impact the public's health. The demographics of disease are also changing because of the aging of both developed and developing societies, and, as a result, chronic diseases are becoming more prevalent and costly.

The Complexity of Disease

Disease is often framed as a biological process found in nature. In truth, disease concepts and labels are invented and constructed rather than simply discovered by the medical enterprise. Illness is a word commonly used to characterize the individual person's experience with the disharmony that comes from disruption in personal biology, psyche, and social relations. Understanding the biological aspects of disease can best occur through an environmental and evolutionary perspective of medicine in which the interactions of genes and environment are viewed over long periods of time. Although illness depends on an underlying biology, the cultural narratives that societies craft form a common understanding of disease as well (Kleinman, 1988). For instance, cancer is not merely experienced as the division of cells within our bodies, it is also understood through the basic cultural idioms of "invasion" and "war." Further, a condition such as dementia is not merely regarded as the degeneration of neurons; it can be viewed as a challenge to a person's basic personhood. Diagnoses are first socially agreed-upon labels about conditions that physicians as much invented in their minds as discovered in nature. In every society, the dominant narratives of disease provide a prism through which individuals interpret their illness experiences.

What are the implications of the labels that we currently apply to diseases, and the effects of the stories that build up around those labels in our individual lives and communities? An appreciation for narrative medicine complements an evolutionary perspective in understanding how genes and memes (cultural units of information) exist and change in environments and societies, modifying our experiences of disease.

Often neglected is the importance of spiritual health to individuals and populations. Religious systems can affect conceptions of health as well as play a role in contributing to the delivery of health care. Integrative medicine represents a blend of scientific allopathic medicine with other approaches ranging from indigenous traditions to systems of Asian medicine. In a global perspective, these systems' contributions to health need to be considered, particularly as the limitations of Western medicine increasingly are acknowledged.

Health as a Critical System

Businesses depend on employing people who can function energetically in their roles in the collective enterprise. The cost of health insurance for employees can be a significant business expense. In-house wellness programs are becoming more common. Employee absences because of personal health or the need to care for relatives, particularly elderly family members, represent a significant burden (as well as an opportunity) to businesses, proving health services for employees and care programs for their family members can help retain valued employees. Similarly customers need to be healthy enough to produce income to purchase goods or services. Some might make the obvious point that when ecosystems deteriorate and/or disasters occur, we run the risk of depopulating or "deresourcing" regions of the world, thus leaving fewer living customers. Various stakeholder groups are critical to business, including its leadership, management team, and board, as well as suppliers of necessary components to the business itself. Hence there is no more important critical system to businesses than having healthy people in healthy environments involved in their enterprises.

Current Health Care Systems

Many of the health care systems around the world are so fragmented that they cannot even be considered systems. Lack of information and financial integration among components is the hallmark of many systems, particularly in the United States. Evidence-based medicine has contributed to some improvement in our knowledge about the effectiveness of interventions, yet we overvalue randomized control trials and are inadequately critical of the introduction of new devices, diagnostic technologies, and drugs into the free market.

Ultimately health begins not with external devices or pills, but with a personal responsibility for taking care of oneself. Self-care will likely increase in the future as costs of care escalate and so-called co-pays (putting the financial burden on the consumer) increase. Preventative medicine is widely talked about but too infrequently implemented. Substantial savings could be made through systematic attempts in assisting people to stop smoking, exercise, and lose weight.

Emergency care is costly and often used by those who cannot get access through other means. For people requiring less urgent care, outpatient facilities and clinics provide access for some. Inpatient care is also costly and can be dangerous due to the possibility of hospital-acquired infections or because of errors in procedure or medication; the wrong drugs or incorrect doses can be given or critically important drugs not administered. Long-term care is overburdened by chronic conditions such as dementia. At the end of life, hospice care can enhance quality of life and save money, although it is often underdeveloped and underutilized.

The health care systems of the world face daunting and growing challenges in the near future. Many are not adequately taking care of the most vulnerable in our societies—children and elders. The political power wielded by older people has the unfortunate potential consequence of under-representing children's needs. Both children and the elderly suffer disproportionately from environmental deterioration. As we have seen in the tragedy of Hurricane Katrina in New Orleans, in which warmer waters fueled the emergence of a violent storm, the rising waters associated with global climate change (largely from melting polar ice caps) can decimate communities, particularly those impoverished areas that tend to be inhabited by the very young and very old. Lack of access to adequate clean water and elevated temperatures will affect those with homeostatic mechanisms (self-regulating mechanisms that function to keep a system in the steady state needed for survival, such as breathing and heart rates, temperature control, glucose regulation) that are underdeveloped or affected by aging; disproportionately high numbers of elderly deaths have occurred during recent heat waves in France and elsewhere. Environmental toxins (such as lead) affect developing brains more severely than older brains but may also contribute to late-life dementia (Stein et al. 2008; Wu et al. 2007). Perhaps the major sign of the inefficiencies in health care is cost. Pharmaceutical products increase the cost of care as populations age. Yet despite this spike in costs, the pharmaceutical industry has not been able to develop dramatically more-effective medications for many common illnesses, even with the advent of genomic medicine. Major conflicts of interest exist between the pharmaceutical industry and the medical profession; some have called this relationship the most troubling problem facing medicine today. Inadequate consideration is paid to measuring the long-term safety of drugs as well as their effectiveness in practice. Too little attention to the measurement of quality of life, and economic studies makes it difficult to measure the benefits of new interventions to society. Pharmacoeconomics, the study of the relationships between medication use and health finances (like cost-utility analysis), is a undeveloped field relatively empty of data and full of inadequate modeling efforts and hence exaggerated claims for drug effectiveness.

Selected Diseases

The ecology of disease is changing rapidly as a consequence of social and environmental alterations. In this section we review four classes of illnesses that will dramatically affect the future of business: chronic illnesses as illustrated by dementia; infectious diseases such as malaria; war-related injuries, for example post-traumatic stress disorder; and toxic exposures. Each of these has been selected because of the changes occurring in their epidemiology and their impact on society and business.

Chronic Diseases: Alzheimer's Disease and Dementia

With the aging of the population, more conditions will emerge that are less directly life-threatening and more likely to affect the quality of life for individuals over a longer period of time. These illnesses are becoming more common and costly as populations age, not only in Western countries, but also in the developing world.

A prototypical illness that creates great fear and concern is so-called Alzheimer's disease, said to be the most common form of dementia. Dementia is a blanket term referring to any illness that affects cognitive abilities in more than one area; it can be either static or progressive. Contrary to its singular name, "Alzheimer's disease" actually is not a single condition and is clearly related to normal brain aging. Because of this complexity, efforts to find biological treatments (and especially "cures") for Alzheimer's are likely to be quite limited. With chronic diseases in general, whether they affect heart, kidneys, or other organs, there is an unclear distinction between the actual processes of aging and those that might be considered separate pathologies. Chronic diseases are tempting targets for the pharmaceutical industry because of the large number of affected people and the social resources that could be brought to bear in developed countries. Chronic diseases also attract businesses that attempt to sell products that are not mainstream FDA-approved drugs, such as complementary and alternative medicines (now increasingly linked to mainstream Western medicine by using the term integrative health). Whereas some of these approaches may prove to be effective, much hype and pseudoscience promote this area; for example, the American Academy of Anti-Aging Medicine claims that aging itself is a chronic disease that can be reversed.

Infectious Diseases: Malaria

Global warming contributes to alterations in climate temperatures that allow the expansion of the distribution of mosquitoes that serve as the vectors of malaria. This geographic change can occur across the continents as areas previously too cold to promote the survival of mosquitoes become warmer. These warmer climates increase the number of mosquitoes and reduce the number of days until they are infectious. Attempts to find vaccines for malaria have so far been fruitless, and most effective interventions involve attempting to eliminate breeding sites and human exposure through, for example, the use of pesticides and bed netting to protect people at night. Despite these efforts, malaria is a disease that is growing in its economic and social impact as it spreads into areas ill prepared for such epidemics. Malaria is just one example of the change in distribution of infectious diseases that is occurring as a consequence of changes in our climate. Conditions such as river blindness, yellow fever, encephalitis, hantavirus, and Rift Valley fever are migrating as temperatures rise, and they are likely to increase their distribution.

War-Related Injuries

As social injustice and conflicts over resources continue and likely accelerate, injuries and other health problems related to war will attract greater attention. To pick only one example, look at the consequences of recent wars in the Middle East. Many troops return from these areas with both neurological and psychological damage. During the most recent wars in Iraq and Afghanistan, the combination of sophisticated body armor and rapid access to emergency medical services has led to the survival of many soldiers who would have died in previous eras. However, a consequence of our technology has been an increase in traumatic brain injuries (TBI). Sadly, TBI are becoming known as the "signature wound" of the Iraq war, just as World War II featured an increase in radiation-induced cancer from atomic bombs, and the Vietnam War introduced Americans to post-traumatic stress disorder (PTSD) and the physical effects of exposure to Agent Orange.

Thanks to the concussive force of improvised explosive devices and rocket explosions, TBI are thought to afflict an estimated 300,000 U.S. military personnel. These tragic injuries are putting a strain on families and our health care system and will continue to predispose our soldiers not just to short-term neurological and psychological damage, but also to an elevated risk for late-life dementia. (Guo et al. 2000; Lye and Shores 2000; Plassman et al. 2000).

While severe cases of TBI that involve cracked or shattered craniums have clear and present neurological consequences, even mild brain injuries are problematic. An article published in the *New England Journal of Medicine* surveyed 2,525 U.S. Army infantry soldiers three to four months after their return from a year-long deployment to Iraq; it found that even mild traumatic brain injury (i.e., concussion) occurring among soldiers deployed in Iraq is strongly associated with PTSD and physical health problems after the soldiers return home (Hoge et al. 2008).

Toxins

Much speculation about the future of medicine has focused on the genetic revolution and efforts to improve our health through genetic manipulations. It is becoming increasingly clear, however, that businesses—including health-related ones like hospitals and pharmaceutical companies—are responsible for the dissemination of environmental pollutants that increasingly contribute to the poor health of whole populations. Children appear to be especially vulnerable, particularly in industrial areas, but agricultural toxins can cause significant consequences as well. We have known for centuries the damaging effects of lead, and yet we continue to have problems, as manifested as recently as 2008 by the exportation of Chinese toys contaminated by paint with excess lead levels. Many industrial waste products such as pesticides and mercury are also toxic, particularly to growing nervous systems.

A particular form of toxin that deserves consideration is the distribution of drugs and endocrine disruptors in our water supplies. Humans consume billions of pills each year, and residue from these drugs can be found in the otherwise cleansed effluents from sewage-treatment plants. A recent Associated Press investigative report concluded that a vast number of drugs—including antibiotics, anticonvulsants, mood stabilizers, and sex hormones—have been found in the drinking water supplies of at least 41 million Americans in twenty-four major metropolitan areas (Donn, Mendoza, & AP 2008). Scientists understand the mechanisms of neurotoxins such as lead, polychlorinated biphenyl (PCB), and mercury, but medications may pose a unique danger because, unlike most pollutants, they were carefully engineered to act on the human body. Pharmaceuticals also can produce side effects and interact with other drugs at normal medical doses.

There is already evidence that pharmaceuticals in waterways are damaging wildlife across the nation and around the globe. Notably, male fish living in waters downstream from sewage-treatment plants often suffer reproductive system effects like lower sperm counts that diminish species survival. Some have speculated whether similar results from trace amounts of drugs such as estrogenic compounds (by-products of the widespread use of birth control pills) or other agents may be related to the lower sperms counts of human males around the world.

According to the same AP report, recent laboratory research has found that small amounts of medication affect human embryonic kidney cells, human blood cells, and human breast cancer cells. The cancer cells proliferated too quickly; the kidney cells grew too slowly; and the blood cells showed biological activity associated with inflammation.

Ultimately, these four classes and examples of selected diseases represent only the tip of the iceberg of changes in health care that will be needed as a consequence of changes in distribution of disease. These trends will have profound implications for business, as well as society at-large.

Solutions and Future Ideas

Health as a critical system needs to undergo a fundamental exploration of its values and approaches. Medical expenditures are literally unsustainable, particularly in developing countries with older populations that are served by high technology. Profit-motive-inspired conflicts of interest between physicians and the medical–industrial complex are serious, and they undermine the values in our health care system and increase the cost and likelihood of achieving reasonable outcomes. As the population grows we must be cautious not to use a disproportionate share of health care resources for the elderly at the expense of children. Issues of so-called intergenerational ethics, or responsibilities of one generation for another, should foster more social discussion. It also appears clear that we are entering a time period where medicine needs to think differently about its basic science and processes. For example, reductionist genetic approaches are not proving to be as fruitful as hoped, and environmental concerns are growing. The use of gene-based therapies and stem cells to treat conditions ranging from diabetes to dementia are two examples of much-hyped but largely unproven technologies. Medicine should be based on an evolutionary approach that understands how genes and environments interact over time. Moreover, health is not only a biological process. The growth of narrative medicine, which recognizes the power of stories to heal individuals and communities, deserves greater emphasis in the future. These new approaches to medicine and health will create business opportunities, particularly involving information technology. Communities need to be (re)designed to foster healthy and environmentally responsible behaviors, such as walking and producing local food.

Our health care systems need to change with regard to the technologies that are presently dominant. Information technology has been severely neglected in health care systems to the detriment of patients because medical histories and patient narratives are the most important elements of making a diagnosis and of providing care; knowing the patient's background and history is often more important than giving him the latest diagnostic tests. Health care systems also need to embrace total quality management. Increasing evidence has criticized medicine for excessive numbers of medical errors and deaths as a result of dysfunctional health care systems, not just because of the incompetence of individual physicians and other health care professionals. Evidence-based medicine has provided some hope that we can be more systematic about determining how to improve health outcomes. We must recognize, however, that we cannot afford all the randomized control studies necessary to determine the effectiveness of every intervention used in medicine; it is often difficult to generalize the results of such studies to clinical practice. The future will demand different approaches to providing care. As the population ages and as more serious illnesses threaten not just the health but the lives of patients, emphasis on palliative care should increase. The philosophies of palliative care focusing on quality of life rather than length of life deserve emphasis throughout health care, not just in the care of, for example, terminally ill cancer patients. At the same time we focus on care at the end of life, we need to emphasize prevention of illness. Such efforts should be focused on basic aspects of health, such as the importance of maintaining cognitive vitality, physical exercise, and healthy diets. These prevention approaches need to be linked to another major approach in medicine: to empower patients and communities to be responsible for their own health and not depend so much on the health care system. More integrative and holistic approaches to health are needed.

Finally, it is important that health care systems take on the responsibility of finding themselves as sustainable enterprises. Large health care systems often have a huge ecological footprint relating to medical waste, the construction of buildings, and the use of energy. It is time that we examine the principles and practices around which sustainable green clinics, hospitals, and long-term care organizations could be developed and promoted throughout our health care systems.

We must also challenge businesses to adapt their models in a way that confronts issues of major public health importance. It is presumable that businesses which take ownership of emergent health issues will gain a sustainable competitive advantage in the marketplace, attracting a new customer base, strengthening existing customer loyalty, and helping businesses establish a stronghold on market share. As Mary Dillon, executive vice president and chief marketing officer of McDonald's (2006), has said, "Today's consumers are more often making choices based on their perceptions about a company's social responsibility performance." Indeed, corporate humanitarianism will build consumer loyalty and trust and augment sales at a time when many are questioning the honesty, integrity, and principles of corporate America. The benefits to business will be manifold. In addition to promoting healthier populations through their commerce, businesses can strengthen their own internal ethos, which can contribute to better employee morale and health.

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See also Development, Rural—Developed World; Development, Rural—Developing World; Development, Urban; Health Care Industry; Human Rights; Municipalities; Pharmaceutical Industry; Poverty; Water Use and Rights

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Hospitality Industry

The reduction of operational costs through energy and water conservation and responsible waste management, as well as the creation of competitive advantages in the market, provide the major incentives for leaders in the hospitality industry to implement environmentally sustainable practices. Sustainable certification programs, which currently focus largely on environmental indicators, also need to address social responsibility to encompass all aspects of sustainability.

In a narrow sense the hospitality industry comprises commercial tourist accommodations and food services for people who are staying and eating away from home. The wide variety of hospitality services offered ranges from private, self-catering accommodation facilities such as second homes, timeshares, private yachts, and motor homes to full-service commercial facilities such as holiday resorts, hotels, motels, farmhouses, and cruise ships.

In the past fifty years, the number and structure of facilities offering food, drink, and accommodation have increased tremendously, and the hospitality industry has grown into a global industry sector. Still, the majority of businesses in the hospitality industry are small and medium-size enterprises located in naturally or culturally attractive but sensitive locations. Visitors and hospitality operations can greatly impact the natural environment, the local economy, and the host community and its culture. Negative impacts include the overuse of natural resources such as water and energy, the pollution of the natural environment with waste and greenhouse gas emissions, and the exploitation of the local community, which may destroy local culture. On the other hand, the hospitality industry creates jobs and contributes to the local economy. In developing countries, tourism may contribute to alleviating poverty. To prevent the negative effects of hospitality operations and to contribute to the sustainable development of the host communities, principles and guidelines for sustainable hospitality management and operations are necessary.

Barriers and Motivators

To implement sustainable practices in the hospitality industry, leaders, managers, and decision makers have to overcome several barriers, including high investment and operational costs and the amount of time and effort necessary to realize sustainable practices. Lack of awareness and knowledge of sustainability among leaders, as well as scarce governmental support, are also barriers for implementing sustainable practices.

Hospitality leaders are mainly motivated to implement environmentally sustainable practices when they are convinced that these measures will reduce operational costs and create competitive advantages in the market. Improving image, publicity, and promotional opportunities are also major desires. In addition to these motivations, personal values like healthy living, awareness, and knowledge levels influence leaders when they consider putting sustainable practices to work in their hospitality businesses.

Sustainable Management Practices

In the hospitality industry, sustainable management is relevant in the following business areas: project planning, including site selection, architecture, construction, outside facilities, energy and water supply, and disposal systems; housekeeping; food and beverage services; programs for (guest) mobility; communications; marketing; and customer service (reservation and reception offices). According to a study among European hoteliers concerning their attitudes toward the environment, "nearly 85% of the hoteliers stated that they were involved in some type of environment-oriented activities" (Bohdanowicz 2005). The main areas of engagement were energy and water conservation and responsible waste management, all of which lead to significant cost reductions. The level of engagement in sustainable practices was higher in chain hotels than in independent hotels, which could lead to the conclusion that sustainable commitment at a corporate level may lead to sustainable behavior at independent hotels. The spheres of activities in sustainable hospitality management are energy and water management, wastewater and waste management, the use of chemicals, contribution to biodiversity and nature conservation, contribution to community development (for example, purchasing practices), and social issues at the workplace.

One of the most effective sustainable practices in the hospitality industry is energy management, which aims to reduce energy consumption and to enforce the use of renewable energy. The hospitality industry is energy intensive since many recreational facilities such as pools, saunas, and Jacuzzis, as well as infrastructure like central heating or air conditioning—all of which are important for making guests comfortable—require a large amount of mainly fossil fuels for operation. It is estimated that a "typical hotel annually releases between 160 and 200 kg of CO_2 per m^2 of room area" (Bohdanowicz 2005). Effective practices for reducing energy consumption include the following:

- Replace energy-inefficient heating and air-conditioning systems as well as other inefficient food, beverage, and housekeeping equipment (for example, refrigerators, ovens, dishwashers, laundry machines) with modern technologies that preferably use renewable energy.
- Replace regular bulbs with energy-saving compact fluorescent light bulbs and use sensors and timers to turn off unnecessary lights.
- Encourage guests and staff to save energy by lowering heating or air conditioning, switching off unneeded lights, and operating dryers and dishwashers only with full loads.
- Insulate the building and switch to renewable energy such as wind, solar, or geothermal power to reduce the use of fossil fuels, which contribute to air pollution and climate change.

Water, a scarce resource in many regions of the world, is used extensively in hotel bathrooms (both private and public) as well as in supporting other facilities such as the kitchen, laundry, and swimming pool. Sustainable practices include reducing water usage and preserving the quality of water resources. Water-saving practices consist of the installation of relevant devices such as low-flush toilets and low-flow shower heads and faucets, the continuous detection and maintenance of damaged devices (for example, leaky faucets), the use of recycled water, and the training of guests and staff in water-saving practices (such as not changing linens and towels everyday and not letting the water run when brushing teeth). Reduction of water use leads to a reduction of wastewater, which is produced by guests and hotel operations (kitchen, laundry, and housekeeping). Wastewater containing chemicals as well as fecal matter may pollute groundwater and surface water if no appropriate wastewater treatment system is available. To improve wastewater quality, practices such as the installation of grease/oil separators in kitchens, the use of biodegradable detergents and cleaning supplies, and the use of active oxygen for cleaning swimming pools can be employed. Hospitality businesses should have to ensure proper wastewater treatment and possibly reuse treated water for flushing toilets or watering gardens.

Solid waste represents another significant pollution factor in the hospitality industry. The primary goal is waste reduction followed by proper waste management and disposal. The introduction of an effective waste-management system builds on the "three R's": reduce, reuse, and recycle. Good practices include buying products with less packaging (for example, avoiding portion packs at the breakfast buffet or personal soap and shampoo packs) and collecting, separating, and recycling waste.

In view of the social dimension of sustainability, local communities may benefit from hospitality businesses. Good practices include employing local people and providing fair and safe working conditions, offering training programs to develop the local labor force, purchasing goods and services from local providers, engaging in cooperation with local providers, and supporting social projects to enhance community well-being. Concerning their own employees, hospitality businesses have to respect employees' human rights, which emphasize concern for working conditions, child labor, and sexual harassment, as well as fair and equal treatment and fair wages, especially for women and indigenous people.

Industry Support for Sustainability

The hospitality industry is encouraged to implement sustainable practices through international and regional guidelines and a variety of voluntary tools such as certification programs, codes of conduct, guidelines, handbooks, and training programs. Certification programs or labels indicating quality and/or a set of standards can particularly motivate businesses to implement and continuously improve ecologically and socially responsible measures within their companies. Certification programs are either dynamic and process oriented—whereby the program aims to improve the sustainability performance of a company continuously, without determining particular target values—or static and outcome oriented, whereby achievements are measured against predetermined indicators.

Currently, a large, complex range of certification programs and ecolabels for sustainable tourism products (first introduced in the early 1990s) are available. The majority of ecolabels exist in Europe, and they address the accommodation sector. In 1993, the World Travel and Tourism Council (WTTC) established Green Globe, the first internationally operating certification program, which incorporates not only ecological but also socioeconomic and cultural aspects. Through international cooperation with organizations on all continents, Green Globe Certification's worldwide network extends across more than fifty countries.

Sustainable certification programs focus mostly on environmental indicators. Systems incorporating aspects of social responsibility are still scarce. This is in the process of changing, however, because sustainability indicators are taking into account the increasing relevance of socioeconomic and cultural aspects. This will lead toward a certification program that embraces all aspects of sustainability.

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See also Ecolabeling; Facilities Management; Travel and Tourism Industry; Water Use and Rights

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Human Rights

Several multinational corporations have begun examining their human rights impacts in recent years. As more corporations are learning, environmental health and human well-being go hand in hand, and it makes good business sense to assess the potential risks of doing business in particular states or business sectors. As consumers become more aware of such issues, the importance of corporations' respect for human rights throughout their operations becomes vital to their viability as a global business.

Companies have been implicated in human rights issues for many years, dating back to the creation of the modern enterprise. There is now general acknowledgment that companies can affect the environmental, social, and economic fabric of the societies in which they operate.

In 2009, over 70,000 companies were operating cross-border (and thus known as transnational corporations), and between them over 700,000 subsidiaries and millions of suppliers were adding to the complexities of global commerce. In his February 2006 interim report, John Ruggie, professor of human rights and international affairs at Harvard's Kennedy School of Government and the United Nations secretary-general's special representative on business and human rights, stated: "The rights of transnational firms—their ability to operate and expand globally—have increased greatly over the past generation as a result of trade agreements, bilateral investment treaties, and domestic liberalization . . . . [I]n light of this transformation in the institutional features of the world economy, it is hardly surprising that the transnational corporate sector—and by extension the entire universe of business—has attracted increased attention by other social actors, including civil society and states themselves."

Companies not only come under scrutiny with regard to their own conduct; they often must answer for the actions of other businesses in their supply chain. It has become important for large retailers to examine the compliance of their suppliers in accordance with international standards to ensure that the final products sold are produced in a way that does not abuse human rights. A key question for business representatives in such circumstances is to determine how far down the supply chain their responsibility goes.

Companies are also connected to human rights abuses when operating in countries with poor human rights records. Companies may become involved in situations where state-provided security brutally cracks down on protestors at a company site. Although the state may be directly responsible for the human rights violations, the company is also implicated.

Efforts to reconcile the rapidly expanding global economy with the international system of human rights protection have significantly increased since the beginning of the twenty-first century. Nongovernmental organizations (NGOs), trade unions, governments, and the United Nations have developed several initiatives to encourage improvements in the practices of business everywhere. Similarly, responsible businesses have taken the lead in developing innovative business models that can respond to human rights challenges.

Despite progress, "more efforts are needed to prevent and repair the business-related human rights abuses that are still occurring today, and more must be done to maximize the contribution business can and does make to human rights around the world. There's no doubt that much progress has been made in recent years on the business and human rights agenda and we should celebrate that but also redouble our efforts to ensure that the lessons learnt become part of a much wider circle and that there is accountability" (Mary Robinson, president of Realizing Rights: The Ethical Globalization Initiative and honorary chair of Business Leaders Initiative on Human Rights, speaking at the International Seminar on Business and Human Rights in Paris, December 2008).

Companies interested in better understanding the sustainability of their business will often explore both the environmental and social (human rights) impacts their operations may have. There are links between the environment and the need to respect human rights; for instance, the right to health and the right to water have clear environmental components, and they are dependent upon one another.

Global Protection of Human Rights

Human rights include such rights as the right to privacy, the right to life, the right to freedom of expression, the right to a standard of living adequate for health and well-being, the right to security of person, the right to work, and the right to vote. The human rights system dictates that individual states have a duty to meet their human rights obligations as described in international treaties and other sources of law. It also makes it possible for individuals to bring a case against a state for an alleged abuse of their human rights.

At the core of the international human rights regime are three agreements that form the International Bill of Human Rights:

- The Universal Declaration of Human Rights (1948)
- The International Covenant on Civil and Political Rights (1966)
- The International Covenant on Economic, Social, and Cultural Rights (1966)

The Universal Declaration of Human Rights is the only globally accepted document setting out the rights of human beings. In part, it was formulated in response to the atrocities committed during World War II. At 1993's World Conference on Human Rights in Vienna, all 171 states in attendance reaffirmed their commitment to the Universal Declaration. The three agreements that comprise the International Bill of Human Rights have inspired numerous human rights treaties and more specific documents that relate to the rights of women, children, people with disabilities, migrant workers, indigenous peoples, and others. A complete list is available at the website of the Office of the United Nations High Commissioner for Human Rights (2009).

Companies can affect any of the recognized human rights in the international system. With the Universal Declaration of Human Rights at its core, the international human rights regime has become a key tool for exploring the balance of power between corporations, individuals, communities, and governments.

Companies and Human Rights

At the website of the Business & Human Rights Resource Centre (2009), news stories feature companies involved in issues such as forced labor, child labor, use of water resources, community relocations, land acquisitions, pollution-related health issues, violence towards trade-union representatives, or employee suicides. These issues can relate to any company, from any sector, in any country.

While there are situations in which companies are directly responsible for human rights abuses, it is more common for companies to be connected to abuses being carried out by others, most often states. In such circumstances, companies are deemed to be *complicit* in the abuses. Some mining companies have faced allegations that their actions assisted rebel groups in attacking and killing civilians, as in situations where rebel groups have been able to use company-owned vehicles or landing pads. Similarly, private air carriers have been accused of moving alleged terrorists from state to state and, therefore, of being in part responsible for the torture these individuals suffered.

The impact companies can and do have on the lives of individuals, whether positive or negative, has been watched much more closely since the beginning of the twenty-first century. Lawyers and human rights activists have sometimes turned to the law and brought complaints to court in order to hold companies accountable for their involvement in human rights abuses.

In 2004, a case involving Unocal, a large U.S. oil company, was settled out of court following allegations that the company had assisted the military forces in Myanmar (Burma) in the use of forced labor to build a pipeline. The case against Unocal, which was brought by a group of Burmese residents supported by international NGOs, was unique at the time since it relied on a U.S. law, the Alien Tort Claims Act, which dates back to 1789. The case set a precedent for many more to be heard before the U.S. courts.

In 2007, Yahoo! Inc. was brought before a U.S. court in California by Chinese dissidents who had been imprisoned in China; they alleged that the subsidiary Yahoo! Hong Kong had provided information to the Chinese government that contributed to the arrest of a journalist. This case was also settled out of court. In addressing these issues, Yahoo!, along with Google and Microsoft, created a new initiative for their sector that looked specifically at dilemmas related to the right to privacy and the right to freedom of expression.

The Global Network Initiative is designed to give guidance to the information and communication technologies (ICT) industry with regards to protecting the right to freedom of expression and the right to privacy. The initiative works in collaboration with NGOs, academics, and investors to do this. All members commit to work together to advance these two human rights particularly in light of demands from governments to censor or hand over user information.

In 2009, a case involving Shell, a global group of energy and petrochemicals companies, and its operations in the Niger Delta in Nigeria was concluded in a court in New York following accusations that the company was complicit in serious human rights abuses. The case dated back to protests against the company in the 1990s when community leader Ken Saro-Wiwa and eight others were tried and executed by the military government. The case against Shell was settled in June 2009 when the company agreed to a \$15.5 million settlement.

In 2009, a case was filed in the U.K. courts involving Trafigura, a multinational oil-trading company, in relation to the company's alleged involvement in the dumping of toxic oil in Côte d'Ivoire in 2006; over 30,000 claimants from Côte d'Ivoire suffered serious health problems from the toxic oil spill. This case was settled out of court, however, for an amount of £30 million (\$48.5 million). Another case involving the alleged dumping of toxic waste into the Amazon River by the oil company Chevron was also before the courts in 2009. In that case, individuals were seeking US\$27 billion in compensation.

Several complaints have been brought before National Contact Points (national organizations established by governments in the European Union) under the Organization for Economic Cooperation and Development (OECD) Guidelines for Multinational Enterprises in relation to the human rights conduct of companies operating or headquartered in OECD countries. These guidelines are not legally binding, but they are designed to hold companies to account through their home governments. There is a system to allow individuals to bring complaints to their National Contact Point under the guidelines, which has raised awareness of company conduct overseas.

United Nations Responses

In 2003, the United Nations Commission on Human Rights (now the Human Rights Council) produced a document entitled the "Norms on the responsibilities of transnational corporations and other business enterprises with regard to human rights." This document was the first attempt to set out the obligations of businesses with regard to human rights. At the time, the norms generated a great deal of debate among nongovernmental organizations and businesses alike.

Following various consultations and further research at the United Nations level, it was determined that the norms would not become a legal document. Instead the United Nations created the role of special representative on business and human rights; John Ruggie was appointed to this role in 2005.

In June 2008, Ruggie put forward a framework for business and human rights that was unanimously approved by the Human Rights Council. This framework was made up of three parts:

- The state duty to protect human rights
- The corporate responsibility to respect human rights
- The need for victims of human rights abuses involving companies to have access to remedies

By validating this framework, the Human Rights Council recognized for the first time that companies have a responsibility to respect the human rights of individuals. The framework applies to all companies, irrespective of their business sector and country of operation. In order for companies to meet their responsibility to respect human rights, they must take steps to carry out "human rights due diligence." This due diligence will depend upon the human rights situation in the particular country of operation, the human rights impacts the company may have as a result of the business it runs, and the relationships the company has with other companies, suppliers, customers, or the government.

The guidance provided by this framework is an important step forward in clarifying the debate on the human rights responsibilities of business. The process of defining the obligations of businesses with regard to human rights is due to be concluded in 2011 with the final report from Ruggie.

Company Responses

A number of multinational corporations have been driven to examine the human rights impacts of their business operations globally. Not only does it make good business sense to assess the potential risks of doing business in particular states or business sectors, but reputational damage following alleged involvement in human rights abuses may also be a driving force in this kind of examination. Some companies look at their human rights impacts because of a particular human right that is close to their industry. For instance, the pharmaceutical sector can play a key role in recognizing the right to health and contributing to this right by releasing patents on expensive brand-name drugs and allowing production of affordable generic brands. Similarly, mobile communications companies can ensure better communication and access to information for individuals by connecting communities, and companies providing access to electricity in more remote areas can play a key part in development that is in line with the core purpose of their business. As of 2009, 242 companies had a human rights policy in place; this number increased significantly when labor rights policies were included in the total. Additionally, over 5,000 companies had signed the United Nations Global Compact, the world's largest corporate-responsibility initiative. Six of the ten principles in the U.N. Global Compact are based on human rights.

Human rights are a concern for all businesses. All sectors can be implicated in human rights abuses in various ways, and a number of companies are engaged in this issue. Furthermore, much work has been done to elaborate the business case for human rights by identifying the key advantages for companies that decide to assess their human rights record and take positive steps to improve it. (See, for example, the U.N. Global Compact [n.d.] and *A Guide for Integrating Human Rights into Business Management* [Business Leaders Initiative on Human Rights et al. 2009].) Some of the advantages for businesses examining their human rights impacts include:

- Reputational risk management
- Staff retention and motivation
- Maintaining the social license to operate
- Managing legal and financial risk
- Following expectations of investors
- Leadership and competitive advantage

Additionally, a number of tools have been elaborated to help businesses translate human rights into operational terms and guidance. A selection of these tools is listed in table 1.

Industry Initiatives

From 2003 to 2009, fourteen multinational corporations worked together as members of the Business Leaders Initiative on Human Rights (BLIHR) to find practical ways to bring the Universal Declaration of Human Rights into a business context. The companies involved were from a variety of different industry sectors including retail, banking, infrastructure, information technology, food and beverages, and oil and mining. They worked closely with expert human rights advisors to tackle the challenging aspects of this debate and provide a collective business voice.

The first three years of the project were dedicated to road-testing the norms established by the United Nations

Table 1. United Nations Business Tools Regarding Human Rights

Name of tool	Description
A Guide for Integrating Human Rights into Business Management (Business Leaders Initiative on Human Rights, Office of the U.N. High Commissioner for Human Rights, United Nations Global Compact)	A generic guide for companies to start integrating human rights into the various aspects of a business management system.
Conflict-Sensitive Business Practice (International Alert)	A tool to ensure that the business practices of companies operating in conflict zones do not contribute to conflict or cause human rights abuses and that they contribute to social and economic development.
Guide to Human Rights Impact Assessment and Management (International Business Leaders Forum, International Finance Corporation, United Nations Global Compact)	A tool to provide companies with a process for assessing potential human rights impacts and making appropriate management decisions.
Human Rights Compliance Assessment (Danish Institute for Human Rights)	A diagnostic self-assessment tool to help companies detect risks of human rights violations caused by the effects of company operations on employees, local residents and other stakeholders.
Community Human Rights Impact Assessment (Rights and Democracy)	A tool to develop a process through which affected communities can understand the impact of foreign investment in human rights terms.
Human Rights Matrix (Business Leaders Initiative on Human Rights)	A tool for companies to map policies and practice against the content of the Universal Declaration of Human Rights and to prioritize against what is essential and beyond essential.

Source: United Nations Global Compact (2007).

Commission on Human Rights in 2003 (refer to the previous section, United Nations Responses) and commenting on their practical implementation. The next three years were spent developing tools for companies to use that translated human rights into business-friendly language. The BLIHR program ended in March 2009 and inspired two new legacy organizations: The Institute for Human Rights and Business and the Global Business Initiative on Human Rights.

Several sector-specific initiatives have also been designed to explore human rights challenges, some in response to particular human rights dilemmas within different business sectors. A selection of these initiatives follows.

Retail

During the 1980s and 1990s, many companies created codes of conduct based on the practical guidance provided by the International Labor Organization to stop both child and forced labor, to ensure freedom of association for trade unions, and to stop discrimination. The anti-sweatshop movement led efforts to encourage companies to assess their human rights records, which affected key brands producing clothing, footwear, and other textiles. This movement brought together companies, governments, trade unions, and NGOs, and resulted in several initiatives that remain in place, including the Fair Labor Association, which focuses on ending sweatshop labor and improving working conditions in factories worldwide; the Ethical Trading Initiative, which works in partnership with companies, trade unions, and voluntary organizations to better the conditions of workers globally; and the International Labor Organization, in particular the Better Work program, which is focused on improving labor conditions in supply chains, particularly in countries such as Cambodia, Vietnam, Jordan, and Lesotho.

Extractives

Sectors with heavy environmental footprints such as the oil and gas or mining sectors have examined their human rights impacts most often with regard to their relations with communities (including indigenous groups) or governments. For instance, mining companies may need to consult with local indigenous groups who claim rights to the land they wish to use; if these negotiations are successful, they help ensure the company's *social* license to operate. Additionally, serious problems can arise if negotiations are unsuccessful, resulting in clashes between the state-provided security forces and community members. Key initiatives involving companies from the extractives sector include: the Extractive Industries Transparency Initiative, which works with governments, companies, and civil society groups to improve governance by calling for transparency on company payments and government revenues from oil, gas, and mining activities; the Voluntary Principles on Human Rights and Security, which focuses on guidance for the oil, gas, and mining sectors with respect to aligning their security operations, whether public or private, with human rights requirements; and the Kimberley Process, which is designed to prevent conflict diamonds from entering the market by establishing a certification procedure for the goods.

Finance

Two separate initiatives are aimed specifically at the finance sector in light of the role played by banks and other investment institutions in funding company projects with human rights risks. The Equator Principles (n.d.) provide social and environmental guidance for project finance, and the United Nations Environment Program Finance Initiative (2009) has created a human rights tool kit aimed at lending managers.

Information and Communications Technology

A recent collaborative effort between companies, civil society organizations, investors, and academics produced the Global Network Initiative. This initiative is aimed at the ICT sector in light of the challenges these companies face to comply with local laws and regulations that conflict with the internationally recognized human rights of freedom of expression and privacy.

Linked to this, the electronics industry has faced problems similar to those of the retail sector in terms of allegations regarding working conditions, working hours, and child labor. The Electronics Industry Citizenship Coalition (2009) was created in part to address such considerations by providing a collective code of conduct for the industry.

Where Next?

The next phase of the debate on the human rights responsibilities of business lies in the exploration of human rights dilemmas for new and expanding business sectors such as ICT. Additionally, as greater challenges develop concerning access to natural resources, transnational corporations should play a key role in developing solutions given their involvement in water and/or land access. Similarly, as the expanding global economy increases demand for migrant labor, companies can play a key role in the movement of workers and in ensuring that their human rights are respected.

As the human rights debate continues to evolve and as business operations continue to impact the lives of individuals globally, companies are well advised to explore their potential and actual human rights impact as part of their overall business strategies on sustainability.

Kathryn DOVEY
Global Business Initiative on Human Rights

See also Activism—NGOs; Corporate Citizenship; CSR and CSR 2.0; Equator Principles; Fair Trade; Information and Communications Technology (ICT); Investment, Socially Responsible (SRI); Risk Management; Social Enterprise; Transparency; United Nations Global Compact

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I

Information and Communications Technologies (ICT)

Sustainability efforts have benefited greatly from information and communication technologies (ICT), a trend expected to continue. Computer systems are infused in all areas of business operations. Hardware and software innovations have enabled the design of industrial systems that use energy and materials more efficiently, help track toxic materials and resources, aid efforts to comply with environmental regulations, and help reduce emissions by enabling people to work remotely.

At the height of the Internet boom, the environmental planning expert Nevin Cohen (1999) predicted that the growth of electronic commerce would lead to the elimination of packaging materials and the demise of the American shopping mall. While these forecasts have so far proved false, Cohen accurately captured the optimism of the time, the feeling that this new technology had the potential to substantially dematerialize our world. Less packaging and fewer trips to the mall would mean fewer raw materials and less energy being consumed in the manufacturing and transport of consumer products—good news for the environment.

The idea and hope that e-commerce would automatically lead to environmental benefits became so discredited that, to many, the ways in which information and communications technologies (ICT) enable sustainable solutions to environmental problems are often hidden from view. (ICT is a term more and more in use as the fields of "information technology" and "communications technology" become one inseparable field.) ICT is enabling greener ways of living and doing business—and helping to dematerialize our world. Although the problems of e-waste are well documented and desperately need to be addressed by manufacturers and consumers alike, the ICT industry is responsible for many of the green solutions that technology has to offer: the energy savings of telecommuting and the technology behind viable renewable energy projects being a few of the most visible examples. These technologies are supporting new business models and changing the way we work. The result is more efficient use of natural resources, better compliance with environmental regulations, and more satisfied consumers.

New Innovations and Business Models

ICT innovations—which have become so pervasive that in some ways it is hard to grasp how much our lives depend on them, and how many businesses run more profitably because of them—include software tools to manage water consumption and tools that help companies conform to new environmental regulations and more radically innovative applications of ICTs that enable new business models. These business models are emerging as people search for ways to use natural resources more sustainably, reduce the materials and energy content of products, and communicate with a younger generation of environmentally conscious consumers.

Cyber Rain, for example, is a software product from California that helps home owners conserve water while maintaining a green lawn. The Cyber Rain program uses wireless technology to check the local weather forecast and adjust sprinkler watering schedules to match daily conditions. As a result, landscapes get just the right amount of water at the right time—saving up to 40 percent of water use and expense over conventional sprinkler systems that operate on a fixed schedule (Cyber Rain 2009).

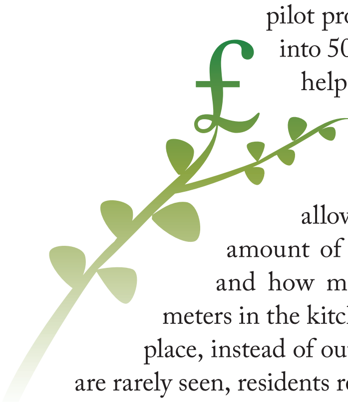
A new sustainable business model has been catching on that Europeans call "consumption without ownership" (Behrendt et al. 2003). It allows people to use products, or consume them, in a way that is not so damaging to the natural environment; the ICT industry plays a big role in ensuring that the technology available is used to its optimal advantage. For example, car sharing services, in which people rent cars short term for trips to the grocery store or to the doctor, require ICT tools to create online reservations, secure electronic access to cars, track car use with global positioning devices, and bill user accounts in an organized and user-friendly manner. One example of such a service provider is INVERS Mobility Solutions, an international entrepreneurial firm that produces software programs designed for car sharing businesses, enabling the development of this ecoservice. In 2009 the World Carshare Consortium identified 1,000 cities worldwide where car sharing services are available (World Carshare Consortium 2009).

Another new business model that is particularly dependent on ICT development involves the shift from companies selling products to offering services as more and more companies find that, as profit margins on their products shrink, the service model is more profitable. Xerox, for example, developed the Office Document Assessment (ODA) tool as part of its Global Services Consulting Division to help clients process documents more efficiently. The Xerox service provider analyzes the workflow in an office and advises clients on the most efficient way to manage the work. Often the recommendation is to use *fewer* Xerox devices (Rothenberg 2007). In this and many other cases, ICT-enabled services are creating competitive advantage for companies, as well as customer satisfaction (and thus higher profits) *and* environmental advantages.

Environmental Intelligence

Many industrial systems were built at a time when energy and natural resources were plentiful and inexpensive. Conservation and efficiency were not always on the minds of the designers of heating systems, irrigation systems, sprinkler systems, and energy systems. Now, however, ICT applications are adding environmental intelligence to these systems, allowing more efficient use of resources.

In July 2009, IBM and Cisco Systems announced a joint pilot project to put "smart" meters into 500 homes in Amsterdam to help homeowners cut energy bills and reduce carbon dioxide emissions (IBM 2009). Smart metering allows home owners to see the amount of electricity they are using and how much it costs. By locating meters in the kitchen, or another convenient place, instead of outside the house where they are rarely seen, residents respond to the feedback the meter provides and decrease their energy use.



Household smart meters influence behavior by providing information about the amount of money spent on electricity rather than the amount of kilowatt-hours used. A measure in the local currency provides a metric of resource use that is more easily understood—especially by people who may not understand exactly what a "kilowatt-hour" is.

Another example of environmental intelligence comes from an Israeli company called Metrolight, which designs smart lighting systems using patented ballast technology and software programs. Metrolight systems allow users to turn individual lights or groups of lights on and off, monitor their status, and create schedules for dimming and maintenance—activities that enable more efficient energy use and cost control. The systems can be controlled remotely via wireless connection or laptop computer, and are marketed for warehouses, shopping malls, gas stations, distribution centers, municipalities, and any other facility that uses lots of lights (Metrolight 2007).

Enabling Renewable Energy

Renewable energy systems are also enabled by ICT. In the North Sea, a giant, floating wind turbine called Hywind uses a computer system to keep its rotor blades pointing in the optimal direction as the tower beneath shifts with the rolling waves. Such tweaking increases the amount of power produced and also makes it possible to operate in a challenging environment without straining the blades and the tower. The software also assesses the success of each attempt to dampen the wave-induced motion so that it can improve in the future (Tilting in the Breeze 2009).

In August 2009, eSolar constructed the Sierra SunTower, a 5-megawatt solar power plant in Lancaster, California, that will provide electricity to 4,000 homes—at a competitive price. Their website describes how the system works:

> eSolar power plant technology utilizes small, flat mirrors which track the sun with high precision and reflect the sun's heat to a tower-mounted receiver, which boils water to create steam. This steam powers a traditional turbine and generator to produce solar electricity. (eSolar 2009a)

Key to making the system work is the ability to direct 24,000 mirrors to "track the sun with high precision." This is accomplished through software developed by eSolar employees at a company office seventy-five miles away from the mirror installation.

Greening of the Supply Chain

One of the strategies for greening industry is to limit the use of toxic materials. In 2003, the European Union adopted the Restrictions of Hazardous Substances Directive (RoHS), which took effect in 2006. RoHS restricts the use of hazardous materials, including lead, mercury, and cadmium, in electronic products (Europa 2009). Compliance with this directive is a complex matter involving the management of thousands of components and ingredients that comprise laptop computers, cell phones, and other electronics. Synapsis Technology Inc. has developed environmental compliance software specifically to aid in manufacturers' efforts to "understand and control the material makeup of their products, and to comply with environmental regulations" (Synapsis Technology Inc. 2009).

Another greening strategy focuses on the supply chain, requiring retailers and manufacturers to be more knowledgeable and transparent not just about what ingredients are in their products, but where and how those ingredients are sourced. Most informed consumers do not want clothing that is sewn by child laborers or produced by workers who are sickened from glue fumes. Lawn furniture might be less attractive to consumers after they learn a rain forest in Malaysia was destroyed to produce it. In a sense, the whole supply chain has become the product that consumers are choosing (Peattie 1999).

Here again, software solutions are assisting companies with the monumental task of tracking the source of all of the ingredients used in their products. For example, consulting company Historic Futures Limited (HF), through its online service String, helps manufacturers and retailers "visualise their entire supply-chain." It does this by collecting and managing Country of Origin (COO) data that includes performance indicators such as product miles (total distance traveled from point of origin to place of consumption), water use, and consumed energy (Historic Futures Limited 2009).

Teleworking, Telecommuting, and Transportation

Another way that ICT is enabling sustainable solutions is through technologies that create business meetings without travel. Air travel for business contributes an estimated 240 billion pounds of carbon dioxide to the atmosphere each year (Westervelt 2008). Even more damaging to the environment, however, are business road trips, given that 81 percent of all business travel is conducted using personal vehicles (Baniewicz, Walker, and Angeles 2009). Video and teleconferencing technologies that can create virtual meetings are providing more environmentally friendly solutions.

Hotels are getting in on this trend. Marriott International and Starwood Hotels are helping business customers avoid travel by renting meeting rooms equipped with "telepresence suites." This ICT technology creates life-size images on a screen to "make participants [who may be on the other side of the world] feel as if they were meeting face to face" (Stellin 2009).

Similarly, allowing employees to work from home, using ICT to "telecommute," can reduce a company's carbon footprint. Half of Bell Canada's 40,000 employees telecommute, reducing the company's carbon dioxide emissions by an estimated 7,395 metric tons annually from commuting and space heating (Adams 2007). Technologies such as Virtual Private Networks (VPNs) and "desktop sharing" connect employees at remote sites and allow them to collaborate on work as securely as if they were in the office (Baniewicz, Walker, and Angeles 2009).

For workers who do travel to the office every day, employers are using ICT to minimize single-passenger automobile driving and increase the use of public transportation and car pooling. Stanford University used GIS technology to analyze where employees live and how they travel. They used this information to work with local transit agencies and reduced the "employee drive-alone rate" by 20 percent (Herrera 2008).

The Second "e"

The first e-commerce (*e* for electronic) transformation, during the Internet boom, integrated ICT into the DNA of business operations so thoroughly that what used to be known separately as "e-commerce" has been absorbed into general "commerce," the electronic part now taken for granted.

A second wave of e-commerce (*e* for environment) is potentially integrating environmental intelligence into the DNA of business operations. Earlier predictions about the "de-malling" of America and paperless offices may have missed the mark, yet this second wave of e-commerce is improving environmental performance of business in several ways: (1) by developing models that emphasize the service side of business and creating incentives to use fewer products and use resources more efficiently; (2) by developing applications that support renewable energy technologies; (3) by providing tools that allow manufacturers to reduce toxins and control environmental damage in supply chains; and (4) by revolutionizing transportation and travel for business and for pleasure. Applying ICT technology, the stage is set for these innovations to continue the greening of industry.

Trudy HELLER
Executive Education for the Environment

See also Consumer Behavior; Data Centers; Energy Efficiency; Energy Industries—Overview of Renewables;

Facilities Management; Investment, CleanTech; Public Transportation; Supply Chain Management; Telecommunications Industry; Water Use and Rights

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Integrated Product Development (IPD)

Beginning in the 1990s, sustainability principles were integrated into the business practice of product development, and design considerations expanded to cover the entire lifecycle of the product—including procurement, manufacturing, distribution, support, and end-of-life. This evolved into integrated product development, with cross-functional teams working in a parallel, coordinated fashion to rapidly develop products that are both sustainable and profitable.

Product development, also known as "product realization" or "product introduction," is an established business process in manufacturing firms. The incorporation of sustainability principles into this process dates back to the mid-1990s, when many companies adopted formal "stage-gate" procedures in order to accelerate time to market while continuously improving product quality and customer satisfaction. These procedures involve a sequence of stages—such as concept development, preliminary design, and detailed engineering—with specific requirements (or "gates") that must be satisfied in order for the product to proceed to the next stage.

An important principle in product development is "lifecycle thinking"—designing the product and its manufacturing processes with full consideration of the entire product lifecycle, including distribution, support, maintenance, recycling, and disposal (National Research Council 1991). This idea has evolved into the modern practice of "integrated product development" (IPD), with cross-functional teams involved from inception to commercialization (Rainey 2005). IPD is generally defined as a process whereby all functional groups (engineering, manufacturing, marketing, and so on) that are involved in the product lifecycle participate as a team in the early understanding and resolution of key issues that will influence the success of the product.

The traditional approach to product development involved "sequential" engineering in which a design was developed and refined in successive stages by different engineering groups, such as materials engineering, packaging engineering, and production engineering. Instead, IPD uses an approach called "concurrent engineering" or "simultaneous engineering," in which the different engineering disciplines work in a parallel, coordinated fashion to address lifecycle requirements. These disciplines include quality, manufacturability, reliability, maintainability, safety, and, of course, sustainability. Concurrent engineering is more rapid and cost-effective since design changes are much costlier as a product proceeds from the concept stage into full-scale development. By anticipating potential problems or opportunities, the design team is able to avoid costly changes and delays due to design iterations. This helps to speed time to market, that is, the time interval between the launch of a new product development effort and the market introduction of the product, which usually enables the product to capture a larger market share.

Design for Sustainability

Design for sustainability is simply the incorporation of sustainability considerations into IPD as one of the concurrent engineering disciplines. Sustainability is a broad subject, touching on issues of environmental quality, natural resource protection, human health and safety, human dignity, economic prosperity, ethics, and justice. All of these issues may influence the design of an initial product concept, as they would in the plan for a water purification system for poor villages.

Following the initial concept stage, the major sustainability issues that influence the engineering and detailed design of a product are its tangible properties—choice of materials; resource requirements; physical dimensions and structure; health, safety, and environmental concerns; and of course costs. The practice of incorporating these issues into IPD is variously described as Design for Environment (DFE), eco-design, or lifecycle design (Fiksel 2009). Typically, the scope of DFE includes the following objectives:

- Environmental protection—Assurance that air, water, soil, and biological organisms are not adversely affected due to the release of pollutants or toxic substances.
- Human health and safety—Assurance that people are not exposed to safety hazards or chronic-disease agents in their workplace environments or personal lives.
- Sustainability of natural resources—Assurance that human consumption or use of natural resources does not threaten the availability of these resources for future generations.

DFE originated in the early 1990s as global companies became more aware of the environmental implications of their product and process designs. A number of driving forces influenced the adoption of DFE: consumers were growing more interested in environmentally responsible products, the International Organization for Standardization was developing the ISO 14000 series of standards for environmental management systems, and government agencies, especially in the European Union (EU), were issuing directives to make manufacturers responsible for the full product cycle, including recovery of discarded products at the end of their useful life.

Recognizing that sustainable business practices could create reputational benefits and potential cost advantages, many companies have adopted voluntary codes of conduct, such as the Ceres principles and the U.N. Global Compact, both of which include commitments to develop sustainable products and processes. Over 50 percent of major U.S. companies are now issuing sustainability reports, a trend that accelerated in the early twenty-first century due to growing shareholder pressures and public anxieties over climate change and energy independence. It has become broadly accepted that the energy and environmental performance of a product is an important factor influencing its success in the marketplace. Even Walmart, the retailing giant, announced in 2009 that it was taking the bold step of developing a "sustainability index" to inform consumers about the performance of all products sold in its stores.

Development Principles

There are seven basic principles of DFE for product development teams to consider (Fiksel 2009).

Lifecycle Thinking

The IPD approach requires design teams to think beyond the cost, technology, and functional performance of the design and to consider the broader consequences at each stage of the value chain, or lifecycle. The product lifecycle involves the five major stages of supply-chain management: source, make, deliver, support, and recycle. At each stage there may be positive or negative consequences in terms of financial performance, human health and safety, and environmental impacts such as greenhouse gas emissions, biodiversity, and natural resource depletion. There are several points along the lifecycle where wastes are generated, representing opportunities for recovery and reuse of discarded materials—known as the "cradle to cradle" approach (McDonough and Braungart 2002). When thinking about environmental consequences, a firm should consider not only potential impacts on its own assets, but also the economic, environmental, health, and safety concerns of affected stakeholders, including employees, customers, suppliers, contractors, and local communities.

System-Level Resource Productivity

A fundamental challenge of DFE is to consider the entire system in which the product is embedded and to determine how stakeholder needs can be met in the most resource efficient, effective, and environmentally benign manner. A useful concept is eco-efficiency, defined by The World Business Council on Sustainable Development (2000) as "delivery of competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing environmental impacts of goods and resource intensity throughout the entire lifecycle."

Essentially, eco-efficiency means generating more value with less adverse ecological impacts. It measures resource productivity as a ratio of two metrics—economic value creation and environmental resource consumption (for example, dollars of revenue per kilowatt-hours of energy use). But companies must be careful to avoid complacency about incremental improvements in eco-efficiency. To make meaningful contributions to sustainability, companies need to design innovative, game-changing products that provide quantum improvements in quality of life and/or environmental footprint.

Performance Indicators

Performance measurement is critical in new product development for purposes of establishing requirements and objectives against which designs are evaluated. Sustainability indicators can reflect a variety of customer or stakeholder expectations as well as corporate priorities and regulatory constraints. When performance objectives are expressed in terms of specific indicators (such as 50 percent solid-waste reduction), these can be translated into quantitative metrics that are estimated and tracked for a particular product design. Examples of environmental performance metrics include toxic use (total kilograms of solvents purchased per unit of production), resource utilization (total energy consumed during the product lifecycle), atmospheric emissions (greenhouse gases and ozone-depleting substances released per unit of production), and waste minimization (percent of product materials recovered at end-of-life). Other sustainability performance metrics related to socioeconomic benefits may include job creation, poverty alleviation, or health improvement.

Sustainable Design Strategies

To assure a repeatable and consistent innovation process, companies should develop a portfolio of design strategies and guidelines suitable for their products, processes, and technologies. The following summarizes four main strategies based on worldwide best practices (Fiksel 2009).

- Design for dematerialization—Minimize material throughput as well as the associated energy and resource consumption at every stage of the lifecycle. This can be achieved through techniques such as product life extension, source reduction, process simplification, use of recycled inputs, or substitution of services for products.
- Design for detoxification—Minimize the potential for adverse human or ecological effects at every stage of the lifecycle. This can be achieved through replacement of toxic or hazardous materials with benign ones, introduction of cleaner technologies that reduce wastes and emissions, or waste treatment.
- Design for revalorization—Recover residual value from resources that have already been utilized, thus reducing the need for extraction of virgin resources. This can be achieved by finding secondary uses for discarded products, refurbishing products and components at the end of their useful life, facilitating disassembly and material separation for durable products, and finding economical ways to recycle and reuse waste streams.
- Design for capital protection and renewal—Assure the availability and integrity of the various types of productive capital that are the basis of future human prosperity. Human capital refers to the health, safety, security, and well-being of employees, customers, suppliers, and other stakeholders. Natural capital refers to the resources and ecosystem services that make possible all economic activity. Economic capital refers to tangible enterprise assets including facilities and equipment, as well as intellectual property, reputation, and other intangible assets. Thus capital renewal may include attracting new talent, revitalizing ecosystems, and building new factories.

Multicriteria Decision Making

Design teams need rigorous, quantitative tools to analyze or predict product performance and to weigh the trade-offs of alternative design choices. Every product requirement can be viewed as a "criterion" with a corresponding verification method that involves physical tests or numerical calculations. There are a number of decision-making methods that can be applied to these multiple criteria, ranging from screening methods (such as material checklists) to advanced methods such as risk assessment, lifecycle assessment, cost-benefit analysis, quality-function deployment, and other Design for Six Sigma tools (Yang 2003). Six Sigma—a term derived from statistical vocabulary—is a business management system developed in the 1980s that provides businesses with tools to improve the capability of their practices and processes; Design for Six Sigma is an approach using the Six Sigma methodology in the early design stages to improve product quality.

Information Technology Infrastructure

Systematic application of the above principles cannot be accomplished unless DfE metrics, guidelines, and analysis methods are integrated into the computing environment that is routinely used by design teams. This requires extension of the commercial software tools used for requirements management, product data management, computer-aided engineering and design (CAE/CAD), and performance simulation. Examples of useful tools include "expert systems" for sustainable design and computer-based modeling of lifecycle economic and environmental consequences.

Learning from Nature

A never-ending source of design inspiration can be found in natural systems, where sustainable and resilient solutions have evolved over millions of years. Many important technologies have originated from "biomimicry" (Benyus 1997), which means to study nature and imitate it in designs and processes; for example, Velcro was inspired by the structure of plant burrs, while new designs for turbine blades mimic the flippers of whales. Natural systems manage to accomplish physical tasks and chemical transformations in elegant ways, without the excessive baggage of industrial supply chains. More broadly, humans can learn from nature how to organize a complex web of processes in a way that generates zero waste. Just as food webs have evolved so that every bit of biomass is consumed by some organism occupying a particular niche, it is possible for industrial networks to convert waste streams into "food" for material or energy production.

Examples of Sustainable Product Development

Many of the foremost global companies across different industries have applied the above principles of sustainable design and achieved considerable success in the marketplace. In many cases, these successes were supported by extensive collaboration and dialogue with customers, suppliers, and external stakeholder groups. The following are selected examples.

- Dow AgroSciences received a Presidential Green Chemistry award for the Sentricon System, which eliminates termite colonies while replacing the need for widespread applications of pesticides. With the Sentricon technology, pest-control companies use monitoring stations to detect the presence of termites, and then insert bait laced with a slow-acting termite growth inhibitor. The amount of pesticide required is as little as 1/10,000 of the amount used in traditional fumigation processes.
- HP introduced the Pavilion dv6929 notebook PC in a recycled laptop bag with 97 percent less packaging than typical laptops. The carrying bag contains no foam, only some plastic bags to be disposed of by consumers. The bag itself, save for the buckle, strap, and zipper, is made from 100-percent recycled fabric. HP is able to fit three bags in a box for shipping the product to stores, thus reducing energy use and costs related to logistics.
- Xerox's iGen3 commercial printing system has over 97 percent recyclable or remanufacturable components, and up to 80 percent (by weight) of the waste that it generates can be returned, reused, or recycled. It emits 80 percent less noise than a typical offset press and uses nontoxic dry inks that have closed containers so that there are virtually no chemical emissions nor any need for protective equipment or abatement costs.
- Researchers at Ford Motor Company have developed flexible, polyurethane foams that contain soy oil, replacing traditional petroleum-derived polyols. Since 2007 Ford (n.d.) has introduced soy foam on the seat backs and cushions of the Mustang, Focus, Escape, F-150, Expedition, Navigator, and Mariner, reducing carbon dioxide emissions by about 5.3 million pounds per year. Ongoing research on sustainable materials includes natural fiber–reinforced plastics to replace glass fiber and polymer resins made from high sugar content plants.
- General Electric is designing a hybrid diesel-electric locomotive that will capture the energy dissipated during braking and store it in a series of sophisticated batteries. That stored energy can be used by the crew on demand, reducing fuel consumption by as much as 15 percent and emissions by as much as 50 percent compared to most of the freight locomotives in use today (General Electric 2010). In addition to environmental advantages, a hybrid will operate more efficiently in higher altitudes and up steep inclines.
- SC Johnson incorporated eco-efficiency into its product development efforts in the early 1990s and has developed the Greenlist process, which classifies raw materials according to their impact on the environment and human health. As a result, nearly all of its product lines boast environmental benefits. For example, by reformulating Windex glass cleaner, the company has avoided 1.8 million pounds (816,480 kilograms) of volatile organic compound (VOC) emissions annually, while achieving 30 percent more cleaning power (Fiksel 2009).
- Nike footwear and apparel products are designed with a "considered" lifecycle perspective—made from sustainable materials, minimizing the use of adhesives, minimizing packaging in the supply chain, and recoverable at the end of their useful life. For example, Nike's Trash Talk athletic shoe has an upper- and midsole made entirely from manufacturing scrap waste, and the outsole also incorporates Nike Grind, which is made from reprocessed postconsumer waste.
- Owens Corning's Atticat fiberglass insulation was Cradle to Cradle certified in recognition of its environmentally intelligent design. The glass feedstock is composed of 60 percent recycled material, and the product is "unbonded loose fill" so it requires no binder chemicals. It is also highly compressible, thus increasing transportation efficiency, and is easier to recycle and remelt than conventional bonded insulation.
- 3M designed a "climate-friendly" replacement for halon fire suppressants, Novec 1230 Fire Protection Fluid, which uses a new technology platform based on fluorinated ketones. It is superior in extinguishing efficiency, and has the lowest Global Warming Potential (a measure used to compare the capabilities of various greenhouse gases to trap heat in the atmosphere) of any halon alternative. It also has a short atmospheric lifetime, is low in acute toxicity, is electrically nonconductive, and is a liquid at room temperature, making it both safer and more convenient.

Future Directions and Challenges

Experience to date has shown that introducing environmental design principles into the integrated product development process provides new opportunities for companies to reduce lifecycle costs and improve overall product quality and profitability, while helping to assure that they are meeting their sustainability commitments. Modern communication technologies enable virtual design teams to share knowledge across time and space so that sustainability expertise can be leveraged across a global corporation. Many leading companies utilize a small corporate-staff group of specialists who provide support to cross-functional teams in different divisions. The motivation for adopting sustainability goals typically flows down from line management, while the sustainability specialists act as change agents, meeting with leaders of business and functional groups to set strategy and coordinate implementation. To move beyond opportunistic design efforts into a more systematic practice, companies are establishing organizational goals, incentives, and accountability for continuous improvement in product lifecycle performance, and modifying business processes and information systems to enable successful accomplishment of these goals.

There are many remaining barriers, including resource limitations, conflicting objectives, cultural resistance, and lack of adequate training. Nevertheless, between 1990 and 2010 the private sector has made significant strides in reducing the resource intensity of industrial supply chains through product and process innovation. Unfortunately these gains have been negated by long-term economic growth, so that overall rates of energy demand, global warming emissions, and environmental degradation continue to increase. It is becoming apparent that voluntary, incremental environmental improvements by individual companies are inadequate to offset economic growth, and that the rapid industrialization of China, India, and other emerging economies will exacerbate this problem. Indeed, the perceived potential of large new markets at the "base of the pyramid" has generated a wave of innovation in products and services specifically designed to alleviate poverty and improve quality of life.

The challenge facing product-development professionals today is how to achieve sustainable growth by dramatically reducing the overall product footprint in terms of resource utilization and emissions. Achieving breakthrough innovation will require extraordinary collaboration among industries, legislators, regulators, and nongovernmental organizations. Perhaps the most daunting barrier is the complexity and interdependence of environmental, energy, and economic systems, making it difficult to assess the long-term consequences of new technologies. Integrated product development will need to expand its boundaries enormously to include design of the infrastructure, the built environment, the engineered ecosystems, and even the social fabric in which enterprises and their customers operate.

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See also Biomimicry; Design, Industrial; Ecolabeling; Lifecycle Assessments (LCAs); Manufacturing Practices; Performance Metrics; Remanufacturing; Supply Chain Management

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Investment, CleanTech

CleanTech *refers to technologies and business models that improve a product or a service's performance, productivity, or efficiency while reducing costs, using less energy and fewer materials, and lessening environmental damage. CleanTech investment in diverse sectors, including energy, water and wastewater treatment, manufacturing, advanced materials, transportation, and agriculture, provides competitive returns for investors and customers. Standardization, legislation, long-term planning, and incentives mediate its risks.*

Since 2004, investment in the venture capital category known as CleanTech has emerged as a new trend that is fundamentally changing the face of the business of sustainability. Such technology—solar power, fuel cells, and aquaculture, for example—drives innovation as it has the potential to become an integral part of corporate value chains. (A "value chain" is a series of activities whose goal is to create value that exceeds the cost of providing a product or service, thereby generating a profit margin.) CleanTech refers to the "clean" technologies and business models that address the source of ecological problems caused by a product or a service's manufacturing or development process. It improves the product or service's performance, its productivity, or its efficiency as it reduces costs, uses less energy and fewer materials, and causes less environmental damage. Such technologies are clustered in diverse industry sectors, including energy (about two-thirds of total investment), water and wastewater treatment, manufacturing, advanced materials, transportation, and agriculture. The products or services cover a wide range including: energy-efficient lighting; wind and solar energy; water filtration; next-generation batteries; advanced materials that make products lighter, stronger, and/or cheaper; nontoxic pesticides; and enabling technologies that improve the performance of smart electricity grids.

Companies are realizing that integrating CleanTech solutions into their operations can potentially "green" their supply chains. It will also reduce their exposure to the uncertainties of climate change and water shortages and pollution, increase market valuations (the amount consumers are willing to pay), and, particularly, develop additional income streams in new markets. The challenge for corporations is to weigh the investment in CleanTech solutions, which often are capital intensive, against the solutions' potential long-term business value. For example, corporations and investors need to contend with the uncertainty of a technology's scalability or robustness and the need for new business models that would allow them to capture the value of the investment. They also need to consider the uncertainties of the financial markets that have hindered debt financing and public offerings, the volatility of oil prices, and the range of proposed policies aimed at adapting to climate change and reducing carbon emissions.

The CleanTech investment space is characterized by high capital investment, long technology-development cycles, a high degree of dependence on government policy, and (as of this early stage) uncertain exit strategies for investors. These characteristics contrast with typical information technology elements (e.g., materials in the solar value chain and smart grids that deliver electricity from alternative power sources), biotechnology (e.g., algae biofuels), and several other more mature investment domains. Hence new business models are needed for CleanTech investments, because investors and businesses that have transitioned from information technology or biotechnology into CleanTech have experienced a significant learning curve, particularly as it pertains to the valuation of companies, the size of investment rounds, and the potential for exit strategies (acquisitions or initial public offerings). The 2009 initial public offering of A123 Systems, which makes lithium-ion batteries that could be used in smart grids, potentially opened a window to access public markets profitably. Acquisitions, however, remain the most likely exit strategy.

Evidence is emerging that corporations are increasingly investing in CleanTech start-ups, joint ventures, and outright acquisitions, particularly in the energy, biofuel, and water-treatment technology areas, for the purpose of strategic differentiation and revenue growth. Examples include Exxon's $600 million investment in Synthetic Genomics during 2009 to develop superior algae strains for biodiesel production, General Electric's 2009 investment in A123 Systems, and Walmart's investment in energy- and water-efficiency companies to reduce carbon and water footprints (Cleantech Group 2009). (Carbon footprints and water footprints measure the amount of greenhouse gases created in the production of goods and services or the amount of freshwater used during daily activities, respectively.) The market for these technologies continues to expand, as more investors and corporations realize how sustainability-driven innovation through investment in CleanTech can better use natural resources in a way that provides economic value. What has fueled this trend, why are companies investing in CleanTech, and how is it related to leading innovations for corporate environmental sustainability?

Growth and Expansion

In the United States, CleanTech dates to the 1970s, when the environmental movement came of age after the Environmental Protection Agency was established. At that time, Congress enacted legislation such as the Clean Air Act and the Clean Water Act in response to public sentiment against environmental pollution and to the widespread evidence of environmental and public health hazards. These events and the oil crisis of 1973 prompted research and technology development for alternative energy generation, water-treatment processes, and "end-of-pipe" environmental treatment technologies that deal with pollution after it happens. Many of these technologies, however, were in an early stage of development, were too expensive, and did not have widespread political support; very few established companies embraced the innovative potential of this sector. This was due, in part, to the cost of these solutions and the absence of business models that would allow investors and companies to capture attractive returns. As a result, environmental technologies were often only implemented in small markets driven by regulatory compliance. Because of these events, the Cleantech Group (which coined and trademarked the term *cleantech*) argues that CleanTech should not be confused with the terms *environmental technology* or *green tech*, commonly used in the 1970s and 1980s.

To date, scores of companies and organizations in the United States and Europe are driving CleanTech business development and helping investors and corporations identify investment and acquisition opportunities. These include Clean Edge, a research and publishing firm dedicated to the CleanTech sector, which targets investors and entrepreneurs; Lux Research, an independent research and advisory firm, which provides corporations and investment funds with strategic advice and ongoing intelligence for emerging technologies; and Cleantech Europe, an advisory firm for entrepreneurs and investors, which canvasses the entire CleanTech space. Aside from business intelligence firms, the financial services industry has embraced CleanTech and focuses on the energy sector by establishing either new specializations within a firm or independent boutique operations.

Even at the start of the twenty-first century, the term *CleanTech* was not in the financial or business community's vocabulary. But since 2004, the sector has matured and gained recognition because it couples new CleanTech products or services with new business models that offer competitive returns for investors and customers. In recent years, this sector has seen a surge in financial innovations that drive businesses and consumers to adopt clean technologies. For example, rooftop solar technology is driven by long-term leasing and purchasing programs. In these programs, the technology is owned and maintained by the solar company, which also negotiates electricity rates with the utility to enable rebates to the consumer. These low-risk value propositions to consumers and peak power–demand mitigation values to utilities are becoming the mainstream for residential and commercial energy production and are being adopted in the waste-to-energy sector. A number of strategic drivers, which determine the success or direction of a company's business strategy, have spurred CleanTech's rapid growth. These drivers include the availability of private and public capital; the decreasing cost of technologies, which affects the scalability of solutions; the competition between governments to build jobs for the green economy; the certainty of climate change, which is influencing companies to disclose and mitigate their exposure risks; a changing consumer base that demands sustainable goods and services; and the resource demands of emerging economies such as India's and China's.

The best evidence that CleanTech has entered the mainstream is that governments around the world have made greening of the economy the centerpiece of their stimulus programs, at a cost that some estimate to be over $500 billion (Edenhofer and Stern 2009). This injection of government capital has accelerated investors' and corporations' interest, resulting in a green technology market rebound of

36 percent in the second quarter of 2009. At that time, more than three thousand venture-backed CleanTech companies were operating globally. Many more were funded through corporate investment, debt-equity financing, wealthy individuals, and government grants. Thus the intent of the technology, and the CleanTech venture based on it, is to mitigate carbon or water footprints through efficiency gains or other means because of their business value. Yet unintended consequences can result when forces other than markets pick which measures will be successes or failures. This has been the case with the ethanol biofuel mandates in the United States and the subsidies and preferential feed-in tariffs for solar and wind energy in Europe. Farmland gave way to energy farms, and food commodity prices spiked as a result. Hence the integration of policies and CleanTech solutions is awkward. Indeed, given the uncertainty of the outcome of the U.N.'s 2009 Copenhagen climate discussions (COP-15), venture firms and entrepreneurs have been positioning themselves to become increasingly less reliant on environmental policies that may have unintended consequences or determine business value.

Impact on Sustainability

Corporations that make targeted investments in internal research and development, joint ventures, and acquisitions of companies that use disruptive technology (advances that improve a product or service in ways that are unexpected by the market) are creating both effective, innovative CleanTech solutions and value in their operations. This is where innovation in clean technologies and sustainability objectives intersect. The rationale is that technology investments help resolve the potential impacts of climate change and water risks on the long-term growth strategies (and thus market valuations) of corporations. Since 2004, disclosures in the financial market of economic, environmental, and social performance have become increasingly common in financial reporting and are important to organizational success. This is evident from corporations' disclosures in their Securities and Exchange Commission (SEC) filings of climate risks to their operations and supply chains and from their innovative solutions to reduce their exposure to the risk.

The Dow Jones Sustainability Indexes (DJSI) have tracked the financial performance of the leading sustainability-driven companies worldwide since 2000, and many organizations such as Ceres, the RiskMetrics Group, and the Carbon Disclosure Project analyze sustainability indicators. For example, Ceres is a national coalition of investors, environmental groups, and other public interest organizations that work with companies to address sustainability challenges such as global climate change. Ceres directs the Investor Network on Climate Risk, a group of more than seventy institutional investors from the United States and Europe that manage over $7 trillion in assets. A 2008 report published by Ceres describes how sixty-three of the largest consumer and technology companies across all industry sectors are positioning themselves to respond to the effects of climate change on their massive operations and supply chains (Risk Metrics 2008, 3). In the responses, the companies plan to reduce their carbon and water footprints. But because sustainability will increasingly become a driver for corporate strategy and differentiation, companies will need next-generation practices that change the existing business paradigms. To develop innovations that lead to next practices, executives must question the implicit assumptions behind their current practices. The Ceres report's recommended actions involve changing pay reward structures, governance systems, and supply chain management; setting renewable energy purchasing targets; and strategically investing in disruptive technologies. CleanTech allows businesses to change the way they operate, because technology differentiation results in strategic differentiation from the competition within and outside their industry sectors.

Many companies focus on the large portion of their carbon and water footprints that are in their supply chains. A number of leading companies began by managing their risks and developing standards to measure their emissions, and then moved forward to identify easy-to-achieve changes and the type of CleanTech investments to target. Consider Nike, whose extensive chain of footwear manufacturing sites accounts for 60 percent of its total carbon footprint. Because it is difficult to measure and control greenhouse gas emissions from raw materials processing, component suppliers, and the transportation of goods, these sites must collaborate with one another and with suppliers. Around 2009, Coca-Cola and Molson Coors started implementing a common industry standard to measure product lifecycle emissions, concentrating on managing their water footprints across the entire supply chain. Dell, Walmart, and several other companies directly engage suppliers in China to ensure that greenhouse gas emissions are assessed and reported.

But many companies go further. Walmart invested in CleanTech companies and technologies that offer solutions for greening their operations. For example, it implemented energy-efficient heating and lighting systems and pervious roofs and parking lot surfaces to restore the hydraulic cycle that moves water through land, the oceans, and the atmosphere. Walmart is even exploring colocating its warehouses with landfill gasification projects to form an off-grid power source. Energy companies such as Exxon and Chevron (alongside venture capital firms) invested heavily in algae biofuel start-up companies because they recognize that algae biodiesel technology may be scalable and produce an alternative to oil. Thus, they explored greening their product mix and tapped into new markets. These companies are particularly focused on the early stages in the value chain, such as the isolation, selection, and genetic engineering of highly efficient strains of algae, and the related extraction process technology. Engineering manufacturing companies such as Bosch and Siemens are diversifying in green technology by investing in start-ups across the solar and wind value chain and through acquisitions. Proponents of improving the corporate value chain believe that core engineering know-how can be directed to improve alternative energy and other technologies. This allows companies to tap into new markets while integrating the innovations into their operations and supply chains.

Risks and Controversies

The investment decisions in the growth and opportunities of CleanTech companies are at the center of a perfect storm: governments are unlocking unprecedented amounts of stimulus funds in order to green economies. Some argue that companies on the DJSI, compared with those not on the list, exhibit an increase of up to 15 percent in price-earnings ratios, indicating that the market values these companies more than it values companies that do not meet sustainability metrics. The market is looking at companies' climate risk disclosures in SEC filings. In addition, climate policies are influencing industry value chains, carbon markets for emissions trading, and consumer behaviors. Yet risks, unintended consequences, and other controversies may affect the future development of CleanTech innovations. Among these impacts are "greenwashing," or incorrectly stating the environmental benefits of a product, technology, or practice; the risk of governments awarding funds and determining policies based on a company's massive investment in targeted innovations; the risk of companies failing to make long-term plans; and the green paradox that policies aimed at curbing emissions may result in the acceleration of oil production.

How can companies and governments address these issues? First, some reporting standards for greening the supply chain and operations are emerging, and analysts are using them. As of the beginning of the twenty-first century, the implementation of climate and water risk reporting within companies is voluntary, and the metrics for various products and services are arbitrary. Increasing the standards of reporting and continuing to release disclosures will aid in the elimination of these risks. If the reporting of climate risks and the proposed mitigation strategies for companies, regardless of sectors, can be standardized, then corporations can hedge their financial risks to climate change and water risk uncertainties. For example, Swiss Re (a leading global reinsurer) and others are piloting weather insurance products that would reduce crop price volatility (affecting the food, beverage, and clothing industries) and transfer risk to financial players (the reinsurers or investors).

Second, the infusion of government capital will have the potential to remake alternative energy and other green technology businesses, influence investment returns, and affect industry value chains. For example, the United States's 2009 "green" economic stimulus plan targets a clean energy future by allotting $117.2 billion, or 12 percent of the $787.2 billion plan (Edenhofer and Stern 2009). It will achieve this through the development of plug-in hybrid cars and renewable energy technology, investment in energy efficiency, and a cap-and-trade program for trading pollution credits in order to reduce greenhouse gas emissions. China's government committed to a circular economy concept that would reduce, reuse, and recycle resources during manufacturing, transportation, and consumption by allotting $218 billion, or 33.4 percent of its budget. This legislation will allow Chinese auto manufacturers to leapfrog automotive technology by a generation and lead the green car revolution. It also identifies an official target for the capacity of installed solar and wind energy plants that well exceeds that of the United States. But history has shown that letting governments rather than markets decide what measures will be successful may be risky. For example, the U.S. government credits for biofuel growers have pushed up commodity prices and caused a food-for-oil trade-off, affecting poor populations and increasing the water footprints of the biofuel industry. The emphasis on hybrid electric or all-electric cars, with their dependence on scarce supplies of lithium-ion batteries, leaves companies exposed to political risk and unsustainable extraction practices.

Third, companies must have a long-term plan that considers the opportunities and sustainability of their investments in CleanTech. The view that CleanTech is a mere add-on with a good cost-benefit ratio is shortsighted. These myopic views may result in companies shedding CleanTech when the market or policy incentives change, meaning the technology's social and environmental impacts will be small. The integration of CleanTech into the company's value structure has a greater potential to shift the company's competitive strategy and have a lasting impact for sustainability.

Finally, the so-called green paradox argues that as governments and companies strive to reduce emissions by reducing fossil fuel consumption (through CleanTech innovations in alternative energy, improved building insulation, and efficient cars), the global extraction of coal, gas, and oil will increase. The argument is that as companies green the economy, they exert a downward pressure on future fossil fuel prices (because less is needed). To maintain profits, owners of oil and gas fields will increase production, thus exacerbating climate change. The implication is that policies need to offer incentives for owners to leave supplies in the ground, rather than attempt to curb demand. The paradox is that curbs on demand have stimulated considerable CleanTech innovation. Taxation disincentives for owners are not politically viable, so a global carbon emissions trading system may be able to cap fuel consumption and slow down extraction rates. This would spur further innovations in carbon financing and bring financial and insurance services up the green value chain. (Carbon financing, as part of the Kyoto Protocol, generally refers to investments in greenhouse gas emission reduction projects and the creation of financial instruments that are tradable on the carbon market. The value chain essentially consists of three major players: project owners, traders or brokers, and buyers of carbon offsets. Even though not all greenhouse gas mitigation projects carry the same value, the carbon markets and their financial services players attempt to authenticate and verify the value of the offsets through financial instruments.)

Future Outlook

The fact that viable business models are generating attractive returns to investors and corporations shows that CleanTech is here to stay, regardless of the market, policy, and technology challenges it poses to corporate operations and value chains. While the United States's 2009 economic stimulus funding will be expended over two years, the impact in the markets of its green investment will take much longer to appear. The traction of SEC filings will continue as more companies participate in the disclosure of climate risks or participate in the Carbon Disclosure Project. With the standardization of measurements coming of age, companies will more easily measure their carbon and water footprints and identify opportunities to mitigate risks. Project financing and insurance pricing are increasingly tied to the climate exposures of corporations, and hence future favorable rates may induce companies to adopt carbon and water management strategies and consider integrating CleanTech solutions into their competitive strategies. In light of the maturation of the sector since 2004, which was driven by venture capital and private equity, the early twenty-first century will be driven by growth and expansion in the mainstream economy that is fueled by government programs. It is, however, important to differentiate the outlook by technology domain.

Energy will continue to be the main sector for investment, particularly transportation (batteries and fuel cells), biofuels (algae and noncrop plants), and the continued expansion of solar and wind power. In the third quarter of 2009, CleanTech investments for the first time exceeded those in software, biomedical devices, and biotechnology, with 25 percent of the total venture investment occurring in the United States (Cleantech Group 2009, 13). Solar is the top sector, with a 28 percent share of investment, closely followed by transportation (25 percent) and biofuels (9 percent) (Cleantech Group 2009, 10). In the short term, analysts expect major consolidation to occur in the value chains for these industries. The causes are the role of government, private capital shortages, overcapacity in the face of lower energy demand, and decreasing prices for the integrated technology. This consolidation will stimulate investment in energy companies because investors can control the whole supply chain and respond to U.S. mandates under the stimulus package. This trend is already evident for the solar industry and is likely to follow in the wind industry. New financial models and incentives will be needed to ensure the stability of this CleanTech industry. For example, utilities pay feed-in tariffs, or set prices for paying the end users who provide solar power to the power grid. Making these tariffs consistent across all solar projects (as is proposed in China) will reduce costs and make the projects viable, thereby allowing companies to calculate risks and returns. Even though it is hard to project where investments are headed, findings from Deloitte Touche Tohmatsu's 2009 *Global Trends in Venture Capital* report shows that 63 percent of venture capitalists around the globe intend to increase their exposure to the CleanTech category over the next three years—a far higher percentage than any other sector. The trend looks set to continue for some time.

The demand for renewable energy by utilities is growing, as they must comply with state (and most likely federal) renewable portfolio standards (RPSs) by 2020. The doubts some have that the widespread, integral use of solar power in the RPSs are waning. (Even in the oil- and gas-intensive city of Houston, Texas, utilities are buying solar technology.) Global competition is playing a role as well, with capacity targets for installed alternative energy systems in China rapidly eclipsing those in the United States. A major challenge, aside from policy incentives, is the creation of a smart grid that can handle the highly variable production of electricity from renewable energy sources, one that will allow for storage and can track the "green" and "brown" electrons. A smart grid links power production, transmission, and distribution from centralized (e.g., coal-fired power plants) and distributed sources (e.g., wind farms or electric vehicles) with consumer demand. With electricity being generated from traditional coal or oil plants (brown electrons) as well as from the wind, solar energy, biofuels, and batteries (green electrons), an intricate management system needs to be developed. In the United States, many start-up companies in all parts of the value chain are working together to develop enabling technologies and management aspects that meet a federal mandate to create a smart grid. Considering the fixed infrastructure of the current grid, companies will likely locate green smart grids along corridors (e.g., in Arizona and California) to test their feasibility. Bond measures will likely fund their construction in a piecemeal fashion, and business models will be developed to monetize them with attractive returns.

In other sectors, advances in battery technology aside from lithium-ion batteries will fuel the generation of cars that will be developed in the second decade of the century. But first, battery costs must come down and their efficiency must improve. Experience with hybrid technology and General Motors's Volt electric car will prove invaluable to assess market demand for this technology and to drive innovations in electrical grid infrastructure. Experience with hybrid and electric technology might also affect business models pertaining to the purchase, maintenance, and afterlife care of the battery system. Corporations may be highly motivated to move in this direction because of their investments in fuel-efficient fleets, whether on an ownership, lease, or joint venture basis. Future fuel prices, the cost of technology, and government incentives will play a major role in the adoption of this technology. Considering the long development cycles and fragmentation of the industry, these innovations will presumably have a long time on the horizon before they play out in the marketplace.

Finally, conservative deregulation in the water industry sector has seen much innovation and investment or acquisition activity, both for ultrahigh-purity and high-volume applications. For example, General Electric acquired Canada's Glegg Water Company, which developed a superior electrodeionization technology and product (the E-Cell) for ultraclean water treatment. Targeting high-value customers such as the pharmaceutical and semiconductor industries, General Electric's Water and Process Technologies division recognized the opportunity as an acquisition and business opportunity. Two main strategic drivers will increase investments in water technologies: SEC disclosures of corporate water footprints and the energy–water nexus. This nexus includes CleanTech innovations that address the energy used for water conveyance and treatment (e.g., to operate filtration systems, microturbines, and fuel cells). Other innovations address water use for energy production from coal, gas, nuclear, biofuel, and utility-scale solar sources. This water industry sector is moving up the value chain due to a number of factors. First, climate change affects corporate risks to water availability and quality. Second, water costs for corporate users are being renegotiated, and finally, multistakeholder water use is starting to drive new legislation.

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See also Biomimicry; Cap-and-Trade Legislation; Climate Change Disclosure; Energy Efficiency; Energy Industries—Overview of Renewables; Green-Collar Jobs; Investment, Socially Responsible (SRI); Product-Service Systems (PSSs); Risk Management; Supply Chain Management; True Cost Economics

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Investment, Socially Responsible (SRI)

Socially responsible investment (SRI) is a process that integrates environmental, social, and community concerns into a traditional financial investment framework. The SRI market's growth, especially in the developing world, depends on development of new research methods, market pressures to encourage further corporate transparency and accountability, and incorporation of SRI into national economies.

Socially responsible investing (SRI) is an investment process that considers social and environmental consequences within the context of traditional financial analysis. Investors—including individuals, institutions, and corporations—use SRI to achieve traditional financial as well as social, environmental, and community returns. They accomplish this by integrating these dimensions onto a traditional financial investment framework. An important goal of SRI is to promote corporate accountability for its social and environmental risks into mainstream financial practices and to engage a wide range of companies in improving their environmental and social responsibility practices.

Origins of Modern SRI

The origins of the modern SRI movement can be traced to the turbulent period in the 1960s when powerful social undercurrents, including environmentalism and antiwar activism, fueled a radical change in the way society viewed faith, values, and commerce. SRI funds were once primarily known as "ethical funds," and given SRI's strong Judeo-Christian roots, this is not at all surprising. The notion of an ethical business is established in Judeo-Christian traditions; examples of it exist in the book of Deuteronomy, which dates back more than 2,500 years. But it is arguably the Quaker faith that has made the greatest impact in connecting commercial activities and ethical values in the modern age. The Quakers were the first group to practice the "negative screening" of investments when they avoided investments in the military sector by faithfully applying their peace traditions to commercial activities. One of the early examples of what we might call an SRI-like activity is an investment fund established by the Methodist Church in the 1960s that avoided investments in armaments, alcohol, gambling, and tobacco. Since the fund managed by the Methodist Church was closed to outsiders, the first modern example of what we now call an SRI fund was the U.S. Pax World Fund, founded by two Methodist ministers in 1971. The first investment fund that specifically addressed ecological concerns was the Ecology Fund, established by Merlin/Jupiter Company in 1988 (Kreander 2001).

The political unrest in South Africa in the 1960s and 1970s set the stage for another major policy push for SRI and the important connection between ethics and business practices. The Reverend Leon H. Sullivan helped draft a code of conduct (subsequently known as the Sullivan Principles) for companies doing business in South Africa. By the early 1980s the Sullivan Principles became the rallying cry for anti-apartheid activism. In 1982 the state of Connecticut adopted the Sullivan Principles and other social criteria to guide its investment decision making. Just two years later, the California Public Employees' Retirement System (CalPERS), the largest public pension fund in the world, and the New York City Employee Retirement System developed their own investing guidelines in South Africa. In the twenty-first century, corporate divestment and boycott campaigns, addressing issues ranging from the genocide in Darfur, Sudan, to the environmental policies of ExxonMobil, got started in large part due to the success of the South Africa anti-investment campaigners (IFC 2003).

Global SRI Marketplace

The global SRI market in the wealthy countries belonging to the Organisation for Economic Co-operation and Development (OECD) was well established by 2010 and, in the case of Europe, entering a major growth phase. In the United States, US$2.7 trillion, or about 11 percent of the US$26 trillion in total investment assets, is invested in one of the three SRI strategies—screening, shareholder advocacy, and community investing. Although much smaller in size, the European SRI market has grown rapidly in recent years and is now estimated to be €2.7 trillion, accounting for as much as 17.5 percent of the asset management industry (SIF 2008). Even in Japan and the Asia-Pacific region, where awareness of social responsibility concerns lags behind North America and Europe, SRI represents one of the few financial market segments that remain vibrant in terms of market development. In addition, the SRI market in Australia grew 41 percent between 2003 and 2004 alone, twice as fast as that country's retail and wholesale investment market (Eurosif 2008).

Key Global Issues and Trends

As SRI moves to the global financial and business landscape, we can highlight three important trends. The first is the emergence of the investing community, consisting of individual and institutional investors, as a new and powerful actor in global economic and sustainability governance. The second trend attempts to determine the business and sustainability effectiveness of SRI. The third trend focuses on SRI's potential role in the mainstream of emerging and developing economies at the base of the economic development pyramid.

Investing Community's Role

The emergence of investors as important financial actors and the rise of responsible investment since the 1970s highlight the complexities of contemporary global governance. For example, the lines between the domestic and the international have blurred (as investment capital increasingly attempts to link local corporate activities with global responsibilities). Other examples are the expansion of actors from a few dedicated mutual funds (mainly in the United States) to several hundred across the world; the rise of global institutional investors involved in promoting SRI principles in their activities; the emergence of a global civil society attempting to influence financial capital; and the variety of transnational issues motivating capital markets (from human rights–related concerns, such as apartheid in South Africa, to environmental sustainability and related concerns).

Although SRI investors can technically be anyone in society who has investment capital, institutional investors—including pension funds, investment companies, insurance companies, or those investors with money under professional management—account for the largest percentage of the total SRI market. Individual or retail investors—who owned as much as 93 percent of all U.S. stocks in 1950 and as much as 75 percent in the 1970s—now own a record-low 34 percent of all shares. In contrast, institutional investors quickly gained greater control over the equity markets, with the percentage of their ownership shares increasing from 47 percent in 1987 to over 76 percent in 2007. In 1985, no company had institutional ownership of 60 percent or above, whereas by 2007, seventeen companies had institutional ownership of 60 percent or above, including six with institutional ownership of 70 percent or above (Conference Board 2007; 2008).

The significance of this trend, in terms of SRI, is that institutional investors are starting to have substantial economic, and albeit more subtle, business sustainability influence through the shares they own in particular companies. The equity investments allow institutional investors the right to bring forth shareholder resolutions and exert influence on companies in which they *do not* own equity shares. They can achieve this through creating standards or screens for future potential equity purchases.

Sustainable Impact and Effectiveness

One of the most commonly asked questions, if not one of the most important, is whether SRI portfolio screening and shareholder advocacy / engagement practices have a positive impact on the sustainable behavior of companies. While it is difficult to determine SRI's long-term sustainable impact and effectiveness, some preliminary evidence suggests that SRI is having a sustainability impact on business behavior. When CalPERS announced that it would start employing SRI principles in its investment management decisions in 2001, the practical results of this policy were initially unclear. A year later, after CalPERS decided that it would divest its investments in Thailand, Indonesia, and Malaysia due to unacceptably low levels of labor standards, political stability, and financial transparency

rankings, finance and stock market officials in those respective countries began scrambling to adopt policies to improve business practices in those areas (Aguilera et al. 2006).

The FTSE Group is the global index provider and the parent body of the FTSE4Good Index Series that measures corporations' SRI performances. As part of its five-year review in 2007, FTSE4Good Index Series announced that it had achieved a number of positive impacts on the corporate environmental and social responsibility practices of the companies around the world in which it invests (FTSE Group 2007). Through the enactment of various standards and protocols on supply chain management, bribery, climate change, and others, the FTSE4Good Index Series has pushed companies to adopt, or at least consider adopting, corporate environmental and social responsibility performance measures beyond basic compliance.

What is becoming clear, at least in the North American, European, Japanese, and some segments of the Asian markets, is that mainstream individual and institutional investors are starting to believe that social, environmental, and corporate governance are important factors in the investment decision-making process. Mercer Investment Consulting's 2009 review of thirty-six academic studies that examine the relationship between financial performance and environmental, social, and governance (ESG) factors reveals that twenty studies show a positive relationship (that is, financial and ESG factors are positively correlated), eight studies show a neutral relationship, and six studies show a neutral/negative relationship. Mercer's 2006 survey of 183 large financial institutional investors indicates that as much as 75 percent of the respondents (22 percent of whom were SRI investors) believe that social, environmental, and corporate governance factors can have a material impact on investment performance (Mercer 2006). The question is whether this fact—that twenty out of thirty-six academic studies find a positive relationship between financial performance and ESG factors—represents definitive evidence (Mercer 2009). It is probably safer to conclude that there is strong evidence to suggest a positive relationship between financial performance and ESG factors, albeit with the usual proviso that additional research is required.

SRI and Emerging Economies

The healthy development in the SRI markets of North America, Europe, and to a lesser degree Asia overshadows the almost complete lack of SRI activity in emerging and developing economies, where more than two-thirds of the world's population lives and works. The most recent International Finance Corporation survey (2009) of corporate executives and investment professionals' attitudes toward ESG factors in emerging markets compared their thoughts about the global financial situation before the crisis (2007) and midcrisis (2009). Forty-six percent of the investors surveyed strongly agreed with the statement that ESG issues are an important part of their research, portfolio management, and manager selection, up from 36 percent in 2007. The majority of asset owners (78 percent) also suggested that the importance of ESG factors has been amplified by the late 2007–2009 financial crisis and may result in greater use of ESG criteria over time in emerging markets (IFC 2009).

According to the International Finance Corporation, the sum of SRI assets in emerging markets is approximately US$2.7 billion, or 0.1 percent of the US$2.7 trillion global SRI market. Its most recent figure for emerging market assets held by SRI investors in industrialized countries is anywhere between US$1.5 billion and US$2 billion, while it estimates SRI assets in emerging market capitalization at the most optimistic level of 0.1 percent, or US$5 billion. While the most reliable figures on SRI assets in emerging markets come from a 2003 International Financial Corporation study, what is noteworthy is that the estimated SRI assets in emerging markets is small no matter which benchmark we use for comparison. Although the economic disparity between the wealthy, industrialized developed world and the developing world is always stark, it is nevertheless startling to see such a gap between wealthy countries and developing/emerging countries in terms of sustainable investing. This is clearly one of the many institutional hurdles SRI needs to overcome if it is to become more than just a niche market and realize its potential for sustainability at the Base of the Pyramid.

Future Development

Will SRI realize its full potential as a global sustainable business mechanism and advance sustainable strategic management? The answer to this question may depend in part on the quality and sophistication of future SRI research methodology. Smaller SRI investment companies, without their own research staff, rely on independent research providers like KLD Research and Analytics in the United States or Ethical Investment Research Service in the United Kingdom for most of their research needs. Larger SRI fund companies rely on their own internal staff to conduct research and shareholder advocacy and/or to engage with companies. While the more simplistic screening of companies from portfolios is still being used, SRI research as a whole is moving toward much more sophisticated techniques, including a myriad of quantitative analyses. Moreover, sustainability business research companies like the U.K.-based Trucost are starting to use sophisticated economic modeling to assess the environmental externalities that may not be captured in conventional financial accounts. The development of global sustainability indexes like the Dow Jones Sustainability Indexes and the FTSE4Good Index Series have become a much-needed investment index to the SRI capital markets and have led to greater pressure on companies to disclose relevant environmental and social indicators.

Another factor in determining the future development of SRI is the degree of market pressure, particularly from institutional investors, for corporate transparency and accountability. The financial crisis that stared in late 2007 has produced a global chorus for transparency in the financial sector, but it remains unclear if this will lead to a fundamental change in how the global financial market, including SRI, will be governed. It is clear, however, that the greater the transparency and accountability pressures, the better it will be for the future growth of the global SRI market. In 2009, a campaign began pressuring the U.S. Securities and Exchange Commission to require companies to disclose their climate change business risks as part of their 10-K corporate filings and other reporting requirements. Similar international policy initiatives like those of the Global Reporting Initiative organization and national/regional government programs are putting increasing regulatory pressure on strengthening disclosures of corporate environmental and social data.

Arguably the most important criterion for determining growth in SRI development worldwide is to what degree SRI becomes a mainstream investment strategy in emerging and developing economies. Just two countries (India and China) constitute 40 percent of the world's population, and China is no longer considered an emerging market. China will become the world's exporter and is expected to replace Japan as the second-largest economy in the world by 2030. Although the current total of SRI assets in emerging economies is a tiny percentage (still less than 1 percent) of the total emerging market capitalization, there are strong signs that institutional shareholder activism and tightening environmental and social regulatory pressures will become the business norm in a certain select number of emerging markets. Case in point: in 2003, the Johannesburg Securities Exchange in South Africa started requiring all companies listed with the exchange to comply with corporate governance codes and to use the Global Reporting Initiative's guidelines for disclosing social and environmental performance. The actual dollar amount may not be as important as the development of the "right" institutional infrastructure and public–private partnerships that steer SRI toward its next phase of green business development and sustainable strategic management, in both the industrialized and emerging/developing economies.

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See also Activism—NGOs; Base of the Pyramid; Corporate Citizenship; CSR and CSR 2.0; Equator Principles; Fair Trade; Financial Services Industry; Human Rights; Investment, CleanTech; Public–Private Partnerships; Risk Management; Supply Chain Management; Sustainable Value Creation; Transparency; Triple Bottom Line; United Nations Global Compact

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Leadership

The prevailing concept of leadership—one that is influenced by modern industry—must change if humanity is to succeed in establishing a more sustainable world. This new visionary paradigm of leadership will pursue higher goals that reflect common interests and values, fostering networks of collaboration more than competition. Many forms and styles of leadership, however, exercised at all levels of society, will be required to achieve sustainability.

Achieving environmental sustainability will be one of the most important leadership challenges of the twenty-first century. It will take leadership exercised at all levels of society and in many different forms and settings to effect the kinds of changes needed to reach this goal. Compared to previous large-scale challenges, sustainability is particularly daunting because rather than being able to hold out the promise of immediate and palpable gains (as with civil rights, economic prosperity, national self-determination), leaders for sustainability have a more modest, less tangible goal—averting social and biotic catastrophe. Compounding the problem is the fact that doing so will require far-reaching changes in existing behaviors and practices that may be perceived as lifestyle sacrifices in some cases. The benefits of such changes will not always be immediately evident, whereas upfront costs may be high. Environmental problems often take the form of "social dilemmas" in which individuals must forgo their own immediate interests for a wider or future social good. Whereas some individuals are naturally cooperative and/or future oriented, many others are not. Leaders will be needed who can persuade followers to act for the common good regardless of the perceived personal costs.

Furthermore, the relationship between human beings and the ecosystems that sustain them is complex and multifaceted, requiring new and more subtle forms of leadership that enable businesses and communities to interact with the natural environment in ways that nurture rather than destroy ecosystems. Command-and-control forms of leadership—which are more authoritarian or managerial—will increasingly need to be replaced by leadership that facilitates adaptation to the complex ecosystems that make up the biosphere. The sustainability challenge is so all encompassing, however, that no one leadership paradigm or approach can hope to "solve" the problem: the only certainty is that sustainability will not be achieved without the exercise of leadership at all levels of society.

For the purposes of this article, leadership is defined as an influence, relationship, or process aimed at achieving common goals. As such, it is more of an emergent quality than a person or position—leadership can be exercised by different individuals in the same group at different times. It can be the result of inborn traits or learned behaviors and typically involves vision and future orientation. One way to distinguish between leaders and managers is the length of the time horizon: to "manage" connotes activity in the here and now, whereas to "lead" suggests forward movement in space and time. Management typically involves short-term planning, day-to-day supervision of staff, and the implementation of existing policies. By contrast, leadership entails formulating or facilitating a common vision and influencing others to accept and act upon that vision, even if the vision itself is an essentially backward-looking one. (For example, someone might say "We need to go back to our roots of living in harmony with the Earth, as our ancestors did" and still be demonstrating leadership.)

In a world of diminishing natural resources and growing environmental degradation, leadership by definition entails environmental concern. The paramount goal of any healthy organism or group must be its own survival and flourishing, and this requires the health of the larger biosphere that sustains it. In this context, leadership will include making sure that the conditions for group survival and flourishing remain constant or are enhanced. A hunter-gatherer community that runs out of food with no alternatives will be the result of failed leadership as much as a modern business that steadily loses money and eventually goes bankrupt because its leaders were unable to foresee changes in the marketplace. Although social scientists are often uncomfortable making value judgments, from a biological standpoint "survival" and "flourishing" are not so much values as fundamental regulatory principles, the standards by which all actions are ultimately measured. As such, leaders must necessarily be attuned to them.

That we now need to be reminded of this fact is due in large part to a different—and declining—understanding of leadership that emerged in a more abundant age.

The Industrial Leadership Paradigm

Leadership models tend to reflect the concerns and ideals of the era in which they appear. Consequently the dominant leadership paradigm that emerged in the wake of the Industrial Revolution celebrates skills, behaviors, and attributes that are suited to the requirements of modern industry. As the scholar and writer Joseph Rost suggests, leadership in the industrial paradigm is understood to be "rational, management oriented, male, technocratic, quantitative, goal dominated, cost-benefit driven, personalistic, hierarchical, short term, pragmatic, and materialistic" (1991, 94). Seen from this perspective, leadership is synonymous with "good management." Also evident is the focus on the short-term economic success of the business enterprise, with little attention to the larger social and environmental costs of its activities. Such a view of leadership became prevalent when natural resources appeared to be limitless, human populations were relatively small, and economic development promised to lift the mass of humankind out of poverty and into a "better life." It reflects the optimism of the American Dream, in which autonomous individuals can succeed if only they work hard enough, and it is based on the assumption that technological control over nature is an unalloyed good that will solve any problem. The industrial paradigm of leadership was reinforced by authoritarian assumptions and hierarchical social structures underwritten by long-held beliefs that some individuals and/or social strata were naturally fit to rule over the rest. Thomas Carlyle's (1795–1881) "great man" theory of history expressed this mindset, as did the emphasis on identifying inborn leadership traits, which dominated the study of leadership during the first half of the twentieth century.

The industrial leadership paradigm remains common today in the business literature on leadership, which celebrates CEOs as "corporate saviors" and employs leadership as a motivational tool to enhance employee productivity and corporate profits. It is reinforced by the pressure put on business leaders to achieve short-term profitability at the expense of all else, and by the hierarchical nature of the modern corporation, in which CEOs and boards of directors can enact fundamental changes to corporate enterprises by fiat.

The scholar and writer Gayle Avery characterizes this as an unsustainable "Anglo/U.S. shareholder value" model of leadership, in contrast to a more sustainable "Rhineland stakeholder approach." In the latter model, which is more common among continental European enterprises, leadership is more dispersed and less focused on top individuals in the corporate hierarchy, takes a longer-term view, and is more cognizant and concerned about the social and environmental impacts of its operations. It places less emphasis on maximizing short-term shareholder value and more emphasis on meeting the requirements of a wider array of stakeholders, including employees, local communities, and the natural environment. Avery suggests that "an increasing demand for sustainable leadership is driving business—willingly or unwillingly—toward leadership principles reflected in the European model" (2005, xiv).

Nevertheless, the industrial leadership paradigm remains entrenched in business as well as in the field of leadership studies. Under this model, movement toward sustainability can occur if visionary individuals in leadership positions make it a priority and are skilled at engaging followers to adopt a sustainable mindset and behaviors. Jim MacNeill, chair emeritus of the International Institute for Sustainable Development, forcefully states this perspective: "Institutionalizing sustainable development . . . will not happen, certainly not in any significant way, if the person at the top is not determined to make it happen" (MacNeill 2007, 21). Similarly, the writer Thomas Friedman argues that in an increasingly "hot, flat, and crowded" world, it is essential that leaders—from the highest levels of government and business on down to the local level—make sustainability a priority, and that the United States of America must take a global leadership role in this endeavor: "Right now, we don't have the focus and persistence to take on something really big, where the benefits play out over the long term. But I believe all that could change with the right leadership—local, state, and federal—properly framing how much we have to gain by rising to this moment and how much we have to lose by failing to do so" (Friedman 2008, 7).

Such calls acknowledge the embedded nature of power and hierarchical relationships in modern Western societies and the fact that change will not happen without the support of those who have their hands on the levers of authority. They also acknowledge the widely shared assumption among students of leadership that hierarchy and power are endemic to human (and other primate) populations and that, consequently, leadership will always entail some degree of positional power and the elevation of certain individuals into pre-eminent social roles. A unifying theme of a 1994 special issue of *Leadership Quarterly* devoted to environmental leadership was "the importance attributed to leaders' values and beliefs to initiate and implement fundamental changes in modern organizations and society" (Egri and Frost 1994, 196). Swift and massive political, social, and economic changes have typically occurred in the past under the influence of paramount leaders with considerable power, and thus it is likely that future advances toward sustainability will occur at least in part due to the efforts of top private and public sector leaders.

The Eco-Leadership Paradigm

Whether or not authoritarian forms of leadership can in themselves produce truly sustainable societies is another question, however, since they reflect mechanistic models of leadership more applicable to factories and pliable subordinates than to complex ecosystems and autonomous human beings living in postindustrial societies. Thus in contrast to the industrial paradigm of leadership, a new "eco-leadership paradigm" is beginning to emerge among students and practitioners of leadership. The writer Simon Western goes so far as to suggest that "the next [leadership] discourse will be that of the eco-leader" (2008, 184). Under this model, systems thinking and "systems intelligence"—a term coined by Peter Senge in 2006—govern leadership behaviors, which are more dispersed throughout organizations rather than residing in a single individual, and as such enable organizations to better adapt to changing environmental conditions.

The eco-leadership paradigm employs ecological models and metaphors to conceptualize leadership on the assumption that such models are better at taking into account the complexities of modern organizations and their relationship with the larger contexts and systems (including ecosystems) of which they are a part. It stresses holism (wholes are greater than the sum of their parts), connectivity (everything is connected to everything else), and interdependence (everything is dependent upon everything else), and it assumes that achieving long-term sustainability will involve mimicking and adapting to the natural world and natural processes rather than triumphing over them. Leadership in this paradigm includes fostering networks of collaboration within and between organizations and social sectors, and building feedback loops into organizations that can help them learn and adapt to changes in the various external systems (including the biosphere) of which they are a part.

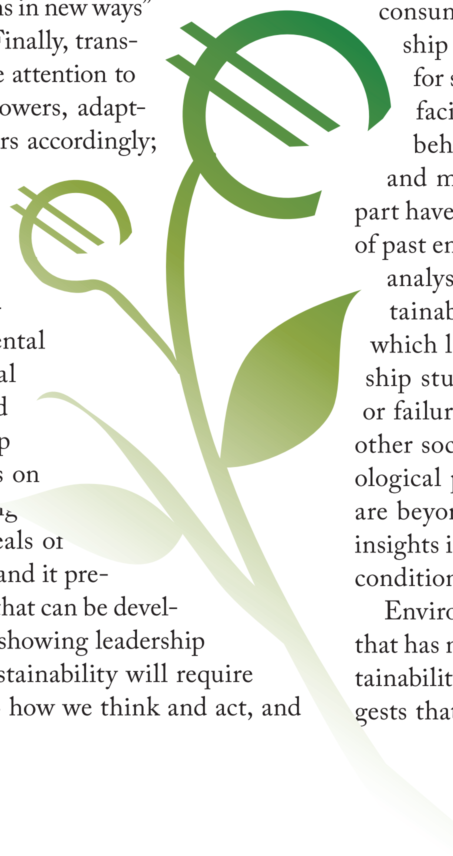
If earlier leadership researchers looked to primate communities as evidence for the "naturalness" of leadership, thinkers working in the eco-leader paradigm take organic and evolutionary processes as "natural" touchstones for conceptualizing leadership. In this model, leadership involves facilitating the operation of autonomous systems more than controlling them from above. It seeks to serve the greatest possible number of stakeholders in any one process or system, based on the recognition that failures in any of the parts can cause failures in the whole system. In this paradigm, centralized planning is replaced with empowerment of local leaders to make changes as needed at the periphery. Paramount leaders in this paradigm must look for "patterns of interdependency" and should be capable of "seeing into the future" (Senge 2006, 40). That is, they must keep an eye on the organization as a complex living being that must be kept in right relationship with its surroundings in order to thrive, and to be cognizant of larger systemic changes on the horizon. To use a nautical metaphor, such a leader is more of a lookout who surveys the functioning of the ship and the wider horizon from above the deck, calling out signals as needed, than an imperious captain who stands on the bridge (or sits in the cabin) barking orders to the crew.

The emerging eco-leader paradigm is not only a response to the growing ecological crisis but to deep and ongoing social and economic changes as well. The notion of a rising "postindustrial society" has become increasingly prevalent since the 1970s and signifies the broad shift away from heavy industry and manufacturing and toward the provision of goods and services and the rise of information technologies and the "knowledge economy." This shift has occurred at the same time as populations and pollution levels have dramatically increased, and as natural resources and nonhuman biotic communities have been forced into severe decline. Democratization and anti-authoritarianism have simultaneously been on the rise (with important exceptions) around the world, along with increasing emphasis on individual rights and the values of equality and diversity. Thus just as modern industry gave rise to an "industrial paradigm" of leadership, postindustrial society is giving rise to a postindustrial model. In each case, a concatenation of factors has combined to produce a vision of leadership deemed appropriate to its time and place.

Transformational Leadership

An influential leadership model that is applicable to leadership for sustainability is transformational leadership. Originally proposed in 1978 by James MacGregor Burns as "transforming" leadership, the model has been subsequently revised and expanded by Bernard Bass since the 1980s and has become one of the more well-researched theories in the field of leadership studies. Much evidence has been marshaled that demonstrates its effectiveness in fostering deep changes in organizations and societies and increasing follower satisfaction. As originally stated by Burns, transforming leaders engage in a teaching role, uniting followers in the pursuit of higher goals that reflect the common interests of leaders and followers and end values like liberty, justice, and equality. Transforming leaders raise their followers to higher levels of morality, and "the test of their leadership function is their contribution to change, measured by purpose drawn from collective motives and values" (Burns 1978, 426).

Building on Burns's theory, Bass and Ronald Riggio distinguish four components of transformational leadership: idealized influence, inspirational motivation, intellectual stimulation, and individualized consideration. In the first instance, transformational leaders serve as admired and respected role models. Secondly, they "behave in ways that motivate and inspire those around them by providing meaning and challenge to their followers' work" (Bass and Riggio 2006, 6). Thirdly, transformational leaders stimulate followers to think and act in new and creative ways "by questioning assumptions, reframing problems, and approaching old situations in new ways" (Bass and Riggio 2006, 7). Finally, transformational leaders pay close attention to the individual needs of followers, adapting their leadership behaviors accordingly; as such, transformational leaders act as mentors or coaches.



Given that the survival and flourishing of all living creatures is a fundamental end value, transformational leadership is a powerful and proven form of leadership for sustainability. It focuses on enacting fundamental change that engage the highest ideals of both leaders and followers, and it prescribes particular behaviors that can be developed by those interested in showing leadership on this issue. Achieving sustainability will require deep and lasting changes to how we think and act, and transformational leadership is in essence a theory of how leaders can help bring about such changes. Burns's model of transforming leadership is aimed more at broad social and political change, while Bass's adumbration of the theory makes it more applicable to particular organizations (including businesses). As such, the model is applicable to a wide range of settings in which sustainability is a goal.

Other Perspectives

Given the fact that achieving sustainability will require far-reaching social, cultural, psychological, economic, technological, and even spiritual changes in the fabric of our lives, there is ample room for a variety of approaches to leadership for sustainability. Recent research on this topic, including perspectives from the fields of history, sociology, religious studies / spirituality, business, literature, communication, psychology, political science, and the arts, will be published in the forthcoming volume *Leadership for Environmental Sustainability*, by Benjamin Redekop and Steven Olson (2010). Research on the narrative aspects of leadership suggests, for example, that leaders interested in sustainability are well advised to develop their storytelling abilities, since stories are one of the most powerful and engaging forms of human communication. We must imagine a sustainable future as a precondition for acting on it, and it is through stories that leaders can help constituents envision the way things can be.

Others argue that moving toward sustainability will require a spiritual transformation from materialism and consumerism to a more profoundly spiritual relationship with each other and the biosphere. Leadership for sustainability from this perspective involves the facilitation of spiritualities that help to transform behaviors in ways that are both more sustainable and more spiritually satisfying. Historians for their part have much to tell us about the successes and failures of past environmental leaders, while sociologists provide analyses of the social forces that impede or foster sustainable behaviors and the social constraints under which leaders operate. One of the bugbears of leadership studies is "attribution error," in which successes or failures are wrongly attributed to leaders instead of other social, economic, and contextual factors. A sociological perspective helps to clarify social factors that are beyond the control of leaders while also providing insights into the ways that leaders can help set the social conditions for sustainability.

Environmental psychology is a growing field of study that has much to offer those interested in leading for sustainability. For example, self-determination theory suggests that internal motivation is one of the best ways to promote pro-environmental behaviors, in part because it results in a cascading effect in which such behaviors are willingly spread to others. Autonomy supportive requests—in which leaders acknowledge the perspective of followers, allow choices (where possible) in how such requests will be fulfilled, and provide a rationale for such requests—are more likely to be effective than more coercive measures. Research has likewise shown that if fear appeals are to be effective, they must be accompanied by expressions of hope and a sense of how constituents can productively respond to the problem. Researchers have identified a personality variable termed "consideration of future consequences" (CFC) that predicts pro-environmental behaviors; they also have provided evidence that populations differ according to their willingness to cooperate in solving social dilemmas. According to this research, about 20 percent of the population are "cooperators," about 60 percent are "individualists," and 20 percent are "competitors." Cooperators and individualists can be convinced to engage in sustainable behaviors, whereas competitors may never willingly cooperate since they measure success in terms of gaining an advantage over others. Much work remains to be done to refine such data and incorporate it into our understanding of leadership for sustainability (Joireman 2005; Osbaldiston and Sheldon 2002).

Outlook for Sustainable Business Leadership

Many business leaders have begun to make their influence felt on this issue. Scholars suggest that—in addition to leaders themselves modeling sustainable behaviors—successful business leadership for sustainability requires embedding sustainable perspectives, processes, and behaviors into every level of an organization. An important first step is the formulation of a corporate vision and mission statement that reflects deep-seated concern for the natural environment and sustainability. Also crucial are the creation of education initiatives that provide employees with the skills and resources to act on the organizational vision, and the formulation of a strong business case for environmental responsibility. Significant savings can result from increased efficiencies, and forward-looking business leaders devote such savings to further measures aimed at achieving sustainability. Among the many business leaders that could be mentioned, Ray Anderson of Interface Inc. (the world's largest producer of commercial floor coverings and carpets) stands out as one of the most prominent and influential business leaders on this issue, and his book *Mid-Course Correction* has been widely recognized as one of the more compelling personal testaments written by a business leader on the topic of environmental sustainability.

An "environmental leadership model" (ELM), originally proposed in 1994 by the scholars Brenda Flannery and Douglas May, specifies four important antecedents to an organization's environmental strategy formulation process, including the existence of moral norms and values for environmental responsibility, the environmental attitudes of top organizational leaders, stakeholder influences, and the perceived degree of control over regulatory, financial, and technological constraints on pro-environmental behaviors. Such models help to conceptualize how businesses and other organizations chart a strategic path toward sustainability, and they highlight the fact that business leaders operate in a larger system that both encourages and constrains pro-environmental behaviors—that is, that leadership is a necessary but not sufficient condition for the achievement of environmental sustainability. They also help to convey the scale and complexity of the leadership task, and the need for both industrial and postindustrial forms of leadership to confront the multifaceted sustainability challenge. Leaders in business and other fields will need to draw from many disciplines and perspectives in order to effectively lead on this issue. Scholars of leadership, for their part, must move the study of environmental leadership beyond its current "fledgling stage" (Egri and Herman 2000, 599) if they wish to play a productive role in the increasingly urgent quest for sustainability.

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See also Corporate Citizenship; Education, Business; Education, Higher; Stakeholder Theory

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Lifecycle Assessments (LCAs)

Lifecycle assessment, together with lifecycle thinking and lifecycle management, are systems approaches for addressing the environmental consequences of an entire product chain, from resource extraction to waste management. Lifecycle assessments are used in business and policy making to promote sustainable consumption and production. They offer alternatives to point-source strategies, which only reduce pollution at its source.

Lifecycle assessment (LCA) is a method of analyzing the environmental impacts associated with a product or service. The method studies the material and energy flows throughout the product or service system, from raw materials extraction, through production and use, to disposal.

An LCA study is defined both by the product system it covers and the procedure used to study it. The procedure consists of several steps. Researchers start by developing the goal and scope definition, which specifies the product to be studied and the purpose of the LCA study. In the inventory analysis step, they construct the lifecycle model of the product system and calculate the amounts of emissions produced and the resources used in the product system, such as raw materials and energy. During the impact assessment step, the researchers relate emissions and resource use to potential environmental problems (e.g., resource depletion and global warming) by classifying and characterizing the environmental impacts. In the weighting step, they add up the different environmental impacts by applying factors that indicate their relative significance, and then they calculate the total environmental impact of the studied product system. The interpretation step is an iterative process of evaluating the modeling of the product system. During this step, the researchers adjust the methodological choices to suit the purpose and the stakeholders of the study and to evaluate the quality of the results. Some formalized definitions of LCA are found in publications such as the Society of Environmental Toxicology and Chemistry (SETAC) guidelines (Consoli et al. 1993) and the International Organization for Standardization standards on LCA (ISO 2006). A comprehensive description of the development, methodology, and the application of LCA appears in the textbook by professors Henrikke Baumann and Anne-Marie Tillman (2004) and in the operative guidelines to the ISO standard on LCA (Guinée 2002).

When the results are presented as the amount of emissions and resources used per functional unit, they are called an LCI, or lifecycle inventory, study. Usually LCIs identify a large number of pollutants and resources, sometimes more than two hundred parameters, making it difficult to summarize the results. Results can also be presented at different levels of aggregation: as inventory results that identify the gases and chemicals emitted during production; as characterization results that identify environmental impacts such as acidification, eutrophication, and global warming; or as results weighted together into a one-dimensional indicator, or one number that indicates the total environmental impact according to various methods. By grouping inventory results into impact categories, researchers can calculate the characterization results, leading to fewer parameters (Guineé 2002). It is possible to further aggregate results through various formalized weighting methods. Different weighting methods express different ways of prioritizing environmental problems. For example, priorities can set through political policies with environmental goals, recommendations by Delphi panels (experts who work together to forecast and revise results), or economic policies that encourage a "willingness to pay" to avoid environmental problems.

Methodologies

LCA is principally a methodology for comparing equivalent product systems, although a stand-alone LCA comparison is also possible. In a stand-alone LCA, researchers compare different parts of one product system. In all types of LCAs, they make a comparison by relating environmental impact to a unit that expresses the function of the product system. For example, beverage-packaging systems can be compared on the environmental impact per liter of packaged drink. The unit of comparison is called the functional unit, and its definition is essential for conducting a fair comparison. Other methodologies that influence the quality of a comparison include the system boundary definition (e.g., deciding whether to include in the system items such as the production of capital equipment), the types of environmental impacts being considered (e.g., aiming at a comprehensive evaluation of environmental impacts versus limiting the study to one or two impact categories), and the level of detail in the study (e.g., deciding whether to use site-specific data or average data over a number of production sites).

Different types of LCA are possible, depending on how the comparison is made. In quantitative LCA studies, researchers calculate the environmental impacts for the product systems, whereas in qualitative LCAs, they identify and evaluate the environmental impacts through reasoning supported by, for example, checklists. Another distinction concerns whether the comparison is prospective or retrospective. In a prospective study, researchers investigate the environmental consequences of the proposed changes to an existing product system. An example is a study of the significance of possible waste-management alternatives (e.g., recycling and incineration) to an existing packaging system. Prospective studies are also called change-oriented LCAs or consequential LCAs. In a retrospective LCA, often called an accounting LCA, researchers compare existing product systems. The comparison of ecolabeled products typically builds on an accounting LCA. (Ecolabeling is a voluntary program in which manufacturers and service providers certify the environmental performance of their products and services.)

The distinction between the change-oriented / consequential LCA and the accounting/retrospective LCA is a difference in focus: in one, the existing situation is compared to an alternative future situation (change-oriented / consequential LCA), and in the other, two existing alternatives are compared (perspective/accounting LCA). In addition, system boundary definition and data choices differ substantively between these two types of LCA study. Studying the consequences of change typically leads to a focus on modeling the parts of the system that are affected by change and to the use of marginal data. But comparing the existing products typically leads to a focus on how complete the model of the product systems is and to the use of average data.

Cradle to grave, *cradle to gate*, and *gate to gate* are other terms for LCA. They indicate the extent to which the product system is modeled in an LCA, from raw materials extraction to waste management, to the factory gate, or between factory gates, respectively.

LCA is also associated with the philosophy of lifecycle thinking (LCT) and the practices of lifecycle management (LCM). Expressions of lifecycle thinking can be found in, for example, corporate environmental policies. Lifecycle management is the managerial practices and organizational arrangements that result from lifecycle thinking. LCM's goal is to coordinate environmental concerns and work among actors within the product system, rather than develop independent measures in each company (cf. Remmen, Jensen, and Frydendal 2007).

History

The development of early LCA between 1969 and 1989 is distinct from its development afterward. Since 1990, systematic description and the development of the methodology has come to the fore, making it a subject of academic study. It was not until the early 1990s that the term *lifecycle assessment* came into general use—earlier studies were called ecobalances, resource and environmental profile analyses, or cradle-to-grave studies.

A study conducted in the United States for Coca-Cola by the Midwest Research Institute from 1969 to 1970 is generally considered the first LCA study. Early independent studies were also conducted both in the United Kingdom (for Schweppes by Ian Boustead) and in Sweden (for Tetra Pak by Gustav Sundström). All the early LCAs between 1969 and 1972 studied packaging and waste management. They coincided with the environmental debate concerning wasteful resource use and disposable packaging in throwaway societies (Meadows et al. 1972). What identifies these studies as LCAs is their simultaneous attention to material and energy flows, from raw materials extraction to the waste disposal of a product system and the pollution and resource use associated with it. This distinguishes them from the systems studies focusing on energy that became common after the oil crisis in 1973. Nevertheless, the oil crisis fueled interest in LCA, and a handful of consultants in the world carried out small-scale LCA studies.

Between 1970 and 1989, the consultants William Franklin and Robert Hunt conducted some two hundred studies in the United States, and consultant Gustav Sundström conducted about one hundred studies in Sweden, many of them for private companies. LCA resurfaced in the public debate with the surge of environmental interest during the mid-1980s, again in relation to packaging. In 1984, the Swiss environmental agency conducted a large packaging study (Bundesamt für Umweltschutz 1984) that was widely criticized. The study was updated five years later (Bundesamt für Umwelt, Wald und Landschaft 1989). Its criticism paradoxically increased attention toward the possibilities of LCA and inspired packaging studies in other European countries (e.g., in Denmark in 1990, in Sweden in 1991, and in the Netherlands in 1992). The many packaging studies showed diverging results and partly differing methodologies, starting a new era of methodological discussion and development.

The increased interest in LCA can be explained by industry's shift in focus toward environmental work. Since the early 1990s, manufacturers have increasingly supported the idea that environmental protection should go beyond "end-of-pipes" strategies that deal with pollution after it happens. Many of those in industry see the environmental optimization (identifying where reductions like waste minimization and material substitution can be most efficient) of products as an effective path toward sustainability. LCA's appeal is that it deals with environmental issues in a systematic and comprehensive way, handling several environmental problems at a time and extending the environmental analysis beyond controlling emissions at their point source. In doing so, LCA helps avoid suboptimization, or settling for a lesser outcome, in the environmental management of industrial systems.

Guidelines, Standards, and Developments

The Society of Environmental Toxicology and Chemistry (SETAC) provides a forum for discussing LCA experiences and developing an international consensus on a "harmonized LCA methodology" (Consoli et al. 1993). After sponsoring seven international workshops and conferences between 1990 and 1993, it published the first international guidelines in its code of practice (Consoli et al. 1993). It also established a number of working groups to speed up the process of developing a standardized methodology. The first international standard for LCA, providing its main principles and framework, was issued in 1997 by the International Organization for Standardization. Since then a series of LCA standards have been issued and updated. Other organized efforts to promote LCA take place, for example, through the Life Cycle Initiative, a collaboration between the United Nations Environment Programme (UNEP) and SETAC. This initiative's goals include disseminating widely accepted methods for the reliable and easy use of LCAs, first to developing countries and later more widely (Life Cycle Initiative n.d.). The European Commission also supports the dissemination of LCA through policy and business practices (European Commission—Joint Research Centre 2009).

The core of LCA—flow modeling—has remained much the same since the beginning, while impact assessment methodologies saw the most advances during the 1990s. Since 2000, methods have been developed that include the social aspects in lifecycle impact assessment and the economic cost-benefit analysis along the product chain. These developments better align LCA with the discourse of sustainable development and make LCA more attractive to the business community. But much work remains before such methods become common practice. Much work also went into the development of software, databases, and standardized formats for data exchange: simple data management is crucial to facilitating calculation and data availability since any LCA study requires much data. The exploration of alternative data sources, such as economic input-output tables, led to new types of LCA: IO-LCA (input-output LCA) (Hendrickson, Lave, and Matthews 2006) and hybrid LCA, which combines standard LCA with IO-LCA (Suh et al. 2004). These methods enable researchers to conduct new types of studies (cf. Tukker and Jansen 2006) that explore the consumption activities that have the most-polluting product flows in society (typically transportation, housing, and food). Since these studies include the impacts of production that is outsourced to developing countries, they contribute to the debate on the role of consumption and global industry in sustainability (cf. Hertwich 2005).

A scholarly journal for developments in the field of LCA, *The International Journal of Life Cycle Assessment*, began publishing in 1996. The first conference on lifecycle management was held in 2001, and the European network on IO-LCA also held it first meeting in 2001. In short, research related to LCA, LCT, and LCM is mainly prescriptive, dealing with methodology development. Consequently research exploring the practices of LCA and LCM is less common.

Applications

LCA and LCT attract interest both in business and policy making. Policy makers use LCA in studies to guide policy development away from point-source control and into product-oriented policy making. For example, the packaging studies that were discussed above in the history section were often used to identify which materials should have recycling policies. LCT gave rise to the notion of extended producer responsibility, in which a consortium of companies is responsible for the environmental costs of their products through the end of the products' lifecycles. The result is producer take-back policies that require the manufacturer to pay for the collection, disposal, and recycling of their products. Other lifecycle-influenced policies include ecolabeling, which was discussed along with methodology. The application of LCT to policy making is, however, a challenge: the global nature of business spreads material and energy flows outside the reach of governmental policy makers.

Since the 1990s, LCA has been applied to nearly all sectors of business and society. In the transportation sector, LCA studies are often called well-to-wheel studies. LCA's focus on products has made it particularly applicable to product development and ecodesign as well as ecolabeling. The prescriptive use of LCT in the sustainable design of products and services, for example, appears in cradle-to-cradle design model (McDonough and Braungart 2002). LCA-based ecolabeling schemes have been put forward both by governmental organizations (as in the European Union's "Flower" ecolabel) and by industrial coalitions (as in the International EPD Consortium's Environmental Product Declaration scheme). LCA has also been applied to "greening" the control methods of manufacturing and production systems. Upstream application areas, which occur in the manufacturing and production stages, include greening supply-chain management and procurement. Downstream application areas, which occur around the sale of the product, include waste and recycling management. Several LCA tools are specially adapted to the requirements of the various fields of application.

Despite its widespread use and application, LCA's use in business is relatively limited. Surveys on businesses' adoption of LCA are rare. In 2002, almost 10 percent of the largest corporations in Europe worked with LCA in some way. Compare this with the percentage of corporations that adopted environmental management systems: almost two-thirds in the same survey (Hibbitt and Kamp-Roelands 2002). One reason for this difference is that LCA reaches outside a company's normal boundaries of responsibility. This makes LCA irrelevant or overambitious in the eyes of some; alternatively, others believe it offers a novel and useful perspective on business operations. Most LCA studies done for companies are conducted by consultants or through collaborations with research institutes, sector organizations, or academia. In companies where the LCA process has been internalized, it is typically an experimental activity performed by the environmental or research and development department (cf. Frankl and Rubik 2000; Rex and Baumann 2007). Analysis shows that LCA studies often lead to organizational learning, a new and widened perspective on business operations, and, often, surprising insights. In just one such example, people in a paper mill were about to reduce their point-source emissions by investing in more state-of-the-art, end-of-pipe technology, but they realized through an LCA that they could save money and reduce their emissions tenfold through simple changes in the logistics from forest to mill (Baumann and Tillman 2004).

Little is known about the business rationales for LCA since proponents inside the company drive much of the LCA work. But studies show that, in companies where LCA practices are institutionalized, risk aversion or trust-building with actors in the supply chain are the business rationales for LCA (Rex and Baumann 2007). In these companies, specially adapted LCA tools and considerations were implemented in the business process, for example, in product development or procurement. The same studies also show that LCA practices differ greatly among businesses, even between similar, same-sector companies. For example, LCA practices in product development in European truck companies range from using simple LCA-based guidelines to combining extensive LCA studies with strategic planning.

Implications

There are many controversies over LCA methodology. Concerns about the inappropriate use of LCAs in the United States led a coalition of state attorneys general to decide that "the results of LCAs should not be used to advertise or promote specific products until uniform methods . . . are developed" (ENDS 1991). Such concerns are strong reasons for standardization efforts. Because LCA is quantitative and describes physical flows with scientific methods, it is often thought of as an objective method that produces general scientific results. But this is far from the case. Many methodological choices depend on the purpose and the type of LCA. Methodological alternatives are also a matter of choice. Eventually gaps and unresolved ambiguities develop in the methodology. Together, these issues lead to the possibility that similar LCA studies would have divergent results. Such results pose special problems for the ISO standard on LCA, since it aims to be a comprehensive standard for all types of LCA.

Debate is particularly intense and enduring over two issues: how to allocate environmental loads across several products, and how to conduct impact assessment. Since LCA focuses on a single product at a time, the material flows of different products being connected to each other can complicate the inventory analysis. Whenever more than one product is produced in a process, an allocation problem occurs in the LCA. It also arises when many products are collectively treated in the same waste-treatment process and when a product's material is recycled into another product. The allocation problem concerns how the environmental loads of a process are divided among the process's different products. Several methods exist for dealing with this, including applying various principles to partition the environmental loads onto the products based on physical relationship, weight, volume, or economic value. Another approach is system expansion, which includes the parts of the surrounding industrial system that are affected by changes related to the object of study. Some people argue for strict recommendations for partitioning the environmental loads, and some argue for more-open recommendations that allow researchers to choose the method depending on the purpose of the study. The ISO standard is contradictory because it acknowledges both the need to choose the method based on the goal and prescribes an allocation procedure that ignores the goal-dependant method.

Many debates about impact assessment concern what counts as an environmental impact and where to model the impact in the cause-effect chain between emissions and their effects. Methodology is being developed to cover additional types of impacts, including some social and economic impacts. Some impacts are difficult to describe; for example, the effects of eco-toxicity and land use on biodiversity result in LCA studies that emphasize easily modeled impacts. Some researchers debate whether to describe impacts through end-point or midpoint assessment, that is, whether the methodology should describe real or potential impacts. The significance is that real impacts depend on the location of the impact, which adds geographical complexities to modeling. As a result, several impact assessment methods exist. Many of these methods conflict with work on potential impacts, thereby rendering them generally applicable but inaccurate.

The time and resources it takes to carry out an LCA study have always been a contentious issue, and many claim that the costs of performing the lifecycle inventory are too high. Efforts to simplify the execution of LCA studies take various paths. One path develops screening and streamlining methodologies that drastically reduce the amount of data needed. An alternative path increases the availability of data by setting up and maintaining databases for researchers to use.

Research activities also reflect different perspectives on how to further the use of LCA. The dominant approach intended to resolve the methodological problems in LCA, and it led to many prescriptive, relatively realistic recommendations concerning LCA's application. A small but growing body of knowledge aims to develop an understanding of practices related to LCA, LCT, and LCM in business and policy making. This more descriptive research indicates that many of the prescriptive recommendations for LCA application are too general to fit a diverse business community.

Many find LCA complicated and time consuming, but this is more a case of LCA reflecting the complexities of our world. LCA offers a systematic way to describe the environmental consequences of production and consumption in a comprehensive way that enables communication about large, complex environmental issues. LCA development has mostly taken place in the engineering community, but cross-disciplinary integration with the social, economic, and management sciences is increasing. Such integration can modify the technical LCA approach to be more useful for business and other actors in society.

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See also Biomimicry; Cradle to Cradle; Design, Industrial; Ecolabeling; Energy Efficiency; Integrated Product Development (IPD); Manufacturing Practices; Natural Step Framework, The (TNSF); Product-Service Systems (PSSs); Remanufacturing; Zero Waste

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Local Living Economies

Essential building blocks of a socially, environmentally, and financially stable global economy, local living economies are rooted in smaller, more accountable local businesses instead of transnational conglomerates and superstores. Locally owned, independent businesses enable communities to prosper through higher economic multipliers, greater self-reliance, and stronger labor, ecological, and social standards.

The nonprofit organization Business Alliance for Local Living Economies (BALLE), formed in late 2001, popularized the term *local living economies*. BALLE is currently the leading organizer of local business alliances in North America, with more than sixty official networks in existence (as of early 2009) and dozens of others in formation. In the words of the BALLE (n.d.) mission statement, a local living economy "ensures that economic power resides locally, sustaining healthy community life and natural life as well as long-term economic viability."

Contours

The term *local living economy* emerged from two intellectual currents. The first was the writings of David Korten, a leading thinker about the challenges of globalization and author of numerous books, including the best-selling *When Corporations Rule the World* (1995). Korten believes we now depend on a "suicide economy," which is sowing the seeds of its own destruction through unsustainable economic growth, environmental disruption, inequality, social unrest, repression, militarism, and war. A core problem, he argues, is the emergence of powerful global corporations that are unaccountable to communities and ecosystems. He calls for an alternative "living economy" rooted in smaller, more accountable local businesses.

The second intellectual current concerns localism, expounded in such early works as E. F. Schumacher's *Small Is Beautiful* (1973) and Jane Jacobs's *Cities and the Wealth of Nations* (1985). The writings of Michael Shuman, including *Going Local* (1998) and *The Small-Mart Revolution* (2006), make the case that local ownership of business and community self-reliance are key requirements of prosperous local economies. Local ownership means that majority control of a company exists in close geographic proximity to its operations. Examples of locally owned businesses include small family-owned companies, nonprofits, cooperatives, and municipally owned utilities. National or global companies, such as chain retailers or multifactory producers, are usually not regarded as local, and consequently the term *independent* is often paired with local.

Local businesses are usually synonymous with small but not always. Zingerman's in Ann Arbor, Michigan, started as a small delicatessen, but has since grown into more than a half-dozen sister businesses employing more than 500 people. It is regarded as one of the premiere examples of a local living economy business.

Mission

Underlying the concept of local living economies are three major goals: local ownership of business, community self-reliance, and high social performance.

Local Ownership

Local ownership of business matters for community prosperity. One key reason is that locally owned businesses spend more of their revenue locally than do nonlocal businesses. This contributes to the economic multiplier, the benefits that flow from a dollar circulating many times in a community. In 2002, the economic consulting firm Civic Economics analyzed the relative impact of a proposed non-local Borders bookstore in Austin, Texas, as compared to two local bookstores the chain was gunning to put out of business. The researchers found that one hundred dollars spent at Borders would circulate thirteen dollars in the Austin economy, while the same one hundred dollars spent at either of the two local bookstores would circulate forty-five dollars (Civic Economics 2002, 14). Roughly speaking, the study suggested that every dollar spent at the local store contributed three times the jobs to the local economy, three times the boost to income, and three times the tax benefits (Civic Economics 2002, 4).

Subsequent work has confirmed these results. In 2004, Civic Economics improved its methodology by expanding research to include analysis for additional business types and completed another study of Andersonville, a neighborhood in Chicago (Civic Economics 2004, 2 and 8). The principal finding was that a dollar spent at a local restaurant generated 25 percent more economic multiplier than a chain. The local advantage was 63 percent more for local retail, and 90 percent more for local services. In 2007, Civic Economics did its most in-depth study yet, encompassing the city of San Francisco and neighboring communities of South San Francisco, Colma, and Daly City. Looking at books, toys, sporting goods, and fast food, the researchers found that if San Franciscans shifted just ten cents of every dollar of their spending from chain stores to local retailers, they could add nearly 1,300 more jobs and $200 million more in annual output to the city's economy (Civic Economics and San Francisco Locally Owned Merchants Alliance 2007, 27).

An economy made up largely of locally owned businesses confers other advantages on community economies as well. While the exit of absentee-owned businesses moving to Mexico or China may throw the community into an economic tailspin, businesses anchored locally through ownership stay and produce wealth for many years, often many generations. Because local businesses tend to stay put, a community with primarily local businesses can raise labor and environmental standards with confidence that its businesses will adapt rather than flee. The stability of local businesses also tends to contribute to greater social stability and higher levels of political participation. And the small-scale, unique, and dynamic features of local businesses make them better equipped to promote smart growth, draw tourists, attract talented young people, and seed a self-reinforcing entrepreneurial culture.

The broad, popular perception that all local businesses are inefficient, mom-and-pop retailers is incorrect. All retail stores, in fact, make up only 7 percent of the entire economy, and small businesses in all sectors (under the definition of the U.S. Small Business Administration) constitute roughly half the entire private sector. Small businesses—those with less than 500 employees—moreover, produced almost twice as many new jobs between 1993 and 2008 and thirteen times as many patents per employee as large businesses (SBA 2009).

More serious doubt about local businesses concerns competitiveness. Are we not in an era when bigger businesses can better achieve economies of scale? In fact, in all but seven of the thousand-plus sectors of the roughly 1,100 industrial categories of the North American Industrial Classification System (NAICS), there are more examples of competitive small-scale enterprise in each sector than large-scale enterprise. Put another way, the U.S. economy is full of models of small-scale success that could guide entrepreneurial activities in even very small communities.

Mindful of all these advantages and opportunities, advocates of a local living economy seek to maximize the number and competitiveness of local enterprises, and to increase their relative presence in a community economy.

Community Self-Reliance

A second feature of a local living economy is a higher degree of economic self-reliance, effected through a strategy known as import substitution. *Degree* is an important qualifier here, since few advocates envision or desire a community withdrawing from the national or global economy altogether into a state of autarky. But increasing the relative percentage of the economy focused on local markets is important for several reasons.

Every time a community imports a good or service that it might have cost-effectively produced for itself, it "leaks" dollars and loses critically important multipliers associated with them; this is known as import leakage. Unnecessary imports—of petroleum, for example—also subject a community to risks of major price hikes and disruptions outside local control. They deny a community a diversified base of businesses and skills needed to take advantage of unknown (and unknowable) future opportunities in the global economy. And unnecessary dependence on outside shipments of food or other easy-to-produce goods increases the burdens that distribution systems—transportation, packaging, refrigeration, middle people, and advertisers—impose on the environment, especially with each step consuming energy and releasing climate-disrupting carbon dioxide into the atmosphere.

Some economists disparage import substitution, pointing out that such policies in Latin America in the 1960s and 1970s tended to mean higher tariff and nontariff trade barriers that increased domestic prices, choked foreign technology and investment, and generally stifled economic development. But import substitution can also mean educating consumers (citizen, business, and governmental purchasers) about cost-effective local buying opportunities and encouraging them to take advantage of these. So reconceived as demand driven rather than trade restrictive, import substitution actually turns out to the most effective way to develop export-oriented businesses, as Jane Jacobs long argued.

Jacobs's argument was essentially this: suppose North Dakota wished to replace imports of electricity with local wind-electricity generators. Once it built windmills, it would be self-reliant on electricity but dependent on outside supplies of windmills. If it set up its own windmill industry, it would then become dependent on outside supplies of machine parts and metal. This process of substitution never ends, but it does leave North Dakota with several new, strong industries—in electricity, windmills, machines parts, and metal fabrication—that are poised to meet not only local needs but also export opportunities.

The strongest local economy, in theory, will be one in which its businesses saturate local markets and maximize global markets. To local living economy advocates, a mistake of mainstream economic development has been to focus on global markets and expect trickle-down benefit to local businesses. A growing body of evidence suggests that the causality works in the opposite direction. Instead of putting all of the community's eggs in one export-oriented basket, a community should develop myriad small businesses, grounded (initially at least) in local markets, with confidence that many will naturally graduate into exporters. Ultimately, having a local economy with multiple points of connection with the global economy, rather than just one "comparative advantage," provides better insurance against the natural ups and downs of global markets.

Social Performance

A final goal for local living economies is to increase performance of local businesses in noneconomic areas. These goals are expressed in terms like *social responsibility*, *the three E's* (efficiency, equity, environment), and *the triple bottom line* (profit, people, planet). In fact, there are far more than three dimensions to social performance when all the stakeholders of a business are considered: workers, suppliers, consumers, contractors, owners (passive and active), plant neighbors, local charities, and so forth.

The local living economy movement seeks to find exemplary companies with respect to each stakeholder and spread these models of success to other companies and communities. The Sustainable Business Network, the BALLE affiliate in Philadelphia, Pennsylvania, is trying to improve the social performance of each sector of the local economy through exemplary "building block" organizations in food, energy, finance, clothing, housing, and so forth.

While advocates of local living economies believe there is much local businesses can learn from the performance of exemplary nonlocal businesses, like the Ben & Jerry's and the Benettons of the world, they also believe that kinder, gentler, friendlier, and greener nonlocal businesses can only go so far in reforming themselves before the brutal logic of globalization undoes their progress. How much credit do you get if you give your workers better wages and health care benefits this year but shut down the plant the next? Or if you reduce your energy use, like Walmart, while encouraging millions of purchasers to skip nearby downtown stores and drive literally billions of additional miles per year to the supercenters? At the end of the day, argue local living economy activists, any business that sacrifices its bottom line in the name of responsibility leaves itself vulnerable to a hostile acquisition by another global firm that has the mettle to make such "hard choices." That's what happened to the organic yogurt maker Stonyfield Farms, which was acquired by the Danone Group and has since become a major supplier to Walmart, the bête noire of localization advocates. These dynamics underscore the rationale for believing that social responsibility must include local ownership.

Implementation

One cornerstone of the local living economy movement is to end what are regarded as counterproductive practices by most economic developers. The conventional paradigm today is that a locale should attract and retain globe-trotting companies that expand clusters of existing business and allow a community to achieve one or two global comparative advantages. While economic developers often praise local business, the majority of their spending—some believe well over 90 percent—aims to attract or retain nonlocal businesses through public "incentives." The best estimate of the annual cost of these subsidies by state and local governments is $50 billion per year, and federal agencies contribute at least as much. A growing body of evidence suggests that this kind of economic development is ineffectual at best and a huge waste of local resources and opportunities at worst.

Advocates of local living economies seek to focus scarce public and private money on a series of initiatives that tend to be minimized or ignored altogether by economic developers. There are several key questions currently receiving scant attention:

- Local Planning—Where are significant import leaks in the local economy that could be plugged with new or expanded local enterprises?

- Local Entrepreneurship—How can a new generation of entrepreneurs be nurtured and trained to lead local firms?
- Local Business Organizing—How can existing local businesses work together (through, for example, purchasing cooperatives) to improve their competitiveness?
- Local Investing—How can local savings, whether currently in banks or pension funds, be redirected to support new or expanded local businesses?
- Local Purchasing—How can local businesses achieve greater success through "Local First" purchasing by consumers, businesses, and government agencies?
- Local Public Policy Making—How can the myriad biases that exist against local businesses, such as security laws that have all but made it impossibly expensive for "unaccredited investors" (98 percent of the U.S. public) to invest in local businesses, be overhauled so that they can compete on a level playing field against nonlocal businesses?

These questions have unleashed a new generation of economic development initiatives in the sixty communities in which BALLE is active—and in many more. These programs include leakage studies, local business incubators, farm-to-school collaborations, local stock markets, and business-to-business purchasing networks.

Overall the local living economy movement remains relatively new and small, but there is scarcely a community where its influence cannot be seen in signs that read Local Bank, Local Food, and Local Crafts. In March 2007, the cover of *Time* proclaimed, "Forget Organic, Eat Local." Many economic trends, such as the rising price of oil and the shift of family spending from global goods to local services, almost guarantee that this movement will grow in the foreseeable future.

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See also Agriculture; Community Capital; Corporate Citizenship; CSR and CSR 2.0; Fast Food Industry; Investment, Socially Responsible (SRI); Municipalities; Smart Growth; Triple Bottom Line; True Cost Economics

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M

Manufacturing Practices

Since the 1980s, some of the manufacturing industry has adopted practices that emphasize sustainable manufacturing, and integral to this concept is a decrease in or elimination of waste. Reducing energy and water use is often the first step, but sustainable manufacturing also involves standards and performance frameworks. Sustainable manufacturing must address social and economic sustainability in addition to the environment.

Sustainable manufacturing practices are mainly based on the concept of resource productivity, which promotes increasing the efficiency of resources to reduce waste. These practices seek to create goods while using fewer resources (energy, water, and materials); because of these practices, the materials used in the supply chain should have low embedded energy and water (energy and water used in the chain to prepare the material). These practices favor renewable energy and materials with recycled content. Companies are modifying manufacturing practices to lower the volume of wastes going to all environmental media (air, water, and land). While many companies have some waste reduction programs in place, the judicious use of resource productivity is increasingly important.

A number of independent events occurred in the late 1980s to trigger a directed movement that helped shape what we know as sustainable manufacturing practice. From these five events many companies developed separate sustainability methods; the combination or integration of these methods, however, is the heart of sustainable manufacturing.

In 1987 the U.S. Congress amended the Stevenson-Wydler Technology Innovation Act of 1980 to establish the Malcolm Baldrige National Quality Award, which promotes awareness and recognition of performance excellence. At the time, foreign competition challenged the country's manufacturing quality and costs, and for two decades U.S. manufacturing productivity growth had improved less than that of other countries. Congress believed poor quality was costing companies up to 20 percent of their sales revenues and that improved quality of manufactured goods and services would be accompanied by improved productivity, lower costs, and increased profitability. The award provides a process management category that calls out best practices for manufacturing processes. Sustainability and corporate social responsibility are specifically included in later versions of this important business-excellence guide.

The World Commission on Environment and Development published its findings in the 1987 book *Our Common Future*. This book is widely referenced as the source of the original definition of sustainable development—a marriage of economy and ecology—that encourages governments and their people to take responsibility for environmental damage and the policies causing that damage. The United Nations established the commission in 1983 to reexamine the critical environmental and development problems that were being recognized all over the world. The U.N. sought realistic proposals to solve these problems and to ensure that human progress would be sustained through development, without bankrupting the resources of future generations. Companies that have been practicing sustainability pay particular attention to the term *eco-efficiency*. It is the forerunner of the term *resource productivity* described above.

Also in 1987, the International Organization for Standardization issued a three-part quality management system (ISO 9000) for manufacturing companies:

1. The model for quality assurance in design, development, production, installation, and servicing applies to companies whose activities include the creation of new products.

2. The model for quality assurance in production, installation, and servicing is basically the same as number 1 but does not cover the creation of new products.
3. The model for quality assurance in final inspection and testing covers only the final inspection of finished products.

Even though the standard emphasizes conformance with procedures rather than the overall management process, it was an important step for manufacturing to better control processes. In 2000, the related ISO 9001 was changed to emphasize a process focus and a systems approach to management. It is a foundation for companies involved in making resource productivity part of a sustainable manufacturing practice.

The U.S. Environmental Protection Agency released a draft of the *Waste Minimization Opportunity Assessment Manual* in 1988. The manual derived from a set of manufacturing sector reports produced by the state of California. The manual discussed "source reduction" and examined both product and process change as a means for promoting the judicious use of resources, energy efficiency, reuse of input materials during production, and reduced energy and water consumption. Such changes would include these benefits:

- reduced risk of criminal and civil liability
- reduction of operating costs
- improved employee morale and participation
- enhancement of the company's image in the community
- protection of public health and the environment

The manual proposed a hierarchy of waste management that favored waste elimination over waste reuse and recycling. Waste treatment and disposal would be considered as a last resort. This was a major shift in thinking for the manufacturing industry.

Finally, people recognized the link between the growing interest in total quality management (TQM) and the interest in pollution prevention (Pojasek 1987). Quality management tools (e.g., root cause analysis, process mapping, brainwriting, bubble sorting, and action planning) could be used to involve employees and suppliers in systematically reducing or eliminating all wastes from all manufacturing processes. This was the birth of the "systems approach to process improvement." Widespread deployment of manufacturing methodologies such as Lean and the Six Sigma process improvement followed.

Different professionals in the industrial and environmental engineering communities used these efforts independently. Ultimately people would integrate performance frameworks with management systems and use process improvement to drive the continual upgrading necessary to achieve sustainable manufacturing practice.

When Is Sustainable Manufacturing Sustainable?

The term *sustainable manufacturing* means different things to different people. Many of these differences come from the discipline and bias of the manufacturing professional. People often are needlessly sidetracked by definitional disputes. Nevertheless, the achievement of sustainable manufacturing in any business is a journey, not a static state. Sustainable manufacturing is a key component of operating a sustainable business that creates value for its constituents. Manufacturing industry sectors are very interested in sustainable manufacturing, and the world has experienced a major shift in philosophy, acceptance, and emphasis on it since its humble beginnings.

Becoming sustainable often starts when a company adopts a formal program to drive resource productivity. Many companies use the ISO 9001:2008 standard as a foundation. They integrate elements of ISO 14001, risk management (draft ISO 31000), social responsibility (draft ISO 26000), and a business excellence framework (the Baldrige Performance Excellence Program). These integrated management systems help make sustainable manufacturing practices part of the companies' day-to-day operations. Products made in this manner can be certified to sustainable product standards issued by the American National Standards Institute (ANSI) and similar standard-setting bodies.

The manufacturing process then must operate in an eco-efficient manner. Companies analyze the direct and indirect use of all resources (energy, water, and materials) and the loss of resources from each activity in the manufacturing process. The indirect use and loss of resources comes from supporting processes and facility infrastructure (air compressors, air and water pollution control equipment, boilers, chillers, and heating ventilation and air conditioning). Companies use process mapping and resource accounting to ensure they follow what ISO 9000:20000 calls a process focus and a systems approach to management (Pojasek 2005).

An interest in sustainable manufacturing does not automatically translate into a commitment to change the product process. Many businesses worry about the cost and benefit of this path. Many manufacturing executives view this as a choice between being more environmentally responsible and allowing employees to keep their jobs. But such executives are slowly realizing that business opportunities that gain positive feedback from environmentally conscious customers can result in an increase in sales.

Reducing energy and water use are the most common and simplest places to start converting to a sustainable manufacturing process. Eliminating all waste from all business practices is an important midpoint goal. In the long term, the business can develop sustainable manufacturing technology and products that raise the sustainability level. Environmental and social responsibility in manufacturing includes both contributing to the company's sustainability and being able to manufacture supplies that will facilitate other sectors' ability to become sustainable. This involves lifecycle management, which is based on the interconnectedness of materials and processes.

Successfully transitioning to sustainable manufacturing requires a company to align its manufacturing program with its vision, mission, and core values (Pojasek 2007). The management support necessary for the business to complete the process can only be gained by fully integrating the sustainable manufacturing effort with the core business. Employees and stakeholders need to be involved in the program's planning and implementation. Employees are a key source of knowledge for the transition. Mutually beneficial relationships with suppliers, customers, and key stakeholders are also important.

Success usually depends on the integrated use of performance frameworks, management systems, and process improvement. Sustainable manufacturing uses these proven methods to meet customer and market needs, while providing eco-efficient processes and their benefits to the environment, key stakeholders, and the community. Sustainability comes from the value to the business's top line (branding) and the bottom line as it helps create a robust local economy. This may be the best argument to use when seeking senior management's support for sustainable manufacturing processes.

Innovative Practices

Vigilance and discipline lead to initial improvements in resource productivity. Employee involvement programs bring about many suggestions for using and losing fewer resources. Occasional innovations occur simply by altering machinery. For example, if an industrial laundry places its incoming city water pipe inside the wastewater discharge pipe, the heat from the discharged wastewater heats the incoming water. This lowers the amount of fuel the boiler needs to heat the wash water. To a low-tech company, this is innovation. (Later the company can invest in a more-efficient heat exchanger.)

The coatings area has seen many innovations. New and more effective technologies have improved the application of coatings and adhesives. Painting went from the spraying of liquid paints, which contain many volatile solvents, to the application of high solids paints, which have much fewer volatile organic solvents to carry the pigments onto the surface to be painted. The move to powder paints, which have no carrying agent at all and thus no volatile organics, followed.

Even something as mundane as cleaning mixing vessels has improved with spray-ball technology. Previously technicians cleaned a vessel by filling the tanks with cleaning solvent, turning on the mixer, draining the tank, and repeating the process. Now a "ball" with many small holes shoots a high-pressure spray through holes, using a fraction of the cleaning fluid. Other cleaning applications employ air knives—high-pressure air that blows material off a surface—before using a liquid to remove the remaining contaminants.

Some innovations follow a new approach called "servicizing," where a business or supplier refocuses from selling products to providing services. For example, carpet companies lease carpeting and service it instead of replacing it. Because of legislation in Europe, companies take back their products and reuse portions in new products. Recyclable and reusable toner cartridges are one example, and plastic housings from old cathode ray tube (CRT) computer monitors are converted into roofing shingles.

The design of a product and the design of its manufacturing process influence the use and loss of resources. Some companies require their design professionals to work on the plant floor to learn how to increase resource productivity with new products. Similarly, designers are beginning to use biomimicry to develop new products. Biomimicry seeks sustainable solutions by emulating nature's designs and processes. For example, the tubercles on a humpback whale's flippers, which allow it to move quickly in the water, inspired WhalePower Corporation's tubercle technology. Products using tubercle technology, such as wind turbines, fans, and compressors, are often at least 20 percent more energy efficient than conventional technology (WhalePower 2009).

Innovation does not happen by accident or good intentions. It can be sparked by the challenge of improving resource productivity after the easy solutions are taken. A sustainable manufacturing company can involve employees and suppliers in a culture that develops processes and methodologies and encourages innovations. The drive to increase resource productivity can create impassioned internal champions, or employees focused on making the program successful (compared with managers, who must juggle many responsibilities). By evangelizing innovative means for extending resource productivity and regularly communicating the efforts of those involved, champions lay the groundwork for further innovation. The company that uses sustainable manufacturing processes, no matter their source, and keeps a process focus in all of its efforts is positioned to be highly innovative.

Controversies

A number of controversies come up in discussions of sustainable manufacturing processes. Some are addressed below.

Green versus Sustainable Manufacturing

The term *green* is usually restricted to manufacturing that has substantially lowered it energy use or waste production, or that uses materials with high recycled content. But sustainable manufacturing seeks to move beyond green. We must examine three types of outcomes—environmental, social, and economic—to consider whether practices are sustainable. This is controversial because many manufacturers limit their so-called sustainability efforts to what they call "environmental sustainability." Other manufacturers refer to their work as green manufacturing or "lean to green" manufacturing. If we apply the three outcomes for sustainable manufacturing, then green and lean-to-green efforts do not fit the definition.

Stakeholder Engagement

Many sustainable manufacturing companies show their various stakeholders detailed information about the core processes responsible for their activities, products, and services. Such knowledge takes away some of the stakeholders' concerns and provides transparency and accountability. Often they have good comments that can lead to further innovation.

As noted above, stakeholder engagement includes increasing employee involvement in the process and asking suppliers how they make their products and how others use them. Stakeholders in the surrounding community can discuss their "interest" in the manufacturing process. Some stakeholder engagement tools are easily available (AccountAbility 2007); these tools can be used over the long term once companies become familiar with them and see their value in adding sustainability to manufacturing processes.

Management Systems

A management system is defined as making quality, sustainability, and environmental and social responsibility part of a company's operation. Companies using management systems are usually required by their clients to use ISO standards, which many manufacturing managers are uncomfortable with. So they implement minimally responsible programs to meet the request and consequently realize little benefit from them. The argument that ISO standards are inflexible and bury companies with useless procedures and paperwork is no longer true, although older ISO versions had these problems. ISO revises its standards: ISO 9001:2000 recognized process focus and a systems approach to management; ISO 9001:2008 made the standard easier to integrate with ISO 14001; ISO 14001:1997 was updated to ISO 14001:2004; and ISO 26000 (on social responsibility) will be issued in 2010. These standards help many companies move to sustainable manufacturing. Even the minimally responsible versions can be improved to accomplish what is needed to progress to this goal.

Operating in Silos

Many manufacturing companies operate their process improvement programs and management initiatives independently of one another. Independent programs are referred to as "silos" (Pojasek 2008). Each silo is often run by a champion whose value to the company is determined, to some extent, by the success of the initiative's (or silo's) activities. Champions are often reluctant to consider integrating programs (e.g., management systems, business excellence frameworks, risk management, and process improvement techniques like Six Sigma); they find it threatening. Employees become confused by many initiatives and the competition between them for attention, and the initiative champions will not be able to help employees do their jobs more effectively. But if the integration focuses on equipping employees with a single, integrated approach to their work, some threats can be mitigated. In this way, the silos are not destroyed—they are harmonized to help employees move to sustainable manufacturing processes.

Ecolabels and Green Marketing Claims

If a company has developed sustainable manufacturing practices, marketing professionals will try to differentiate the resulting products in the marketplace. The ISO standard on ecolabels (ISO 2009a) recognizes three claims by manufacturers:

- seals of approval that are received for meeting the ISO standard
- specific claims that add terms like *biodegradable* or *organic* to the product promotion material
- labels that constitute a grade, such as "USDA choice beef" or "five-star hotel"

The most-effective labels are sector specific, accurate, and third-party verified. There is still much controversy over labeling. The U.S. Federal Trade Commission has been reviewing its ecolabel guidelines to help companies avoid "greenwashing," defined as "the act of misleading consumers regarding the environmental practices of a company or the environmental benefits of a product or service" (TerraChoice Environmental Marketing 2009). A company that exaggerates claims and does not link them to demonstrable sustainability advantages will likely be contacted by consumer watchdog groups looking for greenwashing.

Successes and Impacts

Despite the controversies associated with sustainable manufacturing practices, many large companies have operated successful programs. Many smaller and medium-sized companies have benefited from their examples.

DuPont

For years, DuPont's "goal of zero" has maintained its core direction toward sustainable growth. Its website defines the goal as "the creation of shareholder and societal value while we reduce our environmental footprint along the value chains in which we operate." It further explains: "We will conduct our business with respect and care for the environment; we will implement those strategies that build successful businesses and achieve the greatest benefit for all our stakeholders without compromising the ability of future generations to meet their needs." DuPont (2009) states clearly that all injuries, occupational illnesses, and safety and environmental incidents are preventable, and its goal for them is zero.

DuPont also drives toward zero waste generation by looking at the source of each type of waste and by preventing waste in the first place through process change. It has even stated its desire to drive toward zero emissions. It looks at efficiently using fossil fuels and feedstock, land, water, minerals, and other natural resources: "We will seek to conserve and protect natural resource biodiversity and will manage our land to enhance habitats for wildlife." DuPont (2009) also extends its commitment to its products: "We will continuously analyze and improve our practices, processes and products to reduce their risk and impact throughout the product life cycle." DuPont's Responsible Care Management System helps implement these claims and make them part of how it does business.

Xerox Corporation

Xerox (2009) has long been committed to producing "waste-free products in waste-free facilities. . . . [Its] aim is to design products, packaging and supplies that make efficient use of resources, minimize waste, reuse material where feasible and recycle what can't be reused." Since this program started in 1991, it has prevented over 2 billion pounds of potential waste from entering the disposal stream to landfills and incinerators. Xerox uses ISO 14001 to incorporate this program into its business unit operations. Through employee involvement, it enjoys a 92 percent recycling rate for all nonhazardous materials that are not used in its products. Its annual nonfinancial reports provide the program's progress.

Subaru of Indiana

Subaru of Indiana's improvements in its manufacturing processes allowed it to virtually eliminate the waste sent to landfills—while making over 110,000 vehicles per year (Subaru 2009). Some of the recycle systems (e.g., the paint solvent recovery system) were expensive to implement, and paybacks took over seven years. But Subaru management agrees the money was well spent and they have moved toward their goal of sustainable manufacturing. Many ideas came from enthusiastic employees. Subaru shares its ideas with other automobile manufacturers, other manufacturing industry facilities, and a host of zero-waste groups.

Outlook for the Twenty-First Century

It may be easy to understand the many varied elements that constitute sustainable manufacturing practice. But it takes focus and persistence to set up these elements and begin the continual improvement process that ultimately leads to sustainable manufacturing. Some have said that this is nothing but "good business," but it seems that many manufacturing companies have little time for such good business. When manufacturing volume is high, many companies are too busy to work on these processes and programs. When manufacturing volume is low, they cut the resources necessary to plan and implement them. In contrast, the examples cited in the previous section have been maintained in both bull and bear markets. If we review the annual sustainability reports of the three companies above, we see that they provide accounting of their gains *every* year on their websites. These companies also present papers at large sustainability conferences and demonstrate how persistence leads to sizable savings.

Regulation has increased the cost of waste management, including air and water pollution costs. With less waste, less money is spent managing waste. But every time something is reworked, more resources are used. Thus companies will continue to be interested in accounting for the "embedded costs" associated with energy use, carbon footprints, reuse, and remanufacturing. Their motivation is the need to include the true cost of producing goods in their products' costs, from resource extraction to end of life and reuse or recycling. This true cost is more than the "value added" through these stages; it is also the environmental and social costs associated with product lifecycles. But determining true cost is not easy since we often do not have good data. The American National Standards Institute (ANSI), however, has sustainable product standards that require measuring these values for carpets.

The state of California may require bidders to incorporate costs for all the embedded energy, materials and other resources, labor, and environmental impacts and accompanying social requirements and impacts in the price of their products. The state (2007) already mandates that a carpet must score at the "platinum" level (ANSI NSF 140 Sustainable Carpet Standard) in order to be sold to state agencies. Walmart asks its 65,000 suppliers to answer fifteen questions and submit to a sustainability index for everything they sell to it.

Whether the United States implements a carbon tax or a cap-and-trade system, experts expect a $1 trillion impact on the economy. Companies that begin to incorporate "environmental economics" in the design and production of their products are likely to be ahead of their competition. Once they recognize these costs, they will stop at nothing to eliminate them. This is what sustainable manufacturing will be about in the twenty-first century. While Walmart will drive this practice for retail goods, others will drive it for other manufactured goods.

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See also Biomimicry; Chemistry, Green; Design, Industrial; Ecolabeling; Energy Efficiency; Integrated Product Development (IPD); Lifecycle Assessments (LCAs); Product-Service Systems (PSSs); Remanufacturing; Stakeholder Theory; Supply Chain Management; Zero Waste

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Marketing

Marketing's four components—pricing, product, place, and promotion—play a key role in sustainable business practice. Sustainable marketers consider the needs of the environmental consumer and study product impact from resource use and production to product use and disposal. They face the challenges of assessing consumption, improving consumers' perception of the quality of green products, and making accurate, substantiated claims in labeling and advertising.

The role of marketing in business sustainability has a long, rich history. It has developed in both breadth and depth since the early 1960s in response to changes in consumer attitudes and behaviors, internal corporate strategies, and governmental regulations. Dramatic environmental impacts that have taken place in countries throughout the world—China's move toward adopting the practices of Western industrialized and consumption-oriented societies, for example—have driven many of these changes. Early green marketing was essentially a fringe strategy that a limited number of individuals or small companies used to target a small group of environmentally active consumers with products that typically did not appeal to the mainstream customer. These products were often priced high, did not work well, and had to live up to exaggerated claims about performance. For example, early green detergents often did not produce adequate suds and failed to clean products sufficiently. The Hefty brand of biodegradable bags (made by Mobil) provides another example of a green product that did not meet expectations because they can only degrade under open-air conditions that are not common at landfills.

The phrase "sustainable marketing" has been used interchangeably with "ecological," "environmental," or "green" marketing, but, according to the 2009 *Dictionary of Sustainable Management*, it is generally defined as a marketing approach that highlights "products and production methods that improve environmental performance, further ecological causes, or solve environmental problems" (Presidio n.d.). The researchers Jagdish N. Sheth and Atul Parvatiyar describe sustainable marketing as a way to reconcile economic and ecological objectives through a new understanding of products and systems (Fuller 1999). Others argue that social impacts must be part of any decision-making process dealing with sustainability.

As an activity responsible for creating, communicating, delivering, and exchanging products or services that provide value for customers, marketing has a key role in sustainable business practice. Heightened societal interest in environmental impact has created opportunities for companies to develop new strategies that focus on sustainability using the traditional "4 Ps" of marketing—pricing, product, place, and promotion. In order to develop effective strategies, marketers have spent considerable time researching consumer needs and wants in these areas.

The Green Consumer

A number of studies have been conducted to describe the environmental consumer. The main objective of these analyses is to develop separate groups that can be uniquely targeted by a company. These groups can also be tracked over time to determine any changes in their needs to which companies must respond. One of the most commonly referred-to segmentation studies is the Green Gauge Study developed by GfK Roper Consulting. This report is the only nationwide, long-term syndicated study of consumer attitudes and behaviors toward the environment. It breaks consumers into the following segments (GfK 2007):

- *Apathetics:* This group is the least interested in environmental issues and not likely to respond to them. This segment decreased in size from 28 percent of U.S. consumers in 2000 to 18 percent in 2007. "Apathetics" tend to have lower incomes, be less educated, and have lower interpersonal influence than other consumers.

- *Grousers:* These consumers represented 15 percent of U.S. consumers in 2007, down from 20 percent in 2000. They are generally uninterested in green issues and tend to view them as too complicated and large to do anything about.
- *Sprouts:* They are the classic fence-sitters and represented 26 percent of U.S. consumers in 2007, down from 34 percent in 2000. They will buy green products but evaluate the issues one by one and only purchase a green product if its value exceeds its costs.
- *Greenback Greens:* This category has grown from 5 percent of U.S. consumers in 2000 to 10 percent in 2007. They are interested in green issues, but they will only buy if their comfort and convenience are not jeopardized.
- *True-Blue Green:* This group has jumped the most dramatically from 12 percent of U.S. consumers in 2000 to 30 percent in 2007. They are extremely interested in environmental issues. In comparison to other consumers, they are highly educated, have higher incomes, and are more likely to influence others.

Marketers are often interested in investigating the reasons why consumers purchase green products. They can use this information to develop strategies to appeal to consumer needs and wants. For some consumers, such as the "True-Blue Green," the primary motivation to purchase a green product is the reduced environmental impact—irrespective of the price and quality. For example, these consumers would be willing to pay a premium for an environmentally safe detergent even if it did not do a good job at cleaning. Other green products may be sought because they are truly better on a key attribute that significantly impacts the environment. The hybrid electric Toyota Prius is generally acknowledged as a "better car" because it outperforms other vehicles on miles per gallon; consumers not only save money on gas but also lessen their impact on the environment. Marketers have also found that consumers may purchase green products based on their differences in reducing risk. The Hartman Group (2007) analyzed 1,500 consumers and found that risk reduction is a key motivator behind consumption of sustainable products. Different levels of risk were identified for consumers in this study beginning with personal and family risk, then community-based risks, and finally global risks. The results showed that 52 percent of consumers looked for environmental information to protect their personal or family health. Thus consumers often purchase organic foods not for their green factor but because they reduce the perceived health risk of pesticides and fertilizers. Similarly, a Toyota Prius might be purchased not only because of the greater gas mileage but because it reduces the risk of global warming.

Marketing Strategies and Innovations

The "4 Ps" of marketing—pricing, product, place, and promotion—provide a useful framework to describe company initiatives in the area of sustainable marketing. Although these will be discussed as discrete activities, it is important to note that true sustainable marketing considers all aspects of a company's strategies and also factors in their impact throughout a product/service lifecycle. Thus, marketers must think about the extraction of raw materials, production of goods, transportation, consumption, and final disposal. The elimination of waste produced at each stage must also be part of a true sustainable plan.

Product

There are many approaches to developing sustainable products. The product's key attributes can be developed with the environment in mind, or other aspects of the product can be designed to reduce environmental impact. Companies have researched ways to build products that can be recycled or refurbished or that require less material.

As described above, marketers must understand the relative importance consumers place on product features to help define what features to attempt to make sustainable and whether to focus on these features as a communication strategy. Some products, such as Clorox's Green Works natural cleaners, have focused all key attributes and communications on sustainability. The Toyota Prius hybrid is fuel efficient relative to most automobiles, but the initial appeal of the product was based as much on the technology as it was on the green aspects. Consumers interested in driving the latest technology were attracted to the Prius's ability to take the energy created when braking and store it in a battery. Displaying the car's miles per gallon on the dashboard only added to the "cool" factor; the increased gas mileage was an added benefit. Finally, there are products that contain green aspects, but these are not key consumer decision criteria. An example would be bottled water or sodas—the bottles are typically made from recycled material, but people are motivated more by convenience than conservation.

Electronics, paper, glass, and metals are examples of products that are recycled and can therefore reduce waste and resource demands. (The universal triangle symbol on many products indicates that they may be recycled.) Sometimes these products can be recycled into the same products (for example, glass containers), while other times they must be transformed into products of lower quality.

Each time paper is recycled, for instance, its quality is reduced.

Refurbished or remanufactured products are those that customers may have returned and, in some cases, that the manufacturer must repair. This strategy extends the life of the product. A Motorola refurbished cell phone is an example. Some products are designed for reuse, such as Welch's jam and jelly jars that may be used as drinking glasses.

Companies have successfully developed methods to reduce materials usage in their products. For example, beverage companies have significantly reduced the amount of plastic used in water and soda containers. Arrowhead's "Eco-Shape" bottle uses 30 percent less plastic than comparable bottles. Extending the useful life of a product is another way to reduce materials. Another is to allow the product to be upgraded or simply to make it more durable. Although it may seem disadvantageous to develop a product that lasts a long time, consumers have been willing to pay more for these types of products (for example, Honda automobiles).

Today's innovative sustainable marketers consider product impact from resource use through production, utilization, and disposal. The goal is to design products or processes that minimize these impacts. This process is referred to as Design for Environment, or DFE. Hitachi used this approach in its washing machine: the final design for the machine required only six screws, which led to a decrease in manufacturing time of 33 percent and a reduction in the amount of inventory. Less servicing and higher customer reliability were also benefits of this approach (Esty and Winston 2006). The automotive industry provides another example—this time driven by social and governmental demands as well as limits on available land for product disposal. European automakers must demonstrate reusability and/or recyclability of at least 85 percent, and reusability and/or recoverability of at least 95 percent by weight. Many of these automakers incorporate these rules in aspects of their product design, disassembly, and disposal.

Promotion

With nearly half of the U.S. marketplace stating that they do not have enough information to increase their green behavior, communication needs to play a critical role in the sustainable marketplace. Marketers use advertising, public relations, personal selling, and sales promotions to inform the marketplace. One of the primary decisions sustainable marketers must make is how much their communication strategy should focus on the environmental aspects of the product. Despite the increased interest in low environmental-impact products, consumers are still primarily interested in specific attributes of the product. For example, the fact that a printer is made from 100 percent postconsumer waste is likely to be less important to a consumer than the paper capacity or speed of printing. If the product is already viewed positively against competitors on key attributes, there may be an opportunity to highlight the positive environmental aspects; otherwise, the product needs to primarily focus on traditional buyer decision criteria.

Another important part of a product's communication is the package label. Although there are a variety of words, symbols, emblems, and logos used in labeling, the International Standards Organization (ISO) identifies three types of "ecolabels":

- Type I is the most common type of label. Although Type I labels are typically voluntary, they may be mandatory if toxic ingredients exist. These labels are provided by third-party organizations that allow the use of their symbol if the product meets either specific or multiple criteria. Examples include Germany's Blue Angel, Canada's Environment Choice Program, and the U.S. Forest Stewardship Council. Type I labels do not require disclosure of the detail used to establish the criteria.
- Type II labels do not require third-party verification and include any type of environmental declaration made by any level of a distribution channel. The terms *eco-safe* or *biodegradable* fall under this label type. The confidence in these types of labels can be improved if set definitions can be agreed upon.
- Type III labels are similar to nutritional labels and require an analysis of a product's environmental impact throughout its lifecycle. An open consultation process is required for these labels, and the final products should be easily compared by consumers.

Due to the effects of "greenwashing," which focuses on positive claims made about green products and downplays their negative impacts, there is a growing body of guidelines for communicating the environmental features of a product on package labels. Specific wording is important. Instead of claiming that the product "includes recycled content," labels should state that the "package includes 20 percent postconsumer content." Marketers should ensure that consumers understand whether the claim refers to the product, package, process, or company. Vague, unsubstantiated terms should be avoided. "Environmentally safe," "eco-friendly," and "practically nontoxic" are deceptive descriptors, especially if not followed by clear and prominent qualifying language that limits the safety representation to a particular product attribute that can be substantiated (and provided that no other misleading implications are created by the context). Marketers should also focus on relevant benefits that have significant impact. Many companies still promote the fact that their products do not contain chlorofluorocarbons. This ingredient was banned more than two decades ago, and thus it is no longer a feature that needs to be communicated. Labels also need to include more information. Recent studies, such as the GfK Roper Yale Survey on Environmental Issues (2008, 12), indicate that consumers want labels that describe the environmental impacts of the product's manufacturing process (73 percent of respondents), its use (73 percent of respondents) and the impact of its disposal (79 percent of respondents). Patagonia is an example of a company that presents detailed environmental impact information about its various products.

Legislation to regulate green marketing claims has had difficulty keeping up with the large number of new green products and claims constantly being introduced. Many countries are revisiting their initial guidelines. For example, the U.S. Federal Trade Commission (FTC) is currently revising their list to include the concepts of carbon trading and the general term *sustainability*. Current guidelines provide advice on the use of terms such as *compostable*, *recyclable*, *degradable*, *source reduction*, and *refillable*. Although the guidelines are developed for voluntary compliance, the commission may take action if the conduct is unlawful. For example, the FTC alleged that Kmart Corporation, Tender Corporation, and Dyna-E International each made false and unsubstantiated claims that their products—disposable plates, wipes, and towels, respectively—were biodegradable. According to the FTC, the products would not decompose in nature under conditions of normal disposal practices (most are placed in landfills or are incinerated or recycled). As of late 2009, Kmart and Tender Inc. have agreed to settle their claims while the case against Dyna-E is proceeding to trial.

Price

Similar to any other product, marketers need to consider costs, consumers, and competition when setting the price of environmental products.

One key pricing issue that is constantly debated is the idea of using lifecycle analysis to arrive at the final costs of products. Many advocates of green products do not feel that these products are overpriced but rather that the prices of conventional products do not reflect their true environmental costs. Thus, if the price of a factory-produced bottle of water had to account for the environmental impact of resource extraction (for example, water use and all raw materials), the emission of toxic chemicals during production, the visual impact of trash in the environment, and finally the landfill disposal or incineration costs, then the price would be substantially higher and the price of competitive products would be relatively lower. If consumers in the colder climates of the United States want to eat fruit grown in South America during winter months, then the product should actually reflect the true environmental costs of this product. As software becomes available, the use of lifecycle analysis is increasing to set prices and evaluate alternative production and distribution strategies.

The price of competitive products may be used as a good benchmark for a price bottom or ceiling. But marketers must also consider the varying levels of importance consumers place on environmental versus conventional attributes. If conventional attributes are considered more important, then environmental price premiums may not be warranted.

Customer value must be assessed when deciding the final price. There is somewhat conflicting information on whether consumers are willing to pay a premium for sustainable products. Although the Green Gauge report (GfK 2007) found that 40 percent of consumers are willing to pay a premium for a product that is better for the environment, 74 percent thought green products were too expensive. Home Depot found that consumers were only willing to pay 2 percent more for its line of environmental wood. A number of academic studies have also investigated this topic. One found that consumers were willing to pay 2 to 16 percent more for tables that were labeled as environmentally friendly versus those that were not (Veisten 2007). The type of consumer also plays a role. Another study (Vlosky, Ozanne, and Fontenot 1999) found that consumers with higher levels of environmental consciousness were willing to pay more for environmentally friendly products. The consumer segments of the Green Gauge study also varied in their willingness to pay extra, with the "Greenback Greens" and "True-Blue Greens" willing to pay more. Country of origin also affects a consumer's willingness to pay a price premium. For example, more Canadians than Americans are willing to pay a price premium for green products. Sixty-five percent of Canadians will pay a premium for ecofriendly detergent compared to 51 percent of Americans; 56 percent of Canadians versus 40 percent of Americans will pay more for ecological computer paper (GfK 2008).

Place

Key place or distribution-channel decisions a marketer must make are (1) where the product is available for consumer or business purchase, (2) how it arrives at its location, and (3) where it is manufactured or produced. Sustainable marketing distribution constantly examines the amount of waste created in the channel as the product moves from the extraction of materials to final disposal.

Historically, only retailers that focused on social and green issues carried or promoted environmentally friendly products or communicated other green aspects of their operations (for example, The Body Shop, Whole Foods, Patagonia). But due to increased consumer awareness and interest, anticipated government regulation, and new competition, a number of historically nongreen companies have turned green. This could involve changes in their building and operations or in their product assortment. Home Depot carries over 2,500 products that earn their Eco Options label, including all-natural insect repellents, compact fluorescent lightbulbs, cellulose insulation, front-load washing machines, and certified sustainable forestry products. By 2009, Home Depot expected the Eco Options label to grow to 6,000 products. Walmart's website lists many sustainable initiatives, but in simple terms, Walmart wants its stores to be supplied 100 percent by renewable energy, to create zero waste, and to sell products that sustain resources and the environment. UPS (United Parcel Service) reduced greenhouse gas emissions by purchasing close to 3 million kilowatt-hours of green power for its California facilities; it also has the largest alternative-fuel and low-emission fleet in the industry (19,647 such vehicles worldwide) and streamlined its delivery routes and eliminated close to 30 million miles of driving (Galehouse 2007).

Some methods of transportation are more environmentally damaging than others. Patagonia found that using ground transportation was less damaging than airfreight. (Their website displays the environmental impact of some of their products that are sourced throughout the world). Companies can also improve their sustainability by minimizing the number of delivery trips and mistakes.

Many advocates of sustainable marketing have promoted the advantages of purchasing locally grown and produced products. Advocates claim that locally grown produce has fewer chemicals and uses less fuel. Others argue that efficient distribution and delivery systems have reduced chemical needs and actually use less fuel than the many local trucks used to deliver local products.

Controversies in Sustainable Marketing

Marketers must consider how to integrate sustainability and consumption. How can marketing and sustainability be congruent if the main purpose of marketing is to create consumption that drains the planet's resources and leads to global warming, increasing environmental toxins, and water depletion? A complicating factor in this discussion is that not all groups believe consumption is wrong. Some have argued that marketing-generated consumption accelerates economic development and raises the quality of life of all people—particularly those in impoverished societies. Research on ecological footprints has shown that current consumption is beyond Earth's capacity to provide the continued resources to support it. Fuller (1999) argued that marketers need to focus on a production-consumption system that regenerates itself. Products are designed that minimize resource utilization and can be fed back into this system over and over. Strategies and innovations that consider products from cradle to grave or cradle to cradle will help maintain consumption levels without degrading the environment. Buildings are now being designed that are net producers of energy; utensils are being produced that add nutrients back into the ground as they decompose.

The quality of environmental products poses another challenge. As of 2007, 61 percent of U.S. consumers believed that green products did not do as well as conventional ones (Bonini and Oppenhelm 2007). This may be due to bad press coverage or the consumers' own experiences. Unfortunately, early green products did not perform well or as advertised when they first entered the marketplace. The original compact fluorescent bulbs had a harsh glare and irritating noise when they were on. Even the much-heralded Toyota Prius suffered from an image of poor acceleration and lack of power. Marketers can help improve the perception of quality by delivering on their promises and ensuring that their product performs well on all key conventional attributes.

The term *greenwashing* has a number of definitions but generally refers to advertising, public relations, or packaging information that highlights the positive environmental aspects of a company, product, or service while ignoring its negative environmental impacts. A washing machine that promotes its reduced energy usage but ignores its high water consumption is one example. A dishwashing detergent that claims it is free from phosphates that create algae in streams but in small print lists the toxic chemical chlorine as a key ingredient is guilty of greenwashing as well. The energy producers BP and Shell have engaged in many green activities such as investing in alternative energy and building service stations that have vegetation on their roofs. The fact that the majority of their energy production still focuses on fossil fuels, however, has opened them up to corporate greenwashing charges. Companies can reduce greenwashing incidents by using guidelines provided by governmental agencies such as those provided by the United Kingdom's Department for Environment, Food, and Rural Affairs and Department of Trade and Industry, the United States' Federal Trade Commission, or private consulting groups in environmental marketing such as TerraChoice or Futerra Sustainability Communications.

The Future of Sustainable Marketing

The sustainable market from the 1960s to the1990s did not expand beyond a few companies and a limited number of consumer segments due to poor product quality, limited product choices and availability, bad media coverage, and consumer disinterest. As of 2009, the market has attracted a significantly larger number of companies and consumers. In 2009, consumers are expected to double their spending on green products to $500 billion. The number of self-styled green products released in the United States more than doubled between 2005 and 2007 from 2,607 products to 5,933 (Wasserman 2008).

One study (Esty and Winston 2006) identified a number of critical natural issues that may significantly impact a company, including climate change, energy, water, biodiversity and land use, chemicals, toxics, and heavy metals. Successful sustainable marketers will closely examine how issues such as these can impact the industry in which they operate and develop plans that take advantage of opportunities and minimize problems created from these types of forces. For example, the Dutch government blocked sales of Sony's PlayStation because of a small amount of the illegal toxic element cadmium in the cables. This problem cost them $130 million (Esty and Winston 2006, 1). On the other hand, BP identified ways to reduce greenhouse gas emissions and has saved over $1.5 billion in expenses (Esty and Winston 2006, 2).

As the number of sustainable products proliferates, marketers will have an increasingly challenging time differentiating products. Some experts believe that it will not be long before "green" will no longer be the primary sales pitch for a product. Sustainable marketers, however, will always play a pivotal role in identifying consumer needs and wants in the area of sustainable products and services, and in helping to design green products that are valued at an appropriate price and quality level, communicated without greenwashing, and easily available to the target market.

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See also Consumer Behavior; Ecolabeling; Greenwashing; Packaging; Telecommunications Industry

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Mining

Mining for metals and other resources from any mine cannot actually be sustainable but there are measures a mining operation can take to improve its environmental and social performance: reduce use of resources (including water) and the production of by-products and residues; design mines for energy efficiency; improve technologies; and eliminate health and safety hazards. Controlling the use of "conflict" minerals that fund civil wars is essential.

Many people are uncomfortable using the words *mining* and *sustainability* together in the same sentence. Mining occurs at locations in the Earth's crust where there are concentrations of specific minerals or metals. The resources that can be economically extracted at these locations by a mine, referred to as *ore*, are finite and therefore not sustainable. A term such as *sustainability mining*, although widely used by academics and others to emphasize the importance of this concept in mining, is clearly not accurate, and some may consider it an oxymoron.

In order to continue the ongoing development of world economies, a sustainable materials supply is essential. A more appropriate indicator than supply alone is the services provided by these materials or their substitutes; for example, copper is an excellent conductor of electricity, but if copper can be replaced by another material and provide the same conductive service at an economically, environmentally, and socially sustainable fashion, then that will occur. At present a large number of these services are being provided by materials extracted from the Earth's crust. Recycling is an important component of the overall materials (or service) supply, however, less than 30 percent of the current supply contains recycled materials, apart from some metal alloys that can be as high as 70 percent recycled (Ashby 2009). Primary extraction of minerals and metals from the Earth's crust will therefore be an ongoing necessity for a sustainable society, and mining will remain an important activity in those areas where there are concentrations of minerals and metals that can be economically recovered within the environmental and social expectations of stakeholders in the surrounding areas.

During the last decade it has become clear that the correct way to express the importance of sustainability concepts in mining is to refer to it as "the contributions that mining makes to sustainability and sustainable development" (MMSD and IISD 2002). At the global level, mining contributes to sustainability and sustainable development through the supply of materials that provide important services to individuals and nations. The contributions that a specific mine makes to sustainability and sustainable development must be addressed at the local, regional, and often national scale. The essential components of mining and sustainability are environment, economics, community, governance, and technology.

A large modern mine is a vast industrial complex that depends on sophisticated technology for the mining process and recovery of the metals in the ore as well as the management of the liquid and solid residual and waste materials. Computer technology and continuous monitoring of the process stream are widely implemented.

Ecological Aspects of Mining

When left unchecked, mining activities have the potential for widespread damage to the surrounding ecosystems. The extraction of a material from the Earth requires energy, water, and the displacement of large quantities of surrounding material. The process of separating a mineral or metal from ore requires the use of many reagents, some of which are hazardous, such as cyanide. For example in one estimate, to obtain a kilogram (kg) of pure gold, a mining company consumes an average of 143 gigajoules of energy; 691,000 liters of water; and 141 kg of cyanide, and releases 10.4 metric tons of carbon dioxide into the atmosphere (Mudd 2008). These requirements increase as the purity (or grade) of the ore decreases; as the highest grade (purest) resources are depleted, the environmental impacts of mining operations have the potential to increase. Surface mining requires the removal of vegetation, topsoil, and overburden, as well as the construction of roads for heavy vehicle traffic. These activities change the local ecosystem and can contribute to erosion. Underground mining can cause the surrounding land to sink, an effect known as surface subsidence. In addition, runoff from waste rock and tailings (material left over after the metals or minerals have been removed) can leach and transport metals, acid, residual reagents such as cyanide, and sediment into nearby waterways. In some cases the runoff from mining operations can adversely affect the surrounding fish, aquatic organisms, plants, and human populations. Such contamination can continue for years after a mine has closed. Blasting, crushing rock, and storing and transporting materials may all release dusts (potentially containing heavy metals) into the surrounding atmosphere, where winds can carry them miles from the mine.

Much of the ecological damage caused by mining can be prevented or repaired through careful planning, adequate safeguards, careful decommissioning of the mine, and modern reclamation techniques. Ecologically sound practices increase the costs of operations. In developed countries, such as the United States, less-destructive practices and financial assurance for reclamation are required before a mining permit is issued, and ecological effects are monitored by regulatory agencies before, during, and after mining. Mining companies are expected to internalize the costs of protecting and reclaiming the mine site. In less developed areas, the regulations may be of the same standard but the capacity to implement and enforce them is poorly developed. The ecological failures of mining operations may affect a company's future access to mineral resources, even in countries with more relaxed regulations. In 2003 for example, residents of a small community in Argentina decided in a local referendum not to allow Meridian Gold to develop a mine in the region (Turner 2005). This resulted in a significant drop in the share price of the company. Similarly, Vedanta Resources has had investors sell stakes amid concerns over its bauxite-aluminum operations in India's Orissa province; villagers in the area have been fighting the expansion of the project, which they see as a threat to the forest that sustains their way of life (Jena 2010).

Several measures to reduce the ecological impacts of mining are already in use in many places (Spitz and Trudinger 2009). Reusing water and dewatering tailings (or residues) can reduce the consumption of this resource, which can be scarce in arid and semiarid climates of South America and Africa. Reducing the moisture content in tailings to allow deposition as a paste or drier filter cake will reduce the infiltration of contaminated waters into the subsoil. Unfortunately this measure is more costly than pumping the tailings as a slurry into a tailings management facility. These facilities may leak, and there have also been a number of tailings impoundment failures over the years with severe human casualties and impacts to the environment.

Waste rock can be covered to prevent the infiltration of water that can lead to metal and other chemical constituent releases. Tailings and waste rock can also be used to backfill areas of a mine and in some cases are mixed with cement to provide further stability in underground mines.

Designing a mine for energy efficiency can reduce fuel and electricity consumption and operating costs; in many cases, the proper sizing of pumps, motors, and pipes can save energy (Southwest Energy Efficiency Project 2010). Careful planning and the use of dust control equipment can abate the ecological impact of blasting, ore processing, and transportation. Mine closure activities, including reclamation that is meant to provide for successful future land use such as grazing, must be planned from the initial stages of mine design and development.

Some promising improvements to mining technology and methods can lower operating costs while decreasing the ecological risks of the operations. By using the most advanced prospecting and exploration technology available, such as remote sensing, mining companies can better pinpoint the locations of deposits, which would allow them to minimize the amount of surface disturbance during exploration activities. Biologically based processing techniques have the potential to eliminate the use of some hazardous chemicals while improving recovery rates.

Socioeconomic Aspects of Mining

While mining operations have the potential to bring material wealth to the surrounding communities, they can also bring social and economic harm. Without adequate safety measures, mines—especially those below ground—pose many hazards to workers. While the number of mining-related fatalities reduced dramatically in the United States over the last century, this is not the case internationally. In 2002, nearly 7,000 miners died in China's coal mines (China Labour Bulletin 2006). Because mining requires expensive equipment and/or many laborers, unethical mine owners have been known to exploit workers. When armed security forces are used to protect mining interests, human rights violations may occur. Profits from mining can be used to finance armed conflicts. In eastern areas of the Democratic Republic of Congo, for instance, militant groups thrive on the mining of coltan (a source of tantalum, an essential component of the capacitors used in almost every electronic device). These armed men take a portion of everything that comes from the mines and commit violence against the local populace, using funds from the illicit sale of coltan and other "conflict minerals" to continue a war with the government (Allen 2009).

Mining operations should generate revenue and jobs for host countries that should benefit the local populations. The redistribution of mine taxes to local authorities is one mechanism for accomplishing this. These mechanisms, however, may not be well-developed in a host country, and therefore most of the wealth doesn't reach the communities surrounding the mines. A 2007 study of communities in Ghana indicated that towns closer to mining projects were generally poorer than their more distant counterparts (Akabzaa 2009). Large-scale surface mining operations rely on heavy equipment for the work, meaning fewer jobs are created than in small-scale mining, and those jobs often require skills that the local workers do not have. In Ghana, for example, only 0.7 percent of the working-age population is employed by large-scale mining companies (Akabzaa 2009). Mining interests can impact other resources (i.e., land) and limit their use by other industries, such as farming.

Artisanal mines, which generally are small-scale local or regional operations, can involve thousands of local workers on a subsistence economic level. On a global scale it is estimated that tens of millions of workers are involved with such activities in the recovery of gold, diamonds, gems, and other minerals. These operations rely on simple and often dangerous practices since they are not licensed and regulated. In gold mining, mercury amalgamation is used by many, and it results in widespread human health and environmental impacts. The relations between artisanal mining and large-scale mining are often tense because artisanal miners may occupy the land that a large mining company hopes to access. The ore grades of most large mines are much lower than most areas mined by artisanal miners, albeit these smaller areas can not be economically developed by large companies.

Mining does not have to exact a high social and economic cost. In fact, by working with community members to ensure their needs are met, a mining operation can be good for the community. Colorado-based Newmont Mining Company, for example, has implemented a program for ensuring good relationships with the communities in which it works in North and South America, Africa, and the Asia/Pacific region. The program involves interviewing community members, workers, and other stakeholders to evaluate and improve the company's social impact. The program led the company to help farmers in fifteen Indonesian villages around copper and gold mines to diversify their crops and improve their livelihoods (Newmont 2009).

Legacy Issues

Throughout the world there are many environmental and social legacy issues associated with mining. These legacy sites, also referred to as abandoned and orphaned mines, were previously operated but not properly closed because the regulatory framework did not exist. The major focus of present regulatory processes and other activities is to make sure that no more legacy sites are created. For example, in the United States alone it is estimated that 19,300 kilometers of rivers and streams and more than 730 square kilometers of lakes and ponds have been adversely affected by acid drainage from abandoned mines (Montana State University 2004).

Environmental cleanup at abandoned mine sites is typically paid for by a government, and it is very dependent on national economic conditions. The first priority for abandoned mine sites is to make them safe for the public that may wander into the area. A small percentage of the abandoned sites require extensive environmental remediation, which is usually very costly.

A multistakeholder process in Canada has been very successful in developing strategies and engagement processes on the issue of abandoned mines. The National Orphaned/Abandoned Mines Initiative (NOAMI 2009) has conducted a series of workshops and published a series of reports on these topics.

A Framework for Assessing Sustainability

At the global level, mining contributes to sustainability and sustainable development through the supply of materials that provide important services to individuals and nations. In 2001 a group of stakeholders consisting of academics, representatives of nongovernmental organizations, and mining industry representatives and regulators participated in a series of workshops and writing sessions in North America as part of the Mining, Minerals and Sustainable Development Project; the purpose was to establish the means to evaluate the contributions that a specific mining venture—existing or proposed—makes to sustainability during its design, operation, closure, and postclosure. The objective would also suggest approaches or strategies for effectively implementing such a test/guideline (MMSD and IISD 2002). The project's outcome, referred to as the "seven questions to sustainability," is currently used by researchers and practitioners alike in various assessments (Hodge 2004; Van Zyl, Lohry, and Reid 2007). The seven topics or themes "questioned" are engagement, people, environment, economy, traditional and nonmarket activities, institutional arrangements and governance, and synthesis and continuous learning. (See table 1.)

Availability of Materials

In *The Limits to Growth* (Meadows et al. 1972), a global nongovernmental organization known as the Club of Rome issued a report on the potential scarcity of materials. While there has been much discussion about this topic and also evidence that the predictions were not substantiated, this theme is currently receiving renewed attention (e.g., Shields and Šolar, forthcoming). Generally, two models are put forth in the evaluation of this issue. The "fixed stock" model approaches the availability of materials from the Earth as finite and assumes that the demand will eventually exhaust the available supply. The "opportunity cost" paradigm assesses resource availability by what society has to give up to produce another unit of a mineral commodity, such as a tonne of copper. Over time, depletion increases the opportunity cost of mineral production, while new technology and other factors can offset this pressure (Tilton 2003). Improvements in ore processing, for instance, can turn unprofitable deposits into viable resources. Further advances in the recycling of materials may also alleviate some of the demand. As the supply of a material decreases, economic pressure is likely to prompt the search for an alternate material. In short, the sudden and total depletion of a mineral resource is not likely to occur.

Table 1. **Seven Questions to Sustainability**

Does the project identify stakeholders and engage them in all phases, from planning to closure?
Will peoples' well-being be maintained or improved during and after the project or operation?
Will the integrity or well-being of the environment be maintained or improved during and after the project or operation?
Is the economic viability of the company assured; is the community and regional economy better off not only during operation but into postclosure?
Is the viability of traditional and nonmarket activities in the community and surrounding area maintained or improved with the project or operation?
Are the rules, incentives, and capacities in place now and as long as required to address project or operational consequences?
Does a synthesis show the project to be net positive or negative for people and ecosystems; is the system in place to repeat the assessment from time to time?

Source: (Hodge 2004; Van Zyl, Lohry, and Reid 2007)

Researchers, industry professionals, and other stakeholders have established seven questions to consider in assessing the environmental and socioeconomic impacts of a mining activity.

Outlook for the Twenty-First Century

Pressure from shareholders, communities, governments, and materials buyers will push mining companies toward improved performance. The Church of England and other investors sold their shares in the global metals and mining group Vedanta Resources in 2010 due to publicity surrounding the company's operations in India, and in Guatemala, people in forty-two municipalities voted to prohibit mining. In 2007, labor groups in Guinea staged an uprising that forced the government to reevaluate its mining contracts (Campbell 2009). Organizations such as Oxfam America have been working to protect the rights of communities near mines. Major retailers including Walmart and Tiffany's have pledged to avoid gold suppliers guilty of human rights or environmental violations.

Already some of the largest mining companies are making changes to the way they conduct business in order to ensure their futures. In 2001 the International Council on Mining and Metals (ICMM) was formed "to act as a catalyst for performance improvement in the mining and metals industry. Today, the organization brings together 19 mining and metals companies as well as 30 national and regional mining associations and global commodity associations to address the core sustainable development challenges faced by the industry" (ICMM 2005). The ICMM sustainability framework consists of three parts: a set of ten principles, reporting on their performance, and assurance of the reports. ICMM also publishes a large number of guidance documents (such as the *Community Development Toolkit*) that are widely used by various stakeholders.

Growing awareness of the contributions that mining can make to sustainable development should prompt many mining companies toward improved environmental and social responsibility. While there are clear leaders in the industry, the overall performance of the industry is often judged by that of the laggards.

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See also Base of the Pyramid; Cement Industry; Development, Rural—Developing World; Energy Efficiency; Energy Industries—Coal; Human Rights; Investment, CleanTech; Poverty; Steel Industry; Telecommunications Industry; Water Use and Rights

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Municipalities

Since the 1990s, many cities and towns around the world have made their own commitments to sustainability; what began as a community response to climate change has shaped the municipal sustainability movement. Local governments routinely incorporate sustainable concepts into their plans, addressing aging infrastructures, energy efficiency, public transportation, and outdated land-use policies. Municipalities potentially offer many solutions to environmental challenges.

Since the early 1990s, a global movement of municipalities committed to sustainability has gained strength and focus. Cities large and small have embraced the fundamental principles of sustainability to guide their long-term planning processes and focus their actions to improve the health and well-being of their communities. This journey toward sustainability is no longer an option for many of them. Cities, towns, and counties find themselves on the front lines of today's most pressing global challenges, from climate change and energy demand to economic stability and access to quality health care and education.

Local governments focused on sustainable development recognize the complex and interrelated nature of these environmental, economic, and social challenges. They understand that these challenges are best addressed holistically rather than piecemeal. They also recognize their extensive power to address them through avenues such as land-use planning, infrastructure development, environmental regulations, job training programs, community outreach, and the creation of affordable housing. Collectively these local actions have enormous global impacts.

Defining Municipal Sustainability

In 1987, the United Nations' World Commission on Environment and Development (also known as the Brundtland Commission) released the Brundtland Report, *Our Common Future*, which provided the first agreed upon definition of sustainable development: "[Sustainable development is] development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

While this basic definition has influenced planners and politicians at all levels of government, there remains a lack of consensus on what "sustainable development" means for municipalities. Instead, there are countless definitions of sustainability and its principles. This diversity of language stems from two factors: until recently, most municipalities (especially in the United States) had few examples to follow or frameworks to guide their efforts, and many built their sustainability initiatives on their own from scratch; second, intensive community engagement processes produced sustainability definitions tailored to the needs and makeup of individual communities. There are several examples of this process from a few of the early innovators and leaders of this movement.

Santa Monica, California

"The Sustainable City Plan was created to enhance our resources, prevent harm to the natural environment and human health, and benefit the social and economic well-being of the community for the sake of current and future generations" (Santa Monica Sustainable City Plan n.d., 1).

Seattle, Washington

"From the many discussions and debates that contributed to the development of the Comprehensive Plan, a simple set of four values — Seattle's core values — has emerged. These core values are Community; Environmental

Stewardship; Economic Opportunity and Security; and Social Equity" (City of Seattle Comprehensive Plan 2005, 5).

Melbourne, Australia

"Cities are fundamental for economic opportunities and social interaction, as well as cultural and spiritual enrichment. However, cities also damage the natural environment and exploit natural resources in an unsustainable manner which can jeopardize long-term prosperity and social well-being. . . . The transformation of cities to sustainability will require cooperation between various levels of government, resource managers, the business sector, community groups and all citizens. . . . Our vision is . . . to create environmentally healthy, vibrant and sustainable cities where people respect one another and nature, to the benefit of all" (UNEP 2002, 2).

Vancouver, Canada

"A sustainable Vancouver is a community that meets the needs of the present without compromising the ability of future generations to meet their own needs. It is a place where people, live, work, and prosper in a vibrant community of communities. In such a community, sustainability is achieved through community participation and the reconciliation of short and long term economic, social and ecological well-being" (Sustainable Vancouver 2002).

Background and Milestones

Cities, towns, and counties have long relied on urban planners to manage their land-use and transportation planning processes. Before "sustainable development" was a buzzword, urban planners were working to make their municipalities more livable places by addressing issues such as safety, transportation, and environmental quality. But over time, as the principles of sustainability have become better defined, the profession of urban planning has integrated them into its theory and practice. In 2008, for example, the City of Portland, Oregon, merged its Bureau of Planning with its Office of Sustainable Development to ensure that sustainability principles were at the core of all planning decisions.

The municipal sustainability movement as it exists today can be traced back to 1990, when more than 200 local governments from 43 countries participated in the World Congress of Local Governments for a Sustainable Future at the U.N. headquarters in New York. The four-day proceedings birthed a new organization: the International Council for Local Environmental Initiatives (ICLEI).

ICLEI would grow to foster and lead the movement of local governments taking action against climate change, an issue that has defined and galvanized the municipal sustainability movement like no other. In 2003, however, the organization revised its mission and charter to address a broader array of sustainability issues faced by local governments, and changed its formal name to "ICLEI-Local Governments for Sustainability."

Municipal sustainability initiatives began to take shape in 1992 at the U.N. Conference on Environment and Development in Rio de Janeiro—the Earth Summit—with the adoption of Agenda 21 (1992), a "comprehensive plan of action to be taken globally, nationally, and locally by organizations of the United Nations System, Governments, and Major Groups in every area in which human impacts on the environment."

Agenda 21 called on all governments to adopt strategies for sustainable development, and local governments worldwide embraced their key role. Between 1992 and 1996, 1,812 local governments from 64 countries were involved in "Local Agenda 21" planning activities, including climate and rain forest protection initiatives and programs to address air and water quality, recycling, poverty, and a range of other issues.

After the Earth Summit and Agenda 21, the international community recognized the need to involve local governments in its discussions and programs—ICLEI became the designated organization to represent them at the United Nations—and acknowledged that major responsibilities for sustainable urban development were in local government hands.

Climate Action Driving Sustainability

In the United States especially, the local response to climate change, as mentioned earlier, has driven and defined the municipal sustainability movement. In partnership with the U.S. Conference of Mayors (USCM), Seattle mayor Greg Nickels launched the USCM Climate Protection Agreement in 2005, with mayors across the country signing the agreement and committing to meet or beat the Kyoto Protocol emissions reduction targets in their own communities. By 2009, 944 U.S. mayors had signed on.

Over the same period, ICLEI membership exploded, and by 2009, the organization boasted more than 1,100 members worldwide (with more than 600 of those in the United States) who turned to ICLEI for technical support and guidance on conducting greenhouse gas inventories, setting emissions reduction targets, crafting climate action plans, and implementing measures and policies to meet their goals.

In 2005, a global partnership called the C40, comprised of the world's forty largest cities, recognized that cities and urban areas account for approximately 75 percent of the world's greenhouse gas emissions and worked to set policies and accelerate action (C40 Cities 2009). The most progressive municipalities, large or small, have committed to reducing their greenhouse gas emissions 80 percent by 2050—the widely accepted necessary goal set by the Union of Concerned Scientists (Frumhoff et al. 2007, xii) to halt the worst effects of climate change—and a few have set goals for carbon neutrality in the coming decades.

Sustainability Goals

Climate mitigation is one of the most common and high-profile sustainability goals among local governments worldwide. Other objectives can vary immensely. For some, the scope of their sustainability work is limited to environmental initiatives such as water and storm-water management, air quality, public transit, green buildings and fleets, energy efficiency, and environmental justice. Other sustainability plans address the three sustainability pillars in a more balanced fashion and include goals around economic development, local food, access to health care and affordable housing, educational excellence, public safety, and arts and culture.

There is a good reason for this diversity. In many cases, a community's sustainability goals are not crafted by a single activist mayor or professional sustainability planners—or handed down from a national government. A hallmark of local sustainability planning is engagement with community members and stakeholder groups to determine their needs and priorities. Local elected officials have learned that to chart a course for a more sustainable future for *all* their constituents, not just some, their sustainability planning process must be undertaken in partnership and consultation with community groups, businesses, academic experts, professional groups, unions, and nongovernmental organizations (NGOs). The outcomes of this engagement process, obviously, vary from place to place.

One of the best examples of comprehensive sustainability goals comes from New York City's PlaNYC (2009), which was released in 2007 and is widely considered the gold standard for sustainability plans. Driven by the leadership of Mayor Michael Bloomberg, and resulting from an extensive community engagement process, PlaNYC addresses goals in ten areas:

- Housing: Create homes for almost a million more New Yorkers, while making housing more affordable and sustainable.
- Open Space: Ensure that all New Yorkers live within a ten-minute walk of a park.
- Brownfields: Clean up all contaminated land in New York City.
- Water Quality: Open 90 percent of waterways for recreation by reducing water pollution and preserving natural areas.
- Water Network: Develop critical backup systems for the aging water network to ensure long-term reliability.
- Transportation: Improve travel times by adding transit capacity for millions more residents, visitors, and workers.
- Transportation Network: Reach a full "state of good repair" on New York City's roads, subways, and rails for the first time in history.
- Energy: Provide cleaner, more reliable power for every New Yorker by upgrading the energy infrastructure.
- Air Quality: Achieve the cleanest air quality of any big city in America
- Climate Change: Reduce global warming emissions by 30 percent.

The goals of San José, California, are somewhat different. As an urban center long associated with the high-tech boom, the city seeks to become greener and revitalize its economic development at the same time. According to Mayor Chuck Reed's Green Vision (2007), within fifteen years, the City of San José together with its citizens and businesses will:

- create 25,000 clean tech jobs as the world center of clean tech innovation
- reduce per capita energy use by 50 percent
- receive 100 percent of electrical power from clean renewable sources
- build or retrofit 50 million square feet of green buildings
- divert 100 percent of the waste from landfills and convert waste to energy
- recycle or beneficially reuse 100 percent of wastewater (100 million gallons per day)
- adopt a general plan with measurable standards for sustainable development
- ensure that 100 percent of public fleet vehicles run on alternative fuels
- plant 100,000 new trees and replace 100 percent of streetlights with smart, zero-emission lighting
- create 100 miles of interconnected trails

Both New York's and San José's goals share several notable traits. First, they are specific and measurable. A common saying among sustainability planners, borrowed from the business world, is that "you can't manage what you don't measure" (Reh 2009). For municipal sustainability efforts to be successful, planners must be dedicated to ongoing measurement and monitoring of sustainability indicators and initiatives. Second, these cities' sustainability goals cover a wider range of issues than, say, those of a commercial business, and typically set longer-range targets than businesses, anywhere from five to thirty years ahead.

Sustainability Planning

To reach their sustainability goals, municipalities typically develop at least one of three types of long-term plans. A comprehensive plan or general plan is the broadest and most complete roadmap for a community's development, which defines municipal policies and goals around land use and infrastructure. A sustainability plan is an action-oriented plan that charts development around the three pillars of sustainability (environmental, economic, and social) and can complement or replace a comprehensive plan. A climate action plan is more focused, addressing climate mitigation by outlining multiple actions to reduce greenhouse gas emissions.

The process of developing a sustainability plan is typically lengthy and complex. Gathering research, producing a plan, getting approval, and releasing it can take several years. The specific steps to reach that end point can vary, depending on the size of a city and its governmental structure—for example, a strong mayor versus a weak mayor / city manager setup.

Nevertheless, several keys to success in sustainability planning hold true despite these variables. Any sustainability effort requires a "champion"—a high-level elected official, either a mayor or a city council member—who supports the sustainability plan and can help drive its political progress. Formal buy-in from decision makers such as council members is also essential, along with informal buy-in from the departmental staff throughout the municipality (who will be tasked with implementing aspects of the plan) and important community stakeholders. The creation of interdepartmental teams within the municipality and committees of municipal staff and outside stakeholders can facilitate this buy-in and help collect input at every step. This entire planning process is also best managed by a single person—such as a sustainability coordinator or urban planner—or department.

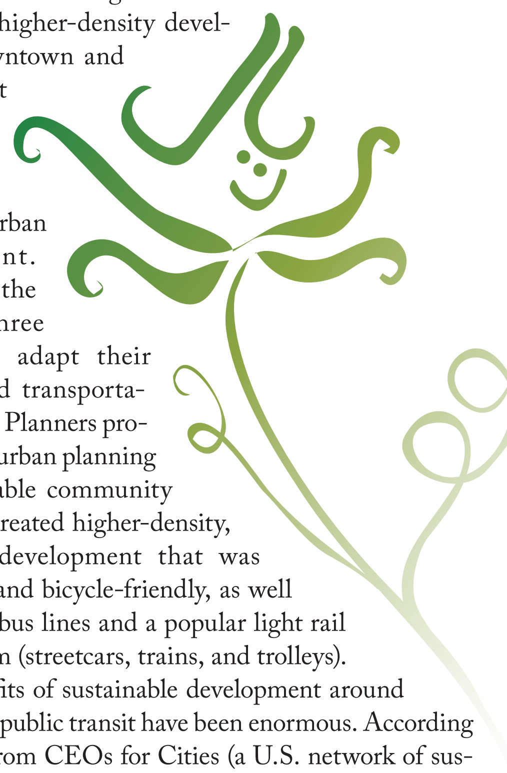
Municipalities typically follow a similar sustainability planning process. A five-step process might be outlined as follows (ICLEI 2009b):

1. Conduct a sustainability assessment to gather data and identify the major challenges and opportunities.
2. Set sustainability goals to address the most pressing challenges.
3. Develop a sustainability plan comprised of policies and initiatives.
4. Implement the sustainability plan.
5. Monitor and evaluate progress using a set of sustainability indicators and report progress internally and to the public.

A key at every stage of this cyclical process is to solicit input from stakeholders within and outside the government and to communicate progress to the public.

Examples of Success

A leading example of success comes from Portland, Oregon, long considered one of the most sustainable U.S. cities. Back in 1980, an urban growth boundary was established around the Portland region in order to promote higher-density development downtown and to prevent the loss of valuable agricultural land to suburban development. This forced the city and three counties to adapt their land-use and transportation policies. Planners promoted good urban planning and sustainable community design and created higher-density, mixed-use development that was pedestrian- and bicycle-friendly, as well as extensive bus lines and a popular light rail transit system (streetcars, trains, and trolleys).



The benefits of sustainable development around land use and public transit have been enormous. According to a report from CEOs for Cities (a U.S. network of sustainability-oriented urban planners), "Portland's Green Dividend" (Cortright 2007), metropolitan Portlanders save \$1.1 billion annually on reduced transportation expenses, and an additional \$1.5 billion due to reduced commuting and travel time. This allows them to reinvest \$2.6 billion in the local economy instead of using it to buy gasoline. The city has developed a culture of sustainability—a love of outdoor activities, a local food movement—and become a magnet for young professionals, which in turn attracted major corporations like Nike, IBM, and Intel to locate in Portland and take advantage of this workforce. Even as Portland's population grows, its per capita greenhouse gas emissions have been dramatically reduced to below 1990

Kyoto Protocol levels, and vehicle miles traveled per capita have declined by more than 10 percent (Cortright 2007, 4).

The city of Växjö, Sweden, is also frequently cited as a strong example of successful sustainability planning. The city has focused efforts to create sustainable energy, water, and waste management systems to reduce greenhouse gas emissions. Since 1993, Växjö has reduced per capita greenhouse gas emissions by 30 percent, while increasing economic growth by 50 percent. A larger goal is to become a fossil fuel–free city by 2050 (Environmental Programme for the City of Växjö 2008, 2).

A key to this success has been a dedicated commitment to efficiency, and the innovative use and reuse of surrounding natural resources. For example, the biggest reduction in carbon dioxide emissions has been achieved by replacing oil in the municipal district heating system with wood waste from the local forest industry. Methane gas is captured from waste management systems and used as fuel, and at the sewage treatment plant, sludge and biogas are used to heat and power the plant. More than 50 percent of the city's energy comes from renewable resources, such as biomass, biogas, and solar.

Växjö is also recognized for its commitment to social equity and a sustainable quality of life. All citizens of Växjö have access to quality health care, education beginning at the preschool level, and a welfare safety net.

Countless other cities around the globe can point to successful individual sustainability initiatives. The most popular initiatives typically deliver multiple benefits. For example, addressing energy efficiency to lower greenhouse gas emissions can also save local governments thousands or millions of dollars, depending on the scope of the project; designing walkable communities and improving public transit enhances overall quality of life for community members. There are several examples:

- In 2005, the City of Seattle, Washington, passed a recycling ordinance that prohibited the disposal of certain recyclables to prevent them from entering landfills. The new ordinance was expected to save residents and businesses as much as $2 million per year, and reduce carbon dioxide equivalent (CO2e) emissions by 260,000 tons per year.
- Curitiba, Brazil, known as the ecological capital of Brazil, has developed a network of twenty-eight parks and wooded areas through integrated planning. In 1970, there was less than one square meter of green space per person; in 2002 there were fifty-two square meters for each person. Residents planted 1.5 million trees along city streets. Builders get tax breaks if their projects include green space. Flood waters diverted into new lakes in parks solved the problem of dangerous flooding and provided aesthetic and recreational value to the thousands of people who use city parks (ICLEI 2002).
- In 2008, the City of Los Angeles, California, passed a strict green building ordinance that, among other measures, required all new projects greater than fifty units or 50,000 square feet (4,645 square meters) to show compliance with the Leadership in Energy and Environmental Design (LEED) certification, making them far more energy efficient than typical buildings. The ordinance is expected to reduce the city's carbon emissions more than 80,000 tons (72,575 metric tons) by 2012, the equivalent of taking 15,000 cars off the road. It will also save taxpayers up to $6 million through energy savings, spur the creation of local green jobs—especially for low-income and disadvantaged peoples—to perform the retrofits, and revitalize public buildings in low-income neighborhoods.

Challenges and Innovations

As more municipalities seek to implement sustainability measures and develop their own sustainability plans, key challenges have emerged. The sustainability planning process can be daunting for a local government to begin, particularly a smaller jurisdiction with limited resources and in-house expertise. Where do they start?

Many nonprofit organizations have taken action to facilitate the sharing of goals and best practices. For example, in 2009, ICLEI created a Sustainability Planning Toolkit for its members, based on the model pioneered by New York's PlaNYC. In Europe, the World Health Organization's Healthy Cities program, founded in 2003, engaged local governments to promote comprehensive urban planning and systematic policy initiatives that addressed health inequalities and urban poverty. The Sustainable Cities and Towns Campaign signed on more than 2,500 local governments from more than forty European countries to commit to Agenda 21 initiatives and helped them to share strategies. In the United States, the nonprofit National Pollution Prevention Roundtable helped local governments understand approaches to reduce pollution upstream, as opposed to traditional treatment and disposal.

Another major obstacle to local government sustainability planning is the absence of a common national framework for sustainable communities. Sustainability efforts thus far have been highly individualized with widely varying initiatives and goals. There are consequences of operating without a national framework:

- There are no accepted benchmarks and indicators for sustainability, no simplified rating system, no standard reporting mechanism.

- There is no common language, vision, or definitions, creating apples-to-oranges comparisons among municipalities.
- There is no standardized process to verify claims made by municipalities, making their validity less certain.

The STAR Community Index, a national sustainability framework to remedy these issues, will emerge in 2010. STAR is the result of a partnership between ICLEI, the U.S. Green Building Council (USGBC), and the Center for American Progress. It is intended to provide a national, consensus-based rating system with indicators and metrics that will help local governments set priorities, implement policies and practices, and measure progress. In the same way that the USGBC's Leadership in Energy and Environmental Design (LEED) is a rating system for buildings, STAR will be a rating system for communities and a means to certify their achievements. The hope is that this new level of standardization and integrity in a rating system will help local governments improve their sustainability performance more dramatically and quickly.

Another benefit of STAR may be that municipalities begin to incorporate economic and social initiatives more fully into their sustainability plans, which are often dominated by environmental initiatives. One effort to more fully integrate economic development with environmental sustainability has been the Climate Prosperity Project, launched by the nonprofit group Global Urban Development.

The project's central theme is that the only way to prosper economically in the twenty-first century is to become more sustainable; local governments can do that by investing in actions that save money (energy efficiency and public transit), capitalizing on local green opportunities (electric vehicle research at a local university, solar photovoltaic manufacturing), and developing local green jobs. A key outcome of these actions is, of course, to mitigate climate change through greenhouse gas reductions. Portland's sustainability efforts illustrate this concept perfectly.

In 2008, pilot municipalities and regions across the United States began to develop climate prosperity strategies that placed sustainability at the heart of their long-term economic development plans. These pilot regions included Silicon Valley / San José; the State of Delaware; metropolitan Denver, Colorado; metropolitan St. Louis, Missouri; southwest Florida; King County / Seattle, Washington; and Montgomery County, Maryland.

One final innovation has been the emergence of municipal sustainability departments runs by sustainability coordinators. When municipalities begin to develop a sustainability plan, they often find that the various departments that deal with aspects of sustainability—public health, public works, energy management—operate in silos and do not integrate their efforts or communicate their practices. A municipal sustainability coordinator, however, can spearhead and coordinate these efforts across departments to address sustainability issues more holistically and efficiently. While many local governments are creating an "office of sustainability," the work of sustainability planning can also be performed ably by planning department staff.

The Road Ahead

As the global population grows and natural resources become scarcer, sustainability is fast becoming the preeminent challenge for municipalities, particularly cities. More people are moving to urban areas: the United Nations projects that by 2050 nearly three-quarters of the world's population will call urban areas home. It will therefore be imperative for local governments to manage and plan for this growth—especially in the Southern Hemisphere, where megacities continue to expand—and to design cities inclusive to all peoples.

Decades ago, cities were considered the problem by many environmentalists—responsible for air and water pollution, the overconsumption of natural resources, and social inequality. But urban areas are now viewed as the solution to many of these issues, due to their compact land-use patterns and access to public transit. At their best, sustainable cities can be vibrant places where people can connect and play, live with a smaller environmental footprint, find high-quality jobs, and access key social services.

Not all local government leaders, especially in the United States, are enthusiastic about sustainability principles, particularly because of the stigma that the environmental movement is politically left-wing and antibusiness. Mayors and their community members may be hesitant to address climate change through local measures that they believe will stall economic growth, raise energy prices, and require higher taxes to implement. A major effort by local sustainability proponents is to spread the message that many sustainability initiatives save money, create jobs, and stimulate the economy.

To tackle the challenges of this century, many more local governments will need to participate in sustainability initiatives. Some of the most pressing challenges for all municipalities, including urban ones, are rebuilding and reshaping old and inefficient infrastructure, maximizing energy efficiency opportunities—especially for buildings—to save energy and lower greenhouse gas emissions, revising outdated land-use policies to foster smart growth and reduce vehicle miles traveled, adapting to the impacts of climate change, and improving education and sustainable job opportunities. The challenges are huge, but leading municipalities have already developed innovative practices and focused goals for other to replicate.

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See also Community Capital; Development, Urban; Energy Efficiency; Green-Collar Jobs; Leadership; Local Living Economies; Public–Private Partnerships; Public Transportation; Smart Growth

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Natural Capitalism

Capitalism as practiced today does not value the intact ecosystems that make all life, and thus economics, possible. A new approach—natural capitalism—shows businesses how to increase profitability through resource efficiency, conduct business the way nature does, and manage business so that it is restorative of both human and natural capital.

The prominent environmentalist David Brower (1912–2000) once said you cannot do business on a dead planet. The way that business is now conducted is testing this dictum.

The challenges facing humankind are daunting: every major ecosystem on the planet is in decline; the global climate crisis is immediate; energy prices are soaring, perhaps because the world has reached peak oil production; populations continues to rise; water shortages may prove even harder to solve than energy shortages; and China—with India right behind—has entered the world market for essentially everything. At the same time, companies, communities, and countries are facing the "sustainability imperative." Clearly a new approach to economics is needed.

Loss of Ecosystem Services

Industrial capitalism, as it is now practiced, does not value but liquidates the most important forms of capital, especially natural capital—the living world whose resources and ecosystem services make all life possible. As headlines report food crises, water shortages, soaring energy prices, wars driven by climate change (like the one in Darfur), and the rapacious appetites of China, India, and the United States, among others, for the world's resources, it is becoming ever clearer that deteriorating living systems cannot sustain a growing human population. The limits to economic growth are being set by the scarcities of natural capital.

In 2001 the United Nations commissioned the Millennium Ecosystem Assessment, a comprehensive study of the consequences of human activity on the world's ecosystems. The work of 1,360 experts in ninety-five nations from twenty-two national science academies and published in 2005, the findings reported that over the past fifty years a rising human population has polluted or overexploited 60 percent of the ecological systems on which life depends (MEA 2005a, 1).

At the heart of this assessment is a stark warning: "Human activity is putting such strain on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted" (MEA 2005b, 5). U.N. secretary-general Kofi Annan said the report demonstrates how "the very basis for life on earth . . . is declining at an alarming rate" (Doyle 2005).

Sometimes the value of intact ecosystem services becomes apparent only when lost. In China's Yangzi basin in 1998, for example, upstream deforestation triggered flooding that killed 3,700 people, dislocated 223 million, and inundated 60 million acres of cropland. That $30 billion disaster forced a logging moratorium and a $12 billion crash program of reforestation.

The 2007 release of the Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) represented the agreement by essentially all of the world's climate scientists that humans have altered the world's climate and that greenhouse gases must be reduced by at least 90 percent by 2050, with more immediate action taken within the next few years. Worldwide economic losses due to extreme weather have risen since the 1950s, a decade that saw twenty "great catastrophes" (those requiring international or interregional assistance), and they have continued to do so more steeply since the 1970s, when there were forty-seven such disasters. In the 1990s an expenditure of $608 billion was required to cope with eighty-seven weather-related disasters. In 2008, weather-related damage cost insurers over $200 billion, compared to $82 billion in 2007 (Environmental Leader 2009). Claims from weather-related disasters are now rising twice as fast as those from all other mishaps. Insurers at Munich Re, which now takes climate change into account in its projections, state that the loss statistics fit the pattern of their climate models, with atmospheric warming causing weather to "run in top gear" (Environmental Leader 2009).

Natural Capitalism

As companies and communities struggle to find ways to meet their needs in the face of challenges, an increasing number are turning to an approach outlined in the 1999 book *Natural Capitalism: Creating the Next Industrial Revolution*. It set forth a way of doing business that is more profitable, but that reverses the planetary destruction now underway.

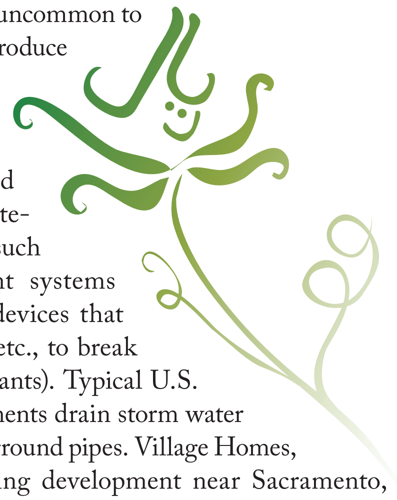
- There are three principles of natural capitalism:
- Buy time to address the challenges facing the world by radically increasing resource efficiency.
- Redesign how the economy makes and delivers all products and services by doing business in the way that nature does.
- Manage all institutions to be restorative of natural capital in ways that reverse the loss of ecosystem services.

Increasing Resource Efficiency

It is relatively easy today to profit by using resources more efficiently because current resource use is incredibly wasteful. Globally the economy mobilizes a resource flow of half a trillion tons per year. Of that, only about 1 percent becomes embodied in a product that is still in use six months after sale. The other 99 percent is waste. Cutting such waste represents a vast business opportunity.

The architect William McDonough criticizes efficiency as simply doing less bad and, therefore, still bad (McDonough and Braungart 2002). Clearly, eco-efficiency alone will not deliver a sustainable society, but the criticism misses the significance of using resources more efficiently. The foundation of a building is obviously not a complete house, but without solid underpinnings, no structure can stand for long. Without eco-efficiency, sustainability is unachievable. More important, using fewer resources buys critical time necessary to solve increasingly severe challenges, like climate change and loss of ecosystems, and to develop and implement more systematically sustainable practices. Eco-efficiency is the easiest component of the transition to sustainability to implement. It is usually profitable and is familiar to industrial engineers.

Building greener buildings and designing better communities is key to increasing efficiency. State-of-the-shelf technologies can make old buildings three to four times more energy efficient and new ones ten times more efficient at similar cost and with better performance. The U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) standards are being adopted by many communities, incorporated into codes, and embodied in government mandates. It is no longer uncommon to have buildings that produce all the energy they need to operate and even export power back to the grid and that treat their wastewater on site using such biological treatment systems as Eco-Machines (devices that use algae, bacteria, etc., to break down organic pollutants). Typical U.S. tract-home developments drain storm water away in costly underground pipes. Village Homes, an early solar housing development near Sacramento, California, instead installed natural water-catchment channels that allowed rainwater to soak in, recharging groundwater. Eliminating storm drains saved $800 per house, enabling investment in edible landscaping and people-centered site planning (pedestrian/bike greenways in front of the houses, tree-shaded streets), saving more land and money. These features cooled the area around the houses, yielding better comfort with little or no air-conditioning, and created a safe and child-friendly neighborhood that cut crime by 90 percent. The development was simply a better place to live. The same integrative design that improved environmental, resource, and human performance also improved market and financial performance. Market values averaged nine dollars per square foot above normal, and houses sold three times faster than average (Rocky Mountain Institute et al. 1998).



Redesigning the Economy

Resource efficiency is natural capitalism's cornerstone, but only its beginning. Natural capitalism means not only reducing inefficiency, but eliminating the entire concept of waste by adopting biological patterns, processes, and often materials. Essentially every product of today's industrial world is produced in unsustainable ways that require fossil fuels, toxic chemicals, brute force, and nonrenewable resources.

Biomimicry, the conscious emulation of life's genius, is a profound approach to sustainability. Janine Benyus, author of *Biomimicry: Innovation Inspired by Nature*, asks a simple question: "How would nature do business?" Nature, for example, runs on sunlight, not high flows of fossil energy. It manufactures everything at room temperature. Nature does make dangerous substances, but nothing like nuclear waste that remains deadly for millennia. It creates no waste, using the output of all processes as the input to some other process. Nature shops locally and creates beauty.

Biomimicry, though, is only half of what is required to redesign the economy. The other half is called cradle-to-cradle production—remanufacturing, reusing, and returning products to use rather than to landfills. In 1976 Walter Stahel, director of the Swiss Product Life Institute (widely recognized in Europe as one of the founders of the sustainability movement), proposed extending the life of products as a way to deliver better value and substitute the use of people for resources such as energy. Stahel analyzed cars and buildings and concluded that every product-life extension saved enormous amounts of resources while generating jobs.

Stahel described how in 1993, as U.S. companies faced hard times, the corporate world made heroes of such restructurers as Al Dunlap and Jack Welch. Dunlap, in the name of "creating shareholder value" gained the name "Chainsaw Al," when in twenty months as CEO of Scott Paper he devastated the 115-year-old company by terminating 11,000 people, or 35 percent of the labor force, including 71 percent of the staff at corporate headquarters. His counterpart at General Electric (GE), dubbed "Neutron" Jack Welch, cut GE employment from 380,000 to 208,000.

Stahel also described how, in contrast, in the early 1990s Honda used its workers to maintain and repair its own machines rather than suffer layoffs that would damage worker morale and lead to work stoppages. Moving toward eco-efficiency, European and Japanese policy makers are increasingly considering tax shifting—eliminating taxes on employment and income and substituting taxes on pollution and depletion of resources. For example, taxes on heavy metal emissions in the Netherlands have reduced water pollution in the county while paving the way for cuts to income and wage taxes (Worldwatch Institute 1997).

The logic of capitalism, the greatest known system in human history for the creation of wealth, hasn't changed: economize on your scarce resources. But with 10,000 more people arriving on Earth every hour, and every ecosystem in decline, today's recipe for prosperity is to restructure the economy, as Stahel outlined, to encourage the use of people and to penalize the waste of resources.

Managing for Restoration

The third principle of natural capitalism is to manage all institutions to reverse the planetwide destruction of ecosystems by reinvesting profits from eliminating waste to restore natural and human capital. For example, wildlife biologist Allan Savory's Holistic Management has shown how to use more ecologically intelligent grazing practices that increase the size of herds while improving even arid and degraded rangelands and increasing ranchers' profits. (Savory and Butterfield 1999). The California Rice Industry Association partnered with environmental groups to switch from burning rice straw to flooding 30 percent of California's rice acreage after harvest. The business model is a far more profitable mix of lucrative hunting licenses, free cultivation, and fertilization by millions of wild ducks and geese, high-silica straw, and groundwater recharge, all with rice as a profitable by-product (personal communication with Ralph Cavanagh, National Resources Defense Council, 1999).

This approach is clearly essential in industries like forestry, farming, and fishing, whose success depends on the health of the natural systems from which they draw, but it is spreading rapidly to other industries as well.

Perhaps the tipping point in the corporate movement toward greener production came when GE announced "ecomagination." As part of the initiative, GE chairman Jeffrey Immelt promised to double GE's investment in environmental technologies to $1.5 billion by 2010. Immelt also announced that GE would reduce the company's greenhouse gas emissions 1 percent by 2012; without action, emissions would have risen 40 percent. Immelt stated at a speech at George Washington University: "We believe we can help improve the environment and make money doing it" (Bustillo 2005).

Critics charged that GE was "greenwashing," badging some of its existing products as green and changing little else. Hypocrisy, however, is often the first step to real change. Less than a year after his first announcement, Immelt announced that his green-badged products had doubled in sales volume over the prior two years, with back orders for $50 billion more, far surpassing his initial prediction of $12 billion in sales by 2010. Over the same time frame, the rest of GE's products had only increased 20 percent in sales. GE also announced that it had reduced greenhouse gas emissions by 4 percent in 2006, dwarfing its 2012 target of 1 percent.

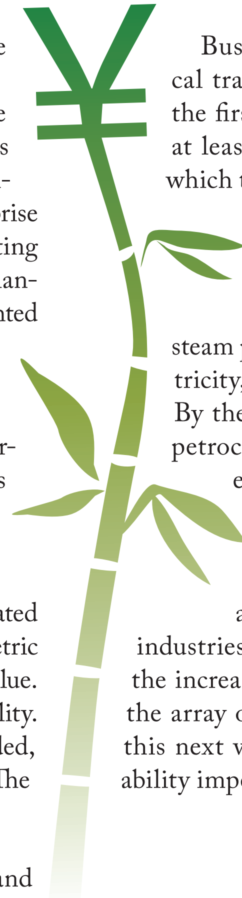
Companies that increase resource productivity and implement such sustainable strategies as biomimicry and cradle to cradle, especially in the context of a broader whole-system corporate sustainability strategy, enhance every aspect of shareholder value.

More recently, a company's profits and stock value have had to increase over each quarter or a company was considered to be on shaky ground. This highly questionable metric is so incompatible with managing an enterprise for long-term value that even the Financial Accounting Standards Board (FASB) has undertaken to rewrite financial reporting to encourage alternatives to such shortsighted behavior.

Sustainability advocates have urged that companies instead manage to a "triple bottom line": achieve profit, but also protect people and planet. While a tempting formulation, this has had the effect of forcing companies to care about the environment and social well-being in ways that increase costs, which reduces the traditional measure of profit.

A much more useful approach is that of the "integrated bottom line," which recognizes that profit is a valid metric but only one of many that gives a company enduring value. Done smartly, behaving responsibly increases profitability. When the other aspects of shareholder value are included, the business case for sustainability is overwhelming. The integrated bottom line measures three major criteria:

- Enhanced financial performance from energy and materials cost savings in
  - industrial processes
  - facilities design and management
  - fleet management
  - operations
- Enhanced core business value by
  - sector performance leadership
  - greater access to capital
  - "first mover advantage," that is, the advantage gained by the first entity in a market segment
  - improved corporate governance
  - the ability to drive innovation and retain competitive advantage
  - enhanced reputation and brand development
  - increased market share and product differentiation
  - ability to attract and retain the best talent
  - increased employee productivity and health
  - improved communication, creativity, and morale in the workplace
  - improved value chain management
  - better stakeholder relations
- Reduced risk by
  - insurance access and cost containment
  - legal compliance
  - reduced exposure to increased carbon regulations and price
  - reduced shareholder activism



Business success in a time of technological transformation demands innovation. Since the first Industrial Revolution, there have been at least six waves of innovation, each shifting which technologies underpinned economic prosperity. In the late 1700s, textiles, iron mongering, waterpower, and mechanization enabled modern commerce to develop. The second wave introduced steam power, trains, and steel. In the 1900s, electricity, chemicals, and cars began to dominate. By the middle of the twentieth century, it was petrochemicals and the space race, along with electronics. The most recent wave of innovation brought computers and ushered in the digital or information age. As we enter "the next Industrial Revolution" and economies move beyond iPods, older industries will suffer dislocations unless they join the increasing number of companies implementing the array of sustainable technologies that make up this next wave of innovation. This is the "sustainability imperative."

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See also Biomimicry; Climate Change Disclosure; Cradle to Cradle; Development, Sustainable; Ecosystem Services; Energy Efficiency; Energy Industries—Overview of Renewables; Energy Industries—Solar; Facilities Management; Green-Collar Jobs; Investment, CleanTech; Investment, Socially Responsible (SRI); Remanufacturing; Social Enterprise; Transparency; True Cost Economics

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The Natural Step Framework (TNSF)

The Natural Step Framework for Sustainable Development, a model created by scientists and implemented by the nonprofit group The Natural Step, is used internationally by many different types of organizations to plan for sustainability. The scientifically-based Framework uses a methodology of backcasting from principles, which starts with a desired goal and then identifies the steps needed to reach that goal.

The Natural Step (TNS) is an international not-for-profit research, education, and advisory organization dedicated to sustainable development. The Natural Step began in Sweden in 1989; in 2009 it had offices in eleven countries. These TNS offices promote a systems approach to dialogue and decision making in partnership with businesses, communities, governments, and academic institutions around the world.

The Natural Step was founded by oncologist Dr. Karl-Henrik Robèrt and began as a broad-based movement promoting sustainable development in Sweden. Recognizing debate and confusion about the state of the planet at the time, Dr. Robèrt led a consensus process that sought agreement among scientists on a basic understanding of cells and the requirements for the continuation of life. Over the years, science-based principles for sustainability and a planning framework for strategic sustainable development have emerged.

This approach, built upon a methodology of backcasting, evolved into the Natural Step Framework for Sustainable Development. (The opposite of forecasting, backcasting envisions a desirable future goal and then identifies the strategic steps needed to reach that goal.) The Natural Step Framework is an open-source framework—one that is added to and developed by its users—that is continually modified, applied, and refined in collaboration with academic, business, and community organizations.

What Is The Natural Step Framework?

The Natural Step Framework (TNSF) is a model that helps people make practical decisions to move toward sustainability. TNSF provides a structured systems approach to planning for sustainability and allows for the effective selection and use of many other tools and concepts needed for sustainable development.

TNSF relies upon five interconnected levels: system, success, strategic guidelines, actions, and tools.

System

TNSF first clarifies the system it is interested in sustaining: human society. Furthermore, TNSF acknowledges that human society is dependent upon the ecosphere, so the ecosphere must also be sustained. Then TNSF identifies the four basic principles widely agreed upon in the scientific community regarding how ecological systems work:

- According to the Conservation Laws of physics, matter and energy cannot be created or destroyed. This means that in isolated systems, energy and matter may be converted into different forms, but the total amounts of energy and matter remain constant. The Earth, however, is an *open* system with respect to energy because energy is coming in from the sun and being radiated back out to space. Unlike energy, the Earth is a *closed* system with respect to matter; essentially all of the matter that is on Earth is staying on Earth, and essentially no new matter is coming to Earth.

- According to the Second Law of Thermodynamics, energy and matter tend to spread spontaneously; everything has a tendency to disperse. This means that eventually all the matter that is introduced into society (either from the Earth's crust or human-made) will be released into natural systems.
- Material quality is characterized by the concentration and structure of matter. Societies cannot consume energy and matter, but they do consume the quality, purity, and structure of matter—its material quality—not its molecules.
- Photosynthesis is the process through which green plant cells capture energy from the sun; it is what allows animals, including people, to indirectly use the energy from the sun. Net increases in material quality on Earth are generated almost entirely by photosynthesis.

Success

With a simple understanding of the human and ecological systems, The Natural Step Framework then identifies what it means to sustain those systems. But it is difficult to say exactly what sustainability looks like: Will society use only solar power in a sustainable future? Will people drive cars in a sustainable future? Instead of defining what is sustainable, TNSF defines what is not sustainable—anything that may destroy human society or the ecological system it depends upon. It follows that as long as people do not do things that destroy the system, people can do anything else they want.

These "conditions" required for the sustainability of human society within the ecosphere include three that address the ecological system and a fourth that addresses the social system (Holmberg and Robèrt 2000; Ny et al. 2006). In a sustainable society, nature is not subject to systematically increasing:

1. concentrations of substances extracted from the Earth's crust (fossil fuels or rare metals, for example);
2. concentrations of substances produced by society (persistent chemicals that do not break down quickly, for example);
3. degradation by physical means (deforestation, loss of wetlands, damage from mining, or soil degradation, for example);

and in that society,

4. people are not subject to conditions that systematically undermine the capacity to meet their needs.

It is difficult to use these conditions to plan within an organization. So TNSF rephrases these conditions into four corresponding sustainability principles that provide clear guidance for how an organization can move toward sustainability (The Four System Conditions 2009). To become a sustainable society we must:

1. eliminate our contribution to the progressive buildup of substances extracted from the Earth's crust
2. eliminate our contribution to the progressive buildup of chemicals and compounds produced by society
3. eliminate our contribution to the progressive physical degradation and destruction of nature and natural processes
4. eliminate our contributions to conditions that undermine people's capacity to meet their basic human needs (unsafe working conditions and insufficient living wages, for example)

Strategic Guidelines

Once success is defined it allows people to plan and prioritize actions in a strategic way that can move step by step toward success. This approach—beginning with success in mind—is a planning procedure called backcasting. Backcasting is frequently applied within the context of a specific scenario, such as, "What do we want our company/product/city (for example) to look like in the future?" These scenarios, or visions of success, are created by disconnecting from current trends so that today's constraints do not limit future opportunities.

It is usually very difficult to get groups of people—let alone society at large—to agree on a specific scenario of what the future should look like; the future may unfold in many different ways, and current technology and imagination may limit the possible scenarios people are able to envision. Therefore TNSF uses basic science concepts to arrive at principles for success that describe only the basic conditions that human society must meet in order to be sustainable. Hence, the Framework is based on the concept of backcasting from sustainability principles.

Once these conditions are known, it then becomes possible to plan for individual, organizational, and societal success within these basic constraints for global socioecological sustainability.

Actions

Using the strategic guidelines, an organization that is using TNSF to direct its planning can prioritize its actions. TNSF employs three overarching questions to guide this prioritization:

1. Does the action move in the right direction, that is, towards compliance with the sustainability principles?
2. Is the action a "flexible platform" that will serve as a foundation for further action into the future?
3. Does the action provide adequate return on investment?

Tools

Finally, with this structured approach it becomes possible to identify the tools and concepts that are needed to make progress toward the goals and deploy them when and where they are most effective throughout the planning process.

Applications of TNSF

TNSF has been used by thousands of organizations around the world. The Natural Step network has used the Framework to support the planning endeavors of many organizations seeking to become more sustainable, including large companies like IKEA, Nike, Scandic Hotels, Electrolux, Panasonic, McDonald's, Hydro Polymers, Rohm and Haas, and Interface. Nike, for instance, launched Considered Design program ("performance without compromising sustainability") in 2008, ten years after TNSF helped the company address its initial sustainability goals. Many small and medium-sized organizations have also used the Framework. Whistler Blackcomb, a resort ski area in British Columbia, Canada, site of many events for the 2010 Olympics, has developed its strategic plan using TNSF as a guide, as have other communities in Canada, Sweden, Ireland, and the United States.

TNSF has been used to assess the strengths and weaknesses of several methods, tools, and concepts related to sustainable development, such as ecological footprinting, Factor 4, Daly's principles, ISO 14001 (environmental guidelines set by the International Organization of Standards), Lifecycle Assessment (LCA), industrial ecology, and product development methods. The strength of LCA, for instance, is quantifying the known environmental impacts of the system of study. From a full sustainability perspective, however, it is important for a user of LCA to know that it will not identify unknown (potential) environmental impacts: that is where TNSF comes into play.

Graduate students in the Strategic Leadership toward Sustainability program at Sweden's Blekinge Institute of Technology have applied TNSF to topics as diverse as biofuels, business incubators, food systems, rock concerts, and conflict resolution. The Framework is also the basis of an international research collaboration initiated by The Natural Step, Blekinge Institute of Technology, and Lund University (Sweden) called Real Change, which is reaching out to involve a growing number of universities around the globe.

The Framework is widely described in various scientific papers, books, and other publications. In addition, scientific consensus declarations are known to have taken place in Sweden, United Kingdom, Australia, and the United States.

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See also Design, Industrial; Development, Sustainable; Ecosystem Services; Integrated Product Development (IPD); Lifecycle Assessments (LCAs); Manufacturing Practices; Municipalities; Performance Metrics; Remanufacturing; Smart Growth

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Packaging

Because product packaging is a highly visible symbol of the impacts of economic development, it has been a frequent target of environmentalists. Whether undertaken voluntarily or regulated by governments, the ways that packaging is designed, used, and managed throughout its lifecycle are changing; it is expected to utilize energy efficiently, avoid hazardous and toxic substances, and be recoverable at end-of-life.

It is worth addressing the question of why we package products in the first place: to protect the product, to increase the shelf life, and to ensure the integrity of the product contained within are all important considerations. Products are also packaged for marketing reasons. The presentation of a product is often the key reason for its success or failure; therefore packaging is integral to modern systems of production and consumption.

The packaging industry has been under pressure for more than twenty years to reduce the environmental impacts of its products. Over that time the emphasis has shifted from a simple concern regarding landfill to the twenty-first century's emphasis on reducing carbon dioxide emissions. Packaging has maintained its high profile in the public discussions on environmental issues because it is a visible symbol of the impacts of industrial development on the environment. This has resulted in government responses varying from strict regulations to voluntary agreements between stakeholders. Most of these measures are developed around the traditional waste management hierarchy: reduction, reuse, recycling, and recovery.

Environmental Regulations

The environmental impacts of packaging are subject to an increasing number of international government regulations and co-regulatory agreements. Because these regulations are extremely varied, companies that manufacture or use packaging need to stay up-to-date on these regulatory trends; indeed these regulations are driving changes in the way that packaging is designed, used, and managed at end-of-life and, of course, in the legal obligations pertaining to that.

One of the key changes is a shift to "product stewardship," or the idea that companies need to share responsibility for reducing the impact of products on the environment over their total lifecycle. Companies are required to look at the impacts of their supply chain and to work closely with suppliers to implement environmental improvement programs. They are also required to design products that use materials and energy as efficiently as possible, as well as avoiding the use of toxic or hazardous substances in the products. Companies must also design products that are recoverable at end-of-life.

In the United States and Australia, amongst others, the "shared responsibility" regulatory model is preferred. There is no federal legislation in the United States specifically targeting packaging and its environmental impact, but state and local government concerns about packaging waste continue to grow. As of 2009, some U.S. states have established minimum recycled content standards for plastic (California, Oregon, Wisconsin), glass containers (California, Oregon), plastic trash bags (California), and newspapers (twenty-seven states). Cities such as Seattle, Washington, and thirty municipalities in California (including San Francisco) have recently banned or restricted the use of expanded polystyrene (EPS, more commonly known as Styrofoam) in "to-go" containers.

The National Packaging Covenant (NPC) in Australia promotes product stewardship in the packaging supply chain through voluntary agreements and action plans. The new draft Australian Covenant focuses more on design for sustainability, incorporating the concepts of cradle to cradle and lifecycle analysis to ensure that sustainable practices are implemented by the supply chain.

The extended producer responsibility (EPR) approach is more commonplace in Europe, where physical or financial responsibility for waste management is placed on producers. EPR makes the brand owner or importer primarily responsible for the recovery of packaging. From the late 1980s to early 1990s, various European countries started developing EPR regulations. To harmonize the approach, the European Union (EU) introduced the Packaging and Packaging Waste Directive in 1994 (amended 2004). The Directive sets standards known as the Essential Requirements (ERs). All companies who sell products in EU member states must comply with the five areas outlined below:

- Source Reduction: Companies must demonstrate that they have reduced their packaging as much as possible and then identify the critical area (such as product protection, safety, consumer acceptance, and so on) that prevents further reduction in weight or volume of a packaging component.
- Recovery Standards: Packaging components must be recoverable by at least one of three recovery routes (energy, organic, or material recovery) and must meet certain requirements specific to that recovery route.
- Reuse: Optional, but a package must meet the requirements of the reuse standard if it is claimed as reusable.
- Heavy Metals Content: Sets a concentration limit for lead, cadmium, mercury, and hexavalent chromium in packaging; standards are similar to those in effect in nineteen U.S. states.
- Reduction of Hazardous Substances in Packaging: Substances classified as noxious (for example, zinc) must be minimized if they could be released in emissions, ash, or leachate when packaging is landfilled or burned.

All packaging placed on the EU market must be in compliance with the ERs, and products that do not comply may be removed from the market. Companies must incorporate the ERs into their packaging design systems and document how each standard was considered into its packaging design protocol.

The assessment process to prove compliance with the ERs is similar to ISO14000 requirements in that it establishes a framework for evaluating the attributes of a packaging system (and identifying areas for improvement) with respect to the requirements of the law. The European standards have been developed to provide a common procedure for assessing and documenting compliance.

A range of packaging regulations have been introduced in parts of Asia including China, Japan, South Korea, and Taiwan. Japan has chosen the EPR option with its Packaging Source and Separation Law (1995), which makes manufacturers responsible for recycling plastic containers, glass, paper cartons, and paperboard boxes. Many Chinese municipalities have adopted recycling mandates or bans for certain food packaging materials.

Various regulations also attempt to prevent excessive packaging through specific requirements, in addition to the incentives that result from fee structures. Several countries have implemented regulations regarding empty space and the permissible number of layers in a packaging system. Many countries, such as Australia, Belgium, the Netherlands, Greece, Slovakia, Spain, and South Korea, require companies to submit a detailed packaging reduction plan. These plans must outline the long-term goals of the manufacturers to reduce their packaging.

Regulations relating to misleading advertising of products as "environmentally friendly," deceptive environmental labeling, and proper material coding have been adopted by many countries. Since 2005, more than thirty countries have introduced environmental packaging design requirements including regulations on toxics in packaging, empty space and source reduction, recycled content, environmental labeling, and packaging prevention planning.

What Is Sustainable Packaging?

The high visibility of packaging married with its importance as an essential facilitator for the distribution, marketing, and safe use of consumer and other products creates significant challenges for advancing sustainable development in packaging. Consumer behavior and spending trends, market segmentation, and developments in distribution are examples of motivators for new packaging formats and technologies, which are often contrary to the principles of sustainable development (James, Fitzpatrick, Lewis, and Sonneveld 2005).

Even though packaging and the relevant environmental regulations are found worldwide, there is no clear international understanding about what constitutes sustainable packaging. The Sustainable Packaging Alliance (SPA) has identified this as one of the most pressing and overarching challenges in advancing sustainable development in the packaging domain.

Various packaging organizations, including the SPA in Australia and the Sustainable Packaging Coalition (SPC) in the United States, have tried to define "sustainable packaging" by establishing sets of principles or strategies that could guide decision making by businesses.

Four Principles of Sustainable Packaging

As defined through research by Australia's Sustainable Packaging Alliance, there are four principles that can be integrated into business systems to guide their packaging practices and product stewardship (Lewis, Fitzpatrick, Varghese, Sonneveld, and Jordan 2007, 16–18). Each of these characteristics needs to be adapted to the specific requirements of the company, and not every action will be addressed or relevant to every business.

Effective: Social and Economic Benefit

Packaging systems add value to society by effectively enclosing and safeguarding products as they travel through the supply chain. Packaging should also encourage educated and responsible utilization. In order to achieve this benefit, businesses must:

- eliminate any excessive packaging
- guarantee that the packaging satisfies supply chain requirements for product protection, containment, distribution, retailing, and use
- design the packaging system to reduce total lifecycle environmental impact
- reduce overall supply chain expenses
- present information to consumers on environmental qualities of the packaging
- provide guidance to the consumer on correct disposal of the packaging

Efficient: Doing More with Less

Packaging systems are designed to use materials and energy efficiently throughout the product lifecycle. Efficiency should be defined through reference to best practice at each stage of the packaging lifecycle, including steps such as:

- reducing packaging volume and weight to only what is needed for product protection, safety, hygiene, and acceptance by the consumer
- increasing the efficiency of the product-packaging system by changing the product
- reducing product waste
- raising energy and water efficiency during manufacturing and recovery systems
- improving transport efficiency

Cyclic: Optimizing Recovery

Recycling of packaging materials used in the system should occur through natural or industrial systems with nominal material degradation. Recovery rates should be improved to ensure that they achieve optimum energy and greenhouse gas reductions. There are many opportunities that businesses can pursue to implement this principle:

- guarantee that the packaging can be collected and processed within identified cyclic loops
- employ reusable packaging to reduce environmental impacts by increasing return rates
- use only one material whenever possible, or use materials that are easy for the consumer to separate and that do not contaminate recycling systems
- identify compostable rather than oxo-degradable materials and ensure that a system is available for collection and processing. ("Oxo-degradable" refers to plastics that have been manufactured in such a way that the degrading process is sped up, ideally to the point that the plastic disintegrates into its component minerals. The process is controversial, with some critics saying that the technology is worse for the environment than ordinary plastic; critics also say the process is unregulated [Smith 2009].)
- specify renewable materials that provide the lowest environmental impact
- utilize renewable energy (both stationary and transport types) with the least environmental impact
- use cleaner production techniques for manufacturing, best practice materials, and energy consumption technologies

Safe: Nonpolluting and Nontoxic

Packaging components used in the system—including materials, finishes, inks, pigments, and other additives—should not pose any risks to humans or ecosystems. Safety includes complete avoidance or minimization of:

- heavy metal–based additives
- any material or additive that can migrate into food and be harmful to the health of living organisms
- materials or additives that may endanger humans or ecosystems during recovery or disposal
- the environmental impacts of transport (considering distance, mode of transport and fuel type) to the greatest extent possible

Outlook for the Twenty-First Century

Associating sustainability with product packaging systems is an abstract and complex concept, and one that is very much open to interpretation. To be able to advance sustainable development in packaging, stakeholders need specific guidance as to how they can implement it into their daily business practice. A collaborative, multidisciplinary approach is required for sustainable packaging because the process involves many professionals, including designers, technologists, marketers, and environmental managers.

Individual large brands and organizations are developing or have developed useful frameworks to support sustainable packaging strategies. Walmart's goal is to reduce packaging used by suppliers by 5 percent by 2013. In an effort to achieve this target, the retail introduced a scorecard system that will allow manufacturers to rank their current use of packaging. Scores will be given on several relevant categories including: greenhouse gas emissions produced per ton of packaging, raw material use, packaging size, recycled content, material recovery value, renewable energy use, transportation impacts, and innovation. Since the beginning of 2008, Walmart has made purchasing decisions based on the scorecard results.

New tools have been developed to evaluate the lifecycle environmental impacts of packaging, while the global warming debate has encouraged some companies to focus on the carbon footprint of packaging as a relevant and simple way of communicating environmental impact.

The issue of sustainable packaging requires ongoing debate with the objective of achieving consensus among stakeholder groups on definitions and key indicators. For example, the sector will need to reconcile the sometimes conflicting lifestyle expectations of consumers, (such as the greater convenience, safety, and shelf life of products) with the sustainable packaging expectations of many of these same citizens (Sonneveld, James, Fitzpatrick, and Lewis 2005).

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See also Consumer Behavior; Cradle to Cradle; Design, Industrial; Ecolabeling; Lifecycle Assessments (LCAs); Manufacturing Practices; Marketing; Supply Chain Management; Zero Waste

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Peace Through Commerce: The Role of the Corporation

The idea of "peace through commerce"—that trade can promote peace—is an old one, but to achieve sustained peace, corporations must attend to the ways in which they do business. In order to contribute to peace, companies can provide jobs and economic development, attend to rule of law, build a sense of community and citizenship, and act in ways to improve harmony where they do their work.

The idea of achieving peace through enhanced trade is an old—and in some circles discredited—one. Neighbors often trade. They also often fight. For example, nearly all the warring parties of World War I traded with each other after the war; Germany and the Soviet Union traded right up to the beginning of World War II. Countries that do trade are not likely to be simultaneously killing each other's citizens, but disagreements over trade can also serve as the cause, or at least pretext, for war: Japan bombed Pearl Harbor after the United States cut off oil exports.

Nevertheless, the idea of "peace through commerce" (as well as Peace Through Commerce, the outreach program developed in the endeavor to sustain peaceful relations in the world) has a lustrous pedigree. The twentieth-century Nobel Peace Prize–winning economist and philosopher Friedrich August von Hayek agreed with the eighteenth-century philosophers Immanuel Kant and the Baron de Montesquieu on the pacific benefits of enhanced trade: one of the three "legs" of Kant's peace theory was free trade; Montesquieu saw peace as the natural effect of trade; and Hayek argued that if the world supported more international trade, then more international peace will follow. Indeed, the notion that strong economies make for peaceful partners seems alive today as well.

But why trust trade? Paul Collier, professor of economics at Oxford University and former director of the Development Research Group at the World Bank, warns that one of the best predictors of a civil war is if a country's main export is an undifferentiated commodity, for instance, oil, diamonds, and timber. Colonialism fostered trade, but is that the kind of model that would lead to sustainable peace? Trade often threatens the cultures upon which it intrudes. Many argue that one of the reasons that terrorists find refuge in many Islamic cultures is because of the resentment over U.S. foreign policy and the economic intrusion into traditional ways of life.

Trade does not always lead to peace, and global trade does not guarantee stability. It can do just the opposite: it can sow the seeds for resentment and backlash, and in certain countries, it may enhance the likelihood of civil war and ethnic violence. It does this because trade does not simply work at a macro level. When governments advance trade policies, the arguments are made in general terms, like enhancement of gross domestic product (GDP). Trade also works at a micro level. The way in which companies do their work can have positive or negative effects. Companies can trigger resentment and sometimes even violence. This is true even if the colonial model is avoided.

Victoria's Secret, Harrods Department Store, and American Eagle all faced protests after they sold women's swimwear and lingerie with depictions of Hindu and Buddhist figures stitched onto them. Actions like this can cause protests; they can also be used to whip up frenzy, as exemplified by the 2006 outrage in Europe over cartoons with a caricatured Prophet Muhammad.

More subtly, but more worrisome, the editor in chief of *Foreign Policy* magazine Moisés Naim has shown that globalization breaks down borders of nation-states. In doing so, it also limits the abilities of nation-states to control slavery, drug trading, arms trafficking, and money laundering. These lines of business have a long and brutal history of violence.

Today there is a growing movement that puts a new twist on the Peace Through Commerce argument. The wrinkle this approach takes is that trade does not necessarily promote stability, but there is a certain kind of commerce that does. It is a commerce that pays attention to the specific actions of businesses individually and collectively. Most analysis of how commerce can promote peace has focused on macroeconomic issues. As the economist Friedrich August von Hayek (1899–1992) argued, support more international trade and more international peace will follow. To be sure, counting up GDPs of various countries may correlate with some levels of stability, but there are more micro- and meso-levels to explore in figuring out how commerce might enhance peace. For example, a macro level would look at balance of trade payments between countries, while a meso or micro level would look at the impact of a particular industry or a particular business.

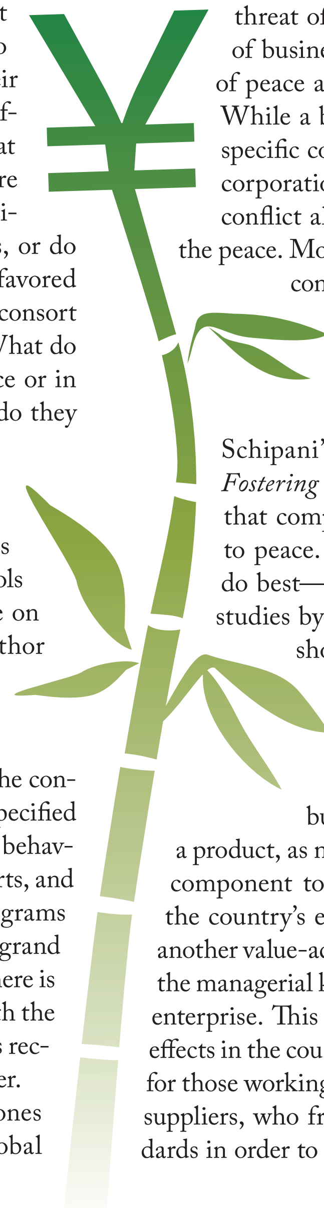
The new Peace Through Commerce approach does not eschew the macro viewpoint; instead it focuses on the particular ways that businesses do their work. How do individual businesses treat their own employees? Who may come and live in different parts of the world? How do businesses treat the citizens of countries in which they work? Are they culturally sensitive, or are they imperialistically domineering? Are they ecological stewards, or do they dump toxic waste in the rivers used by disfavored ethnic groups for their drinking water? Do they consort with corrupt officials, or do they avoid bribery? What do they do about encouraging voice in the workplace or in protecting human rights or gender equity? How do they impact religious beliefs?

This new approach comes right out of schools of management. Indeed, the Association for the Advance of Colleges and Schools of Business (AACSB), the accrediting body for business schools in seventy-two countries, established a task force on Peace Through Commerce (on which this author served) and issued a report surveying the activities of business schools on the topic. Some schools have had very active, focused programming on the issue. Others have engaged in activities in which the concept of peace through commerce was not exactly a specified aim, but which have championed ethical business behavior through cultural exchanges, developmental efforts, and corporate social responsibility and citizenship programs with an international focus. While it may be too grand to call Peace Through Commerce a "movement," there is a growing body of scholarship that looks underneath the macro level to the micro and meso levels where it is recognized that particular behaviors of business matter.

One area of focus is how businesses work in "zones of conflict." For instance, the United Nations Global Compact has identified specific ways that companies can work in conflict-sensitive zones and do so in a way that generally mitigates, or at least does not enhance, tensions. Companies need to be more open, engaging, and transparent in their work. Thus, conducting risk analysis in the first place, engaging in "multistakeholder dialogues," being transparent in how revenue is secured and where it goes, and philanthropically (through time or money) supporting the development of civil society are all ways of creating better understanding in places where companies could find themselves in the midst of violence.

Practical Practices

At a more general level, another approach is to look at how businesses contribute to sustainable peace regardless of whether they find themselves in an immediate threat of conflict. The overwhelming majority of businesses make more money during times of peace and stability than in the midst of war. While a business in a zone of conflict has very specific concerns it must address to do business, corporations that are not directly in a zone of conflict also have a business interest in keeping the peace. Moreover, in a world where violence is not contained within discrete zones of conflict, addressing broader concerns of justice becomes a more central concern of any business.



In Timothy L. Fort and Cindy Schipani's 2004 book *The Role of Business in Fostering Peaceful Societies*, the authors argue that companies could make four contributions to peace. First, they could do what companies do best—spur economic development. Because studies by the United Nations and World Bank show correlations between poverty and violence, companies that generate the profits shareholders desire can also provide jobs and economic development. That is particularly true if the business done is not simply in extracting a product, as noted above, but provides a value-added component to the product so that it differentiates the country's economy. Well-run businesses provide another value-added component in emerging countries: the managerial know-how of how to successfully run an enterprise. This knowledge transfer can have spillover effects in the country for those working for the company, for those working with the company (i.e., the company's suppliers, who frequently must adhere to certain standards in order to supply a multinational enterprise), and those who leave the company to start their own businesses with the knowledge of how to do it well.

Second, there are clear connections between rule-of-law kinds of governance and peace. Corruption is linked to violence, just as rule of law, civil dispute resolution, and enforcement of property and contract rights are linked to peace. Indeed, these kinds of connections are now trumpeted by the Organization for Economic Cooperation and Development (OECD), the World Bank, and others as necessary dimensions of accountability. This is why there is such an effort to curb corruption and why economists such as Peru's Hernando de Soto (b. 1941) champion the reform of property rights in poor countries. In doing so, one can get to some of the causes of poverty (i.e., allowing the poor to access capital they have but cannot get to because of land titling morasses).

Third, companies can institutionalize a sense of citizenship. That works in two ways. The external dimension is what most people consider when they think of corporate citizenship or classic corporate social responsibility: ecological responsibility, cultural sensitivity, and philanthropic engagement. Perhaps the more interesting dimension is how the company creates a sense of belonging within its own corporate walls. In some emerging countries there is little tradition of democracy, yet many studies show that democratic countries do not go to war with each other. A central feature of democracy is voice. While many corporations are as autocratic as many autocratic government leaders, many management strategies require that individual workers speak up if they see a product defect. That is an exercise of voice. Without going so far as to advocate for workplace democracy, it is worth exploring whether these voice-empowering management practices might have a spillover effect of encouraging voice in other (political) aspects of employees' lives. Similarly, studies also show negative correlations between gender equity and violence, and between group sizes (where there is a sense of empowerment because of the relative size of the group) and violence.

A fourth aspect may simply be the name for this as a whole: Track Two diplomacy. Multitrack diplomacy occurs when nonstate actors interact with others in a way that diffuses tensions between peoples. In doing so, they provide room for leaders of nation-states to negotiate differences. Thus, Richard Nixon's Ping-Pong diplomacy with China back in the 1970s is an example of how cultural exchanges can soften the image of another people and can allow leaders then to more easily negotiate agreements with the leaders of another country, which is not quite so fearsome after the exchanges occur. Similarly, businesses can act in a Track Two fashion if they act in ways that improve harmony and friendship where they do their work. How they do this is by practicing the three dimensions just explained: fostering economic development, supporting rule of law structures, and acting as good citizens.

Peace Through Commerce: Corporate Responsibility

Anthropologists, political scientists, and economists have shown connections between certain attributes and violence. The recommendations made by Fort and Schipani in *The Role of Business in Fostering Peaceful Societies* could be called a "governance and peace" approach because the notion is that corporations can be governed in a way that correlates with the attributes of relative nonviolence. Moreover, the specific contributions identified by Ford and Schipani are simply those that have significant currency in most business ethics circles. Responsibility to shareholders and their rights to profits is a standard fiduciary duty. Adhering to rule of law, respecting contract and property rights, supporting civil dispute resolution forums, and avoiding bribery are hardly controversial regardless of whether one comes from a conservative or liberal political approach. More controversial is the community dimension. Voice, gender, rights, ecological stewardship, and cultural sensitivity can be flashpoints in political debates and in schools of management. Yet those flashpoints revolve more around whether there is a corporate duty to, say, encourage voice within corporate decision making. If one moves beyond deontological determinations and simply notes that voice, gender, rights, ecological stewardship, and cultural sensitivity tend to be correlated with more peace and that their opposite is associated with greater violence, then one can leave the question of what to do to aspirational choice. In other words, whether there is a duty for corporations to contribute to dimensions of peace, the positive consequence of doing so creates a persuasive reason to embrace them.

Substantiating both the zones of conflict and the governance and peace approach, the U.S. secretary of state recognizes companies whose work improves diplomatic relations between foreign countries and the United States. Started in 1999 by Madeleine Albright and continued under both Colin Powell and Condoleezza Rice, the Award for Corporate Excellence essentially looks at companies that empower citizens of other countries with knowledge and technology (for instance, Motorola for its work in both Malaysia and China), that respond to disasters in countries by engaging in philanthropic reconstruction (for instance, F.C. Shaffer for its help in rebuilding its competitor's sugar refineries in Ethiopia), or that value the essential worth of their employees through education and health programs (for instance, Ford for its HIV-awareness program in South Africa).

Corporations are major actors on the world stage today. They are not simply the instruments of the projection of nation-state ambitions. They straddle boundaries and have their own self-interests that frequently transcend those of any one state. At this time and place in history, they have power vis-à-vis governments as independent political actors, and the way in which they conduct their affairs makes a difference. Most of them do not have armies to deploy in actual shooting battles (although some do, or they hire mercenaries that do), but one does not have to have armies to have significant political influence. In a very different way, corporate actions make a difference.

But what difference? How would one recommend that corporations act? Why should they be trusted in the first place? Are corporations not prone to scandal, corruption, autocracy, and selfishness themselves?

The solution is not to say that commerce promotes peace, but to specify more clearly what commercial activities and practices contribute to the processes of stability. Academic work to date is suggestive and plausible rather than definitive and compelling. There is more to be developed. In particular, it is worth recognizing that corporate responsibility itself has many dimensions and titles ranging from business ethics to corporate social responsibility to corporate citizenship to corporate governance. Driving all of these differentiated aspects of corporate responsibilities—differentiations that are a bit difficult to really sustain—are legal approaches, managerial (normative and empirical) approaches, and aesthetic, even spiritual, quests for excellence.

These approaches are not the same thing, and they rarely engage with one another. Management articles talk about how codes of conduct are prevalent today solely because of the marketing advantages such codes confer without any awareness of how the U.S. Federal Sentencing Guidelines and the Sarbanes-Oxley Act (also known as the Public Company Accounting Reform and Investor Protection Act of 2002) mandate them. Such legislative efforts require that companies create and monitor "effective" corporate compliance and ethics systems. Legal scholars are frequently unaware that empirical studies have been done to show what makes (or does not make) for effective corporate compliance programs, evidence that one would think would be highly relevant to meet the Federal Sentencing Guidelines standard requiring companies to develop "effective" programs. For all the legal regulations, financial corollaries, and philosophy, few scholars from any of these disciplines pay attention to spiritual reasons why a person might be interested in ethics in the first place.

This lack of awareness of the various strands of corporate responsibility exists in government as well. Economic development is frequently touted as a remedy for many social ills, but as both Yale law professor Amy Chua and economist Mary Anderson have shown in their writings (respectively, *World on Fire* and *Do No Harm: How Aid Can Support Peace—or War*) economic development can sometimes make things worse, and people fight for perceived inequitable distributions of the wealth generated by development. Combating health issues like AIDS is an admirable corporate action, but to be something other than a one-off, feel-good, PR-grabbing headline, it has to be integrated with a business strategy. Just because businesses are waiving the flag of peace does not make them peaceful; hard choices about how to prioritize particular practices that match the unique situations a company is facing are necessary to contribute to peace through commerce. Those choices become hard when one realizes that a lot of things must be integrated in making decisions about what responsibility means; a company recognizing the difficulty of the choices probably is contributing to peace through commerce much more effectively than one blindly touting the one thing about the concept that has seized its imagination. In other words, one can be fundamentalist about peace and business as much as one can be about religion, and many dangers arise from that approach.

The notion of integrity is relevant here. Integrity does not simply mean honesty. It is a holistic virtue that designates a moral person to "integrate" a variety of important virtues with the wisdom of knowing which virtue is most relevant to a particular situation. Similarly, corporate integrity is not simply about transparency and honesty, although those are important virtues; it is about paying attention to relevant legal standards, matching business practices with rhetorical claims for good ethics, and reaching into the very hearts and souls of managers, shareholders, and employees to connect with the biological desires and capabilities of individuals' desires to achieve good. This is a strategic, holistic approach to corporate responsibility—one that is necessary if companies are to build stability.

Quality is a relevant metaphor. For a couple of decades now, quality theorists have made the point that one does not assure quality products and services by conducting an end-of-the-manufacturing-process inspection. By then, it is too late. If it passes, fine. If not, the company has a dilemma: Does it ship out a defective product? Does it swallow the cost of remanufacturing? Neither is a good answer, which is exactly what dilemmas produce. The way to assure quality is to build in quality checks and measurements throughout the manufacturing process. The same is true of ethics. To make ethics habitual, regularized, and dependable, one has to integrate legal, managerial, and spiritual dimensions of ethics. Just as "Total Quality Management" strives to assure quality by a total approach, "Total Integrity Management" integrates the legal, managerial, and spiritual dimensions of ethics to assure ethical business behavior.

In terms of Peace Through Commerce, the three aspects of ethics are consistent with Fort and Schipani's recommendations for economic development, rule of law, and building of community. Finally, they also reflect the three approaches to corporate responsibility today: legal, managerial, and spiritual. This tripartite formulation provides an inherent differentiation that can work as a metaphor for what corporations might do to promote Peace Through Commerce. No one approach will get corporations to achieve corporate responsibility. A corporation attending to the law will miss the softer ways in which it needs to align incentives with ethical rhetoric and will likely crush the spiritual dimension. A corporation attending only to the financial alignment of rhetoric and reward may miss societal demands for what is permissible, and by reducing spiritual quests for excellence to a financial metric, it will do violence to those ambitions. A corporation attending only to spiritual notions will likely not stay in business.

In short, the way businesses can contribute to peace through commerce is to integrate what already has been set out as ethical business practices, but to do so in a way that integrates legal, managerial, and aesthetic/spiritual perspectives. Getting to that point requires extensive thought by academics as well as business people to move beyond boundary-bound approaches to corporate responsibility. The good news is that significant work has already been done to set out what businesses should do from legal, managerial, and spiritual perspectives, and the recommendations are not that controversial. Instead, the practices are pretty well accepted. By more mindfully, comprehensively, and seriously pursuing these practices, there could be an unexpected payoff for ethical business behavior, and that is exactly the kind of commerce that could make corporations into instruments of peace.

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See also Base of the Pyramid; Corporate Citizenship; CSR and CSR 2.0; Development, Sustainable; Equator Principles; Human Rights; Leadership; Poverty; Social Enterprise; United Nations Global Compact

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Performance Metrics

Due largely to pressure from stakeholders, "performance metrics" now analyze not only the economic value of a business or organization but its environmental and social impacts as well. Increasing numbers of organizations report this information, but the quality of data varies widely. It is critical for organizations to improve the quality of reporting for the sake of both internal and external decision making.

For organizations, a sustainability performance framework—metrics to measure and manage social, environmental, and economic impacts—enables management to create enduring value for multiple stakeholders. Leading companies increasingly are examining the impacts of their products, services, processes, and other activities more broadly. They are looking at a more comprehensive set of social, environmental, and economic consequences and identifying and measuring impacts on a broader set of stakeholders. The size of corporate social and environmental expenditures is increasing rapidly, and the necessity of improved identification and management of these impacts has become critical.

But, at the same time, creating and implementing this framework challenges managers to understand the complex interrelationships between economic, environmental, and social performance, as well as the interconnectedness of diverse stakeholder groups. Much of this information is not routinely captured by the financial or cost-accounting systems of the firm; however, by incorporating sustainability metrics into internal decision-making tools and external reporting, managers are increasing their accountability for the firm's sustainability initiatives.

Internal Accountability and Decision-Making Tools

As outlined in *Making Sustainability Work* (Epstein 2008, 127), measures that send the right signals and elicit appropriate decisions within the organization should:

- connect to the strategic objectives
- focus on core cross-functional processes
- identify critical success variables
- act like early warning signals of potential problems
- identify critical factors going awry
- link to rewards

A corporate sustainability performance model consists of a mix of input, process, output, and outcome measures. There are cause-and-effect linkages between these four components of the model (see table 1 on the following page). Metrics must be developed to measure the impact that the inputs have on the processes and to translate the impact of the processes on goals and objectives of the organization.

Many firms have implemented the "balanced scorecard" as a strategic management system, in which typical performance measures are grouped into four dimensions: financial, customer, internal business processes, and learning and growth. Each of these indicators is considered in determining overall progress toward a company's strategic goals. Table 1 shows an example of sustainability measures that could be included in the various dimensions of the balanced scorecard.

Certification and External Reporting Tools

The demand for both environmental and social accountability and reporting is growing, and as frameworks for

Table 1. **Examples of Balanced Scorecard Measures for Sustainability**

Financial		Customer	
Environmental	**Social**	**Environmental**	**Social**
Percentage of sales from "green" products	Philanthropic contributions	Cost of cause-related marketing (for charitable or other worthwhile causes)	Customer perceptions
Recycling revenues	Workers' compensation costs	Number of "green" products	Number of cause-related events supported (e.g., breast cancer, AIDS)
Cost of fines and/or penalties	Employee benefits	Product safety	Contributions to community
Environmental health and safety costs (percentage of sales)	Costs of legal actions	Number of recalls	Number of community meetings
Capital investments	Training budgets	Customer returns	Customer satisfaction
Energy costs	Percentage of sales from socially-positioned products (products affiliated with a cause)	Percentage of products reclaimed after use	Social report requests
Disposal costs	Increased sales from improved reputation	Product life	Number of product recalls
Cost avoidance from environmental actions		Functional product eco-efficiency (e.g., energy costs of a washing machine)	Customer group demographics
			Promotion of healthy activities

Internal Business Processes		Learning and Growth	
Environmental	**Social**	**Environmental**	**Social**
Percentage of materials recycled	Number of employee accidents	Number of of employees trained	Workforce diversity (age, gender, race)
Percentage of waste to landfill	Number of lost workdays	Number of training programs and/or hours	Number of internal promotions
Percentage of suppliers certified	Hours of overtime work	Reputation per surveys	Employee volunteer hours
Number of accidents and/or spills	Cost of warranty claims	Number of employee complaints	Number of involuntary discharges
Energy consumption	Cost of minority business purchases	Number of community complaints	Pay ratios (highest/lowest)
Percentage of facilities certified	Number of suppliers certified	Number of shareholder complaints	Cost of employee education
Percentage of products remanufactured	Environmental quality of facilities	Unfavorable press coverage	Cost of employee benefits
Energy savings	Observance of international labor standards	Number of employees with incentives linked to environmental goals	Employee satisfaction
Packaging volume	Number of safety-improvement projects	Number of functions with environmental responsibilities	"Quality of life" programs (e.g., career counseling, stress management, substance counseling)
Non-product output	Local sourcing of inputs	Number of employees using car pools	Unfavorable press coverage
Number of supplier audits per year			Number of employee grievances
Natural resource consumption			Workforce equity
Emissions reduction			Job training
Hazardous material output			
Vehicle fuel use			
Habitat changes due to operations			

Source: authors

The "balanced scorecard" is a tool to help a businesses analyze its performance in reaching certain goals, in this case environmental sustainability. Identifying areas of relative weakness and strength is the first step in solving problems.

reporting become better developed and distributed, the number of companies issuing environmental and social reports is expected to increase. The demand for this accountability comes from numerous stakeholders, in particular investors and shareholders, government agencies, public interest groups, the local community, and consumers.

Two primary standards have been developed for environmental management systems certification: the International Organization for Standardization's (ISO) 14000 series and the European Union's Eco-Management and Audit Scheme (EMAS). The ISO 14000 series of standards quickly has become the primary international standard for environmental certification; ISO 14000 certifications have increased over tenfold in the past decade, with 154,572 facilities certified as of 2007 (ISO 2009). The European Union (EU) introduced the EMAS standards in 1993 as a voluntary set of environmental performance measures for facilities operating in the EU. While ISO 14000 are process-oriented standards, the EMAS standards emphasize performance measurement by focusing more on significant environmental impacts or outcomes. Released in 2010, the ISO 26000 standard will focus on broader issues of corporate responsibility.

Social Accountability 8000 (SA8000) is a standard that focuses on workplace values and specifies baseline requirements regarding child labor, forced labor, health and safety, freedom of association, discrimination, disciplinary practices, working hours, compensation, and management systems. As of 31 March 2009, 1,942 factories located in sixty-five countries and representing sixty-six industries have been SA 8000 certified (SAAS 2009).

The Institute for Social and Ethical Accountability (ISEA) has published the Accountability 1000 series of standards. These standards are focused on accountability principles, assurance, and stakeholder engagement.

During the past decade, there has been an explosion in the number of companies producing external reports for environmental and social responsibility. Thousands of companies are now issuing corporate environmental reports, or in some cases, corporate sustainability reports that contain additional social and economic measures of performance. Among the companies that do issue social and environmental reports, there is wide variation in both the reporting frequency and in the breadth and depth of information reported. Many companies only center their reports on data that is required by regulatory agencies and include almost no insights into the company's social and environmental strategies, how those strategies are being carried out, and the effectiveness of their efforts.

There is a growing consensus that external social and environmental reports should contain more comprehensive information than just that required by regulatory agencies. Information typically reported by leadership companies includes:

- management systems and policies, including goals, targets, and accountability systems
- inputs such as material, energy, and other natural resource use
- outputs such as waste and emissions
- process management such as risk management methods, accident and safety data, and stewardship practices
- product data such as lifecycle analyses, product packaging changes, and remanufactured products
- financial data related to reactive versus proactive spending, capital and operational expenditures, charitable contributions, and costs avoided
- stakeholder identification and concerns

The Global Reporting Initiative (GRI) Sustainability Reporting Guidelines are designed to help companies articulate and evaluate the alignment between corporate environmental strategy and operational goals and measurements, while providing a framework for communicating with external stakeholders. The GRI guidelines identify six primary areas of sustainability performance reporting: economic, environmental, labor practices and decent work indicators, human rights, society, and product responsibility (GRI 2007).

Implementing Performance Metrics

The practices that have been described are being used successfully by many organizations to better measure and manage social and environmental impacts of corporate decisions. For example, Wisconsin Energy measures employee turnover rates and also employee turnover by diversity classification, to help evaluate corporate human resource practices. The United Kingdom's Cooperative Bank measures accessibility of its branches and services to the overall community to help evaluate community involvement of the bank. Implementing a strategy to improve performance by measuring and managing sustainability impacts can be accomplished through following, in whole or in part, these following eight steps:

- Develop a social and environmental strategy and then organize the corporate structure to effectively implement and measure the success of that strategy.
- Identify and measure social and environmental benefits and costs. Think broadly and consider current and future

impacts on both the company and society through a total stakeholder analysis.

- Prepare an inventory of current social and environmental activities and track and accumulate costs and benefits related to social and environmental impacts.
- Integrate all current and future social and environmental costs and benefits into corporate decisions, including those on product design, product costing, and capital investments.
- Integrate accounting and financial analysis techniques, including risk assessment, into evaluating the social and environmental impacts of corporate decisions. This will help improve analyses of choices between product improvement, process improvements, and capital improvements, as well as better analysis of uncertainties related to changing regulations and technologies.
- Integrate corporate social and environmental performance into performance evaluation systems. Consider sustainability performance as a variable in evaluating the total corporation as well as of divisions and individuals.
- Collect and provide feedback throughout the firm on the effects of various decisions so that the social and environmental strategy can be continuously updated and decision making can be better informed. Use practices to verify and standardize the information collected.
- Institute a reporting strategy for both internal and external stakeholders and decision makers.

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See also Accounting; CSR and CSR 2.0; Equator Principles; Facilities Management; Financial Services Industry; Global Reporting Initiative (GRI); Green GDP; Integrated Product Development (IPD); Manufacturing Practices; Stakeholder Theory; Supply Chain Management; Sustainable Value Creation; Transparency; Triple Bottom Line

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Pharmaceutical Industry

Good health—both individual and public—is essential to a more sustainable world for a number of reasons, and the pharmaceutical industry's role in reaching and maintaining it is critical. But without a changed business model that incorporates increased accountability to all stakeholders, improved environmental awareness regarding ecological impact including chemical contamination, and a different approach to health, the industry cannot follow a sustainable course.

The pharmaceutical industry is important to any discussion of health and sustainability, yet so far it has failed to address many issues of relevance. It constitutes a large economic sector, a global customer base facing unequal market access, and a significant ecological footprint. A sustainable pharmaceutical industry could be one that helps create a healthy world, but conversely, an unsustainable one can generate enormous harm.

The analysis below suggests that the pharmaceutical industry is currently on an unsustainable trajectory. If disaster is to be averted, profound changes are needed to its underlying business model and approach to health, as well as to its relationship with the natural environment. Yet the potential exists—in technological terms as well as in mind-set and business practices—for the industry to transform itself into a sector capable of contributing to a sustainable world.

Sustainability Impacts

The pharmaceutical industry affects the global community in several far-reaching ways. In this section, we begin by considering the economic impact of the industry and then proceed to address health and environmental impacts.

Economic Impacts

Pharmaceutical sales worldwide are approaching three-quarters of a trillion dollars, and had been on a course to reach much higher numbers before a slowdown in sales caused by the worldwide economic downturn that began in late 2007 (FierceBiotech 2009). In the United States, while health care spending grew as a percentage of gross domestic product (GDP), reaching 17 percent in 2008, prescription drugs rose even faster, increasing from 8 percent to a projected 14 percent of total health care expenditures between 1999 and 2010 (Reinhardt 2001, 136). As a large and growing sector of the world economy, the pharmaceutical industry provides jobs and economic development. On the other hand, if spending on pharmaceutical products is not kept in check, it risks bankrupting nations. Current spending levels—driven by the growth in the number of drugs, volume of use, and unit prices—are continuing to rise as a percentage of world gross domestic product, burdening governments and households as well as businesses (American Benefits Council 2009).

The pharmaceutical industry faces sustainability challenges in terms of its competitive dynamics and dominant business model. Success in the past has hinged on the ability to identify promising new molecules, test them in clinical trials, and promote them with what has been called "pinball wizard" sales: bouncing from one doctor's office to another in an effort to influence which drugs are prescribed (Elling et al. 2002). This model has contributed to escalating costs and intense competition. Direct-to-consumer advertising has also been expensive and is increasingly being challenged as a form of marketing. Research and development (R&D) spending although difficult to measure is claimed to average around 18 percent of sales—high by the standards of other industries—in pursuit of blockbuster drugs with annual sales of $1 billion or more

(Pharmaceutical Research and Manufacturers of America 2008). The long and arduous process of developing such drugs has led to a focus on market potential rather than on desirable health outcomes, in turn leading to erosion in public trust (Future Pharmaceuticals 2008). Meanwhile, the pipeline of new drugs continues to weaken thanks to a lack of industry-wide success in bringing novel products to market and a focus on established, revenue-generating products. Most novel chemical entities are eliminated in the early phases of development because they display a lack of efficacy in preclinical models or because of safety concerns that dissuade companies from making long-term financial investments. The long-term financial viability of the industry, however, is contingent on getting over this hump and furthering the development of as many drug candidates as possible into the later stages of clinical development to maximize the chance that some will eventually leave the pipeline as approved products. But still the numbers continue to decline. For the industry as a whole, late-stage pipeline products against novel targets was at 40 percent in 2000, 36 percent in 2004, and 29 percent in 2008 (Booz & Co. 2009, 8).

Another concern is the preservation of intellectual property. Many current blockbuster drugs face looming patent expirations. As generics become more widespread, companies must be constantly on guard for patent violations to safeguard their investments and avoid strategies that seem themselves to be unfair. The growth of emerging markets such as India and China is leading to greater complexity in managing these safeguards. Lobbying governments to preserve pharmaceutical-friendly regulatory environments has become both more expensive and generally less effective.

The pharmaceutical industry's economic challenges have contributed to industry consolidation with a wave of mergers and acquisitions in 2009, including Merck's acquisition of Schering-Plough and Pfizer's takeover of Wyeth. Megamergers are seen as a way to drive profits through cost cutting and synergies in the absence of real research productivity or innovation. Biotech firms have been sources of more innovation than internal R&D programs, but their acquisition by pharmaceutical companies represents a high-stakes gamble, since the likelihood of early products ever coming to market is small. Many observers are skeptical of such an industry strategy, yet it is a reasonable effort to try to buy innovation. (Pierson and Hirschler 2009).

Health Impacts

The industry's challenges of economic sustainability, however, pale in comparison to what is at stake with regards to human health. Pharmaceutical products can be essential to our health through the treatment of illnesses and diseases. By some measures, the pharmaceutical industry has made remarkable progress in developing medicines that treat major diseases. Vaccines have helped control epidemics of diphtheria, scarlet fever, whooping cough (pertussis), and measles. During the twentieth century, the popular notion of "a pill for every ill" appeared, suggesting that a viable drug treatment would emerge for every human malady. More recently, advances in biomedical research, clinical approaches, and information technologies have led to new advances in drug development. Genomic medicine offers the promise of interfering with disease pathogenesis at very early stages. Stem cell research has the potential to change how drugs are developed and even to unravel the biology of disease. Combinatorial chemistry and high throughput screening—two methodologies used to accelerate the processes of research and testing for new drugs—allow a generation of new chemical entities to be tested against animal and cell culture models of disease biology. Computer modeling allows pharmaceutical companies to link disease mechanisms and even causes to the possible consequences of specific treatments. The result of all these advances is the potential to develop a broad array of medicines that help reduce total health care costs by helping patients stay healthier, reducing the need for expensive hospitalizations or surgery.

And yet all is not well in Camelot. The molecular-reductionist underpinnings of the pharmaceutical industry are increasingly under attack. Molecular intervention reduces complex diseases to a limited set of targets that are modulated to produce a therapeutically beneficial response. According to many observers, this approach is not producing high-quality clinical candidates at a rate commensurate with invested resources (Hajduk 2006, 266–272). For those compounds that do succeed, it is failing to produce needed insights into the biological mechanism of action. Recently, a senior executive for GlaxoSmithKline (GSK) claimed that the vast majority of drugs (over 90 percent) only work in 30–50 percent of the population (Connor 2003), which is close to placebo response rates. Pharmacogenomics (linking individual genetic traits to drug efficacy and safety) promises to personalize treatments, but its implementation in practice has scientific, political, and economic barriers. For example, the use of the susceptibility gene ApoE4 (perhaps eventually to match patients with so-called Alzheimer's disease with appropriate drugs) is limited by problems with the theoretical modeling of risk, the availability of adequate empirical data sets in different populations, the pleiotropic effects of genes (a single gene affecting multiple conditions), and the lack of understanding of the science and clinical implications by consumers who might avail themselves of the testing. (Many experts believe Alzheimer's is more than one condition and that it relates to severe brain aging.)

In some cases, drugs have been shown to actually worsen the disease they are intended to treat. For example, recent studies claim there is an increased risk of severe side effects—such as doubling the rate of cognitive decline, increasing the risk of stroke, and even causing death—in patients receiving antipsychotic drugs prescribed to treat Alzheimer's (Ballard et al. 2009, 151–157; Ray et al. 2009, 225–235). Moreover, the Institute of Medicine reported in 1999 that over 100,000 deaths in the United States alone occurred because of medical errors, many involving drugs (Charatan 1999).

There are widespread criticisms of industry efforts to extend diagnostic boundaries and even create new disease categories that open markets in which to push pills. According to a report in the *Public Library of Science and Medicine*, pharmaceutical companies are inventing diseases in order to up their sales figures (Nordqvist 2006). The attempt to create a new medical condition known as "female sexual dysfunction" was developed and defined through research meetings sponsored by, among others, Pfizer, the maker of Viagra. Arguably, Viagra itself represents a huge new market for pharmaceutical-enhancement technologies: making healthy people function better rather than helping sick people get well. Equally, while many people suffer from an overactive bladder, critics claim that pharmaceutical marketing greatly exaggerates the extent of the problem in order to sell drugs such as Detrol. The industry, for its part, tries to deflect these criticisms by hiring experts to educate potential users about the magnitude of the social problems that result from these conditions, and by funding studies that can quantify the social problem on a broader scale. Conflicts of interest among academic experts as well as biases in industry studies, however, are increasingly being recognized as problems.

Moreover, supporting programs to diagnose diseases earlier or identify "precursor" states, as has been witnessed recently in the creation of the diagnostic category called "mild cognitive impairment" (MCI)—a supposed precursor to Alzheimer's—leads to opportunities to increase sales without clear benefit to patients. Others have identified as particularly problematic the industry's influence over panels of experts who develop new prediagnostic categories with arbitrary norms—such as prevascular disease, prediabetes, prehypertension, and pre-osteoporosis—thus widening the market of potential drug users (Brownlee 2007). When the boundaries between a disease state and normal functioning are blurred, potential user populations expand exponentially (Katz and Peters 2008, 348–355). In addition to raising ethical and political-economic issues, this behavior also poses the cultural question of to what extent a society should allow industry to medicalize the continuum of human health and create specific thresholds of disease, particularly for conditions such as dementia and so-called Alzheimer's disease in which the social stigma associated with the label can be so damaging. Further problematic is that drug companies have been fined hundreds of millions of dollars for promoting off-label prescriptions, that is, encouraging doctors to use medicines to treat conditions for which the drugs were not approved.

The pharmaceutical industry is seen as contributing to the unequal distribution of the global disease burden (GDB). Sales efforts are reduced in the case of poor markets, even where medicines exist to treat diseases (Komesaroff 2008). Malaria, pneumonia, diarrhea, and TB (tuberculosis) account for over 20 percent of the GDB (in terms of disability-adjusted life years lost) but receive less than 1 percent of funding for research (World Health Organization 2003). Only 10 percent of the world population lives in Africa, but 40 percent of deaths due to communicable diseases—many of which are preventable—occur there. AIDS drugs are sold to a relatively small percent of the HIV-infected patients who can afford them.

Even past health contributions of the pharmaceutical industry are now being questioned: a growing number of medical historians are suggesting that the decline of infectious diseases over the past century was not due to vaccines and drugs, but to improvements in hygiene, public sanitation, and improved nutrition (Centers for Disease Control and Prevention 1999; Campaign Against Fraudulent Medical Research, 1993). The pharmaceutical industry has come under fire for its tendency to be driven by markets with potential for high returns, such as the so-called lifestyle diseases of wealthy countries: cardiovascular disease, type 2 diabetes, and cancer. Yet these conditions are proving to be exceedingly difficult therapeutic targets.

Environmental Impacts

Like many sectors, the industry's future is rapidly being overshadowed by environmental considerations. A useful parallel is the energy sector, where the primary environmental risk factor is proving to be its historic reliance on fossil fuels (coal, natural gas, and oil), whose combustion to produce energy is a major contributor to climate change and air pollution (carbon dioxide, nitrogen oxide, sulfur oxide, mercury, and particulates.) The future of the energy sector increasingly depends on reducing carbon intensity and transitioning to clean, renewable fuels.

The pharmaceutical industry's primary environmental risk factor is chemical contamination along its supply chain, from manufacturing wastes to the disposal of unused medicines. Active pharmaceutical ingredients (APIs), the chemicals used in the manufacturing of drugs, enter the surface waters and, in some cases, the groundwater and soil. Pharmaceutical products enter the environment through improper disposal (for example, drugs flushed down the toilet or poured into drains) and through human and animal excretion of the product or its active metabolic products. Unused drugs and wasted sample medications that are improperly incinerated contribute to air pollution (Kaiser, Eagan, and Shaner 2001, 205–207). Pharmaceutical packaging is another source of environmental contamination: in one study, 88 percent of the material weight of pharmaceutical samples was found to come from materials other than the pills themselves (Wolf 2009).

API waste in bulk drug manufacturing may be rising as production shifts to China and India. These two countries produced 45 percent of the APIs in the generic market in 2005, and this number is projected to rise to 60 percent by 2010; several studies have shown higher concentrations of drugs in wastewater from production facilities in these countries than in European and American factories (Larsson and Fick 2009, 161–163).

Through surface water, groundwater, and soil, these drugs enter the food chain with the potential for system-wide ecological contamination (Wisconsin Department of Natural Resources 2009). Numerous studies (Desbrow et al. 1998, 1549) have outlined many of the serious negative impacts of contamination, including:

- The promotion of bacterial resistance, particularly in cases where antibiotics such as triclosan are released into biological media (such as wastewater containing human feces), increasing the risk that resistant bacteria will develop and spread
- Change in ecosystem viability by harming the reproduction and sex-ratios of species such as frogs and other aquatic life. For example, oral contraceptive medication that includes steroidal estrogens is known to cause feminization in male fish
- The accumulation of harmful chemicals in our bodies:
  - persistent bioaccumulative toxic substances (PBTs), such as selenium and other heavy metals
  - carcinogens such as cadmium, polycyclic aromatic hydrocarbons (PAHs), and lead
  - endocrine disruptors such as polychlorinated biphenyls (PCBs), implicated in reproductive harm
  - mutagens such as benzopyrene that damage DNA and cell structure
  - teratogens, such as mercury, that cause birth defects

A key concern of ecological contamination is the presence of drugs in domestic drinking water, as low levels of pharmaceuticals are detected in groundwater and surface and drinking water worldwide (Fick et al. 2009). A recent study of waterways in the United States and Europe found over one hundred kinds of pharmaceutical and personal care–product ingredients in significant concentrations, including aspirin, statins, hypertension medications, antibiotics, mood stabilizers, anticonvulsants, and estrogen compounds (Hemminger 2005). Additionally, the Associated Press has recently estimated that the 5,700 U.S. hospitals and 45,000 long-term care facilities annually flush nearly 250 million pounds of pharmaceuticals and contaminated packaging from unused pharmaceuticals down the drain, infusing pollutants into America's drinking water (Donn, Mendoza, and Pritchard 2009). There are many other point sources of waste, including veterinary hospitals, medical offices, and correctional institutions.

As alluded to above, the problem may even be worse in the developing world. Wastewater downstream from Indian pharmaceutical plants has been found to contain 150 times the highest levels detected in the United States, leading to unprecedented drug contamination of groundwater and surface and drinking water (Fick et al. 2009). This, in turn, creates major challenges for producers and regulatory agencies, since current drinking water regulations are written to protect consumers from the threat of pathogens and industrial chemicals but not from drugs and their metabolites (Kreisberg 2007). In the United States, the Environmental Protection Agency (2009) has stated in its effluent guidelines that there are no sewage treatment systems specifically engineered to remove pharmaceuticals, and there may be evidence that adding chlorine, a common process in conventional drinking-water treatment plants, can amplify the toxicity of some pharmaceuticals.

Another concern is the difficulty in assessing the toxicological impacts of multiple chemicals on whole ecosystems. Traditional toxicological testing looks at individual chemicals and how they affect a single species. Much remains unknown about the impact of mixtures of pollutants on complex ecosystems. For this reason, many argue that governments and industry regulators should apply the precautionary principle (having concern for and foresight of consequences of actions) and act before all the scientific evidence of harm can be collected. One recent example of such action is the National Association of Counties (NACo), the largest local-government organization in the United States, unanimously adopting a policy that would enforce producer responsibility for unwanted medicines (Environmental Leader 2009). Under the resolution, the pharmaceutical industry would pay for taking back unused prescriptions and over-the-counter drugs, without state or local funding.

Implications of Current Trends

In the years ahead, the pharmaceutical industry will need a way to regain public confidence with business models that create enduring value for investors as well as for society and the environment. Instead of selling pills, it will need to contribute to positive health outcomes. Instead of rising costs and escalating research-and-development expenditures with low hit rates, it will need to promote a cost-effective model of health in which therapeutic treatments are integrated into, rather than isolated from, the ecological, cultural, and personal contexts of patients.

The marketplace is becoming more transparent. Companies are no longer able to push negative externalities onto society without incurring hidden business liabilities. Table 1 describes the lifecycle value chain for the pharmaceutical industry and its associated negative externalities. Companies that fail to mitigate these negative impacts increasingly face customer deselection, loss of reputation, heightened regulation, and fines and penalties.

Value chain transparency suggests that a new level of scrutiny will force pharmaceutical companies to rethink how value is created. Patients are becoming better informed. Nongovernmental organizations (NGOs) are tracking the ecological damage resulting from chemical contamination by pharmaceutical manufacturing and product use—and they are demanding action to remediate and to prevent further harm. Governments, businesses, and households are paying a larger bill every year, and they want more control over what they are getting in return. In short, pharmaceutical players are facing a new stakeholder-centric marketplace, in which shareholder returns cannot exist at the expense of stakeholders without incurring significant business risks.

Creating Sustainable Value

Sustainability in business is a dynamic state that occurs when a company creates ongoing value for its shareholders and stakeholders. This is sometimes called *sustainable value*, a term used by Chris Laszlo in his 2008 book of the same name. When DuPont designs manufacturing facilities that use less energy, produce zero waste, cost less to build and operate, and are safer, it is creating sustainable value. The new design has a direct impact on the cost base and contributes to the safety of DuPont's staff and to less pollution in the environment. The same is true when Unilever offers liquid detergent concentrates in smaller packaging. Customers prefer them because they are lighter to carry and clean the same number of washes, while retailers like them because they improve shelf-space utilization, and environmental stakeholders applaud the reduced plastic resin and savings in water and diesel. An essential aspect of sustainable value is that, by "doing good" for society and the environment, the company also does better for its customers and shareholders.

TABLE 1. **Pharmaceutical Industry Lifecycle Analysis Showing Environmental, Health, and Social Imapcts**

1. Discovery	2. Development	3. Manufacturing	4. Marketing	5. Sales
Research, validation, screening, optimization	Clinical trials, submission for regulatory approval	Active pharmaceutical ingredients (APIs), drug production		

Environmental risks	Health risks	Social impacts
• Unsustainable harvesting of natural medication sources (e.g. plants)	• Water, soil, and air contamination in the production of APIs and bulk drugs	• Pills instead of outcomes
• Waste and toxins as the by-products of high-throughput screening techniques on synthetic chemicals	• Energy use and carbon intensity	• Samples disposal
• Molecular-reductionist design approaches that do not take evolutionary principles into account	• Worker health and safety risks	• Product end-of-life
• Prioritization of diseases based preponderantly on market potential	• Community integration issues	• Packaging waste and disposal
		• Human health impacts
		• Bio-diversity impacts
		• Lack of transparency
		• Unequal access within markets

The large ecological footprint of pharmaceutical products has much room for improvement, from the initial harvesting of raw materials to marketing to disposal at the end of the product's useful life.

In the pharmaceutical industry, when GlaxoSmithKline (GSK) invests over $300 million into developing a malaria vaccine, it is not only addressing a disease that preponderantly afflicts the poor and kills more than one million people a year worldwide, it is also protecting GSK's reputation and helping to ensure a license to operate in its markets. A product portfolio that spans both blockbuster drugs aimed at the rich and drugs that fight diseases of the poor helps GSK create better relationships with public-health leaders and government regulators. It helps attract and retain talented employees. In short, it is simply smarter business.

Sustainable value occurs only when a company creates value that is positive for its shareholders and its stakeholders. Creating stakeholder value (which emphasizes responsibility over profitability and the idea that businesses serve all involved parties) in ways that support business priorities can fuel competitive advantage for years to come (Laszlo 2008). Companies that create shareholder value—which views the organization as accountable to its owners and stresses profitability—at the expense of stakeholders are in effect transferring value from the stakeholders to the shareholders, with attendant competitive risk. Sustainability does not imply following every whim of environmental and social activists, who may have little understanding of business and may unintentionally pressure companies to undertake loss-making activities. Philanthropy and charity, when unrelated to business interests, are examples of value transfer from shareholders to stakeholders (although improving image many indirectly affect business). Philanthropy and charity are what a company does with its profits once earned, while sustainable value is about how a company earns its profits.

Pharmaceutical companies increasingly find themselves in an "unsustainable" situation. Because of the negative externalities described in table 1, they are perceived to create shareholder value "on the backs" of patients, governments, businesses, and ecosystems.

Undertaking philanthropic activities alone will not fix the problem. A profitable pharmaceutical company that destroys stakeholder value and seeks to counterbalance the problem with charity is not a sustainable company. Pharmaceutical companies need to develop sustainable business models that blend environmental, health, and economic benefits at the core of their activities.

Core Versus Peripheral Sustainability Strategies

Every industry must distinguish sustainability strategies that are core to its activities from those that are peripheral. A core sustainability strategy in the energy sector is to reduce reliance on carbon-intensive, nonrenewable fossil fuels. In the tobacco industry it is product harm reduction. Neither industry would be seen as credible if it focused its sustainability efforts only on things like paper recycling and hybrid cars for its corporate fleet. The latter actions address only peripheral issues in energy and tobacco.

Pharmaceutical companies need to identify those core sustainability strategies that offer the greatest opportunities for sustainable profits and growth. General pharmaceutical sustainability strategies are identified below, each of which will need to be tailored to the specific needs of individual pharmaceutical companies. Progress in each area will move the pharmaceutical industry toward sustainable value creation.

The list of core and peripheral strategies shown in table 2 on the following page is not intended to be comprehensive. It is indicative of the direction and types of actions that pharmaceutical companies need to take to create sustainable value. Taken together, these strategies represent a potentially disruptive innovation to the industry's underlying business model.

Alternative Profit Models

One of the success stories in the area of sustainable practices is that of the chemical industry and its Responsible Care model: chemical manufacturers enter into agreements with their customers that profits will be derived in part from cost savings realized through the development of processes that use fewer chemicals. The manufacturer works with the customer to redesign manufacturing processes to increase the recycling of chemicals or reduce their usage. A reasonable profit equation is developed to incentivize the chemical manufacturer to innovate continuous quality improvement at the customer's plant and to earn profits through these efforts. The results are more efficient processes, lower operating costs at the customers' facilities, and an incentive to invest in continued R&D by the chemical manufacturer beyond the production of bulk chemicals.

The pharmaceutical industry's leaders need to ask themselves the following questions: What if profits to pharmaceutical manufacturers were based in part on actual patient outcomes, not only on the effects of their drugs but also on lifestyle intervention support? What if health care models were revised from treatment of illnesses, many of which are lifestyle related, to incentivized support of wellness models of behavior? What if pharmaceutical

Table 2. **Sustainability Strategies for the Pharmaceutical Industry**

Core Sustainability Strategies

- Prioritization of diseases based on economic and health criteria
- Drug portfolios that serve diseases of poverty as well as diseases of affluence
- R&D based on evolutionary whole-system approaches
- Developing new regulatory models that (for example) foster long-term data collection
- Integration of green chemistry principles into drug discovery and production, such as the American Chemical Society (2009) Green Chemistry Institute's Pharmaceutical Roundtable
- Marketing and sales focused on health outcomes (such as improving quality of life) rather than selling pills
- Encouraging the development of better pharmacoeconomic (comparing the value of one drug or drug therapy to another) models and studies
- Incorporation of more information technology in every stage of the business (R&D, clinical trials, developing product lines) and collecting post-marketing safety data
- Flexible pricing strategies that take into account value-for-money and competitive advantages (such as patent protection) as well as the health burden and level of development of the target market
- Growth based on mergers balanced with innovation and market development
- Collaboration with other stakeholders, including biotechnology companies; hospitals; doctors; patients; academics; government regulators; NGOs; and health-care providers focused on nutrition and exercise, prevention programs, and natural remedies
- Transparency and disclosure along the lifecycle value chain
- Using marketing expertise to not only sell drugs but to promote health
- Avoidance of conflicts of interest with doctors and health care organizations; stricter marketing codes to ban certain practices including those used to influence health care decision makers and direct-to-consumer marketing
- Closed-loop manufacturing processes that eliminate waste from the production of active pharmaceutical ingredients (APIs) and bulk drugs
- Take-back schemes for unused medications (sample products, prescriptions, and over-the-counter drugs) leading to their safe disposal
- Expansion into emerging markets such as China, India, and Brazil that are experiencing a growing middle class and increased government spending on health care; sustainable growth into these markets will require integration into the cultural, social, and ecological contexts
- Provision of universal access to pharmaceutical products in the case of major diseases such as AIDS, malaria, and TB.

Peripheral Sustainability Strategies

- Energy conservation and lowering carbon dioxide emissions
- Reduced water usage
- Reduced packaging waste (balance between drug safety and ecological footprint)
- Materials recycling (stock bottles, prescription vials, paper, plastic, aluminum cans)
- Green buildings
- Green vehicle fleets
- Healthy employee practices
- Encouragement of green processes internally among third party contractors

Some sustainability strategies, such as implementing "take-back" schemes for unused medications, are specific to the pharmaceutical industry (the "core" strategies in this table); other strategies, such as biding by green building codes, apply to many industries (the "peripheral" strategies at the bottom).

manufacturers viewed themselves not as developers or sellers of "biologically active chemicals" but as companies focused on disease management and, even more importantly, disease prevention? What if pharmaceutical manufacturers were properly rewarded for their successes? To achieve true sustainability, pharmaceutical companies will need to apply their formidable resources on a much broader view of their role in society—a truly holistic approach to partnering with the health care industry and their ultimate customer, the patient.

Stakeholder Collaboration

Of the core sustainability strategies, stakeholder collaboration may be one of the most vital. Greater collaboration will enable pharmaceutical players to tackle other complex challenges, such as the move to an evolutionary whole-system health model.

Stakeholder collaboration is an incipient feature of the competitive landscape across all industries. The Internet and its social-networking platforms have enabled new levels of collaboration. The instant and global availability of information has raised public awareness of environmental, health, and social issues; the complexity of solutions to each of these topics is forcing companies to partner with external stakeholders who bring new knowledge and greater credibility to the proposed solutions.

Patients, government health providers, health care professionals, payers, and insurers increasingly expect to have a say in health outcomes and value-for-money. They want greater control over pharmaceutical activities. The U.S. government and the National Institute of Clinical Excellence in the United Kingdom, as well as corporate health plans and environmental NGOs, are all becoming major players in the regulation and practices of the industry (Booz & Co. 2009, 1, 4; PricewaterhouseCoopers 2009).

The Future

Both individual health and public health are critical to a more sustainable world. Unhealthy organisms and organizations not only die prematurely but may also harm the health of others and the larger system. Sustainability is a commitment to the responsible use of scarce resources so that future generations can survive and thrive. It is the ethical *and* business issue of our time. There is no industry more directly tied to creating healthy sustainable communities than the health care industry, especially pharmaceuticals. But the health care systems of most countries are unsustainable both economically and ecologically. The pharmaceutical industry finds itself with a formidable opportunity to show global leadership in a world seeking and demanding sustainability practices. If it can develop business models based on creating sustainable value for its shareholders and stakeholders, the pharmaceutical industry has the opportunity to reverse a downward spiral of value destruction and to energize a new upward spiral of value creation through the appropriate use of its products in service of our health.

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See also Biotechnology Industry; Chemistry, Green; Health, Public and Environmental; Health Care Industry; Lifecycle Assessments (LCAs); Marketing; Packaging; Stakeholder Theory; Supply Chain Management; Sustainable Value Creation; Water Use and Rights; Zero Waste

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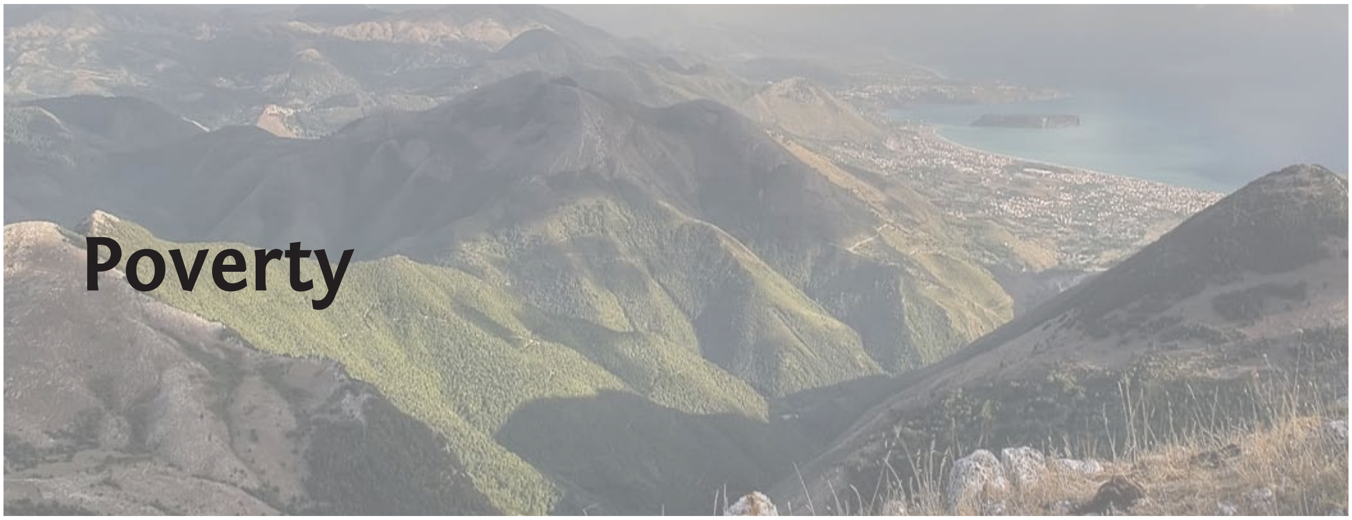

Poverty

The word poverty *is a multidimensional term that often conveys a lack of financial resources. But its meaning is contentious, and different views make poverty a complex social, political, and economic concept. It has both tangible and intangible aspects and can be understood by considering its attributes, the poor's role in poverty alleviation, and the nature of poverty interventions.*

The dominant conception of poverty is that of a deficiency or lack of economic means, particularly money, to achieve a desired level of well-being. Poverty, however, is a hotly disputed notion whose meaning, causes, effects, and cures differ widely across disciplines and fields of interest. Differing perspectives make poverty a complex social, political, and economic concept. While many think of poverty as solely an objective matter, it also has a subjective side. There is much contention over what the word *poverty* means, who is labeled as "poor," who determines the "solutions" to poverty, and the extent to which all of these terms are victimizing, patronizing, or condescending.

Poverty can be framed as a process to be understood or a problem to be solved. These frameworks are critical, as the definition and operationalization of poverty determines the flow and the direction of significant amounts of resources among development agencies (e.g., the U.S. Agency for International Development, the World Bank, the Asian Development Bank) and others trying to address it through aid, assistance, and other forms of intervention. We can achieve a better understanding of poverty by considering three key dimensions: the attributes of poverty, the role of the poor in poverty alleviation, and the nature of interventions to address poverty.

Attributes of Poverty

Poverty has both tangible and intangible aspects: it may be determined by tangible factors such as a lack of health care, nutrition, shelter, education, technology, or environmental resources, or it may be distinguished by the presence or absence of communication, transportation, waste services, and financial infrastructure. Some have criticized material- or consumption-based definitions of poverty—particularly those that rely on a single metric such as per capita income—as overlaying a Western economic understanding of development that is inconsistent with actual lived experience. The use of money or income to define poverty is problematic for cultures where materiality has not been considered a social goal and self-perceptions of poverty do not exist until imposed from the outside.

Intangible factors include such concepts as power, social exclusion, social mobility, influence, access, and knowledge. Poverty in this case is viewed as an outcome of social relationships that subordinate individuals and groups by caste, gender, race, ethnicity, religion, and/or age as a basis for depriving freedoms, opportunities, dignity, social integration, or the availability of choice. Poverty is also expressed by a lack of empathy, the presence of callousness, or the loss of spirit or ethics among those with significant means. Thus a passerby with disdain for a homeless man in an urban setting presents a situation where both actors can be defined as poor (the homeless man in terms of possessions, the passerby in terms of compassion). Accounting for the intangible factors of poverty yields a more holistic understanding but also leads to controversy because such factors are, by definition, difficult to measure.

Poverty exists at multiple levels of analysis—at the individual, community, regional, national, continental, and global levels. Because poverty manifests itself in localized ways, relying heavily on a subset of tangible or intangible indicators tends to render generalizations about poverty inaccurate. Urban poverty differs significantly from rural poverty. Poverty in highly industrialized nations differs significantly from poverty in agrarian societies.

Tangible metrics feel precise, but they mask the fine-grained nature of poverty's causes, effects, and resolutions. Poverty lines set by specific income levels (e.g., $1, $2, or $3 per day) suggest definitive measures at which poverty does and does not occur. Yet such figures conceal the variety of circumstances and intangible elements affecting the human condition. For example, gross domestic product, life expectancy, child mortality, nutritional calories, and income distribution have all been used to determine whether a country is poor. But the aggregate basis for many of these indicators masks the diversity of experiences and conditions and ignores more intangible metrics such as perceived quality of life. The idea of "gross national happiness" and other related concepts (Brooks 2008) suggests alternative measures of wealth, other than money.

A deeper understanding of poverty occurs by taking into account the relationship between tangible and intangible elements that vary within and between geographies over time. Poverty finds its roots in power and influence, exacerbated by corruption, illness and disease, natural disasters, political exploitation, overpopulation, and geographic resources. Therefore the intangible factors, such as knowledge, power, and choice, affect the tangible metrics, such as income. The relationship between tangible and intangible factors determines the nature of poverty and the choice of the appropriate interventions used to address it. Unless the nature of poverty in a given context is clearly defined, prescriptions to alleviate poverty are likely to fall short of intentions.

Role of the Poor

The role of the poor in poverty alleviation is a second important dimension. Interventions often treat the poor as either passive recipients to be "worked on" and rehabilitated or as capable individuals and communities critical to any change process. When depicted as passive recipients, the poor are assumed to be victims in need of rehabilitation and aid. Characterized as having few resources, the poor are portrayed as being in a state where they must be "saved" through external intervention by those willing and able to dedicate the necessary time and expertise. Strong criticisms exist regarding the extent to which this view is patronizing and creates deeper dependencies and disempowerment among the poor.

An opposing view characterizes the poor as creative, resourceful people who possess valuable capabilities, skills, and knowledge to pursue their own best interests. Within this paradigm of choice and empowerment, the poor are viewed as being inherently entrepreneurial and able to leverage available scarce resources to improve their own lives. The poor are seen as catalysts for robust informal economies driven by ingenuity and creativity. Actively engaging the poor in poverty alleviation efforts that are focused on self-directed change becomes the precondition for long-term effectiveness and impact. Critics of this perspective claim that it does not acknowledge obvious and easily addressed material deprivations (e.g., starvation, curable diseases) and that efforts cannot be scaled or replicated in a timely manner. Whether the poor are classified as active participants or passive recipients, however, affects not only the conception of poverty, but also the interventions used to alleviate it.

Interventions

Hence, the third dimension for understanding poverty is the nature of the interventions used to address it. These can be classified into two categories. First, there are interventions intended to directly alleviate deprivation. Such interventions usually come in the form of solutions imposed from the outside by experts who themselves are not likely to be classified as poor. These interventions can be seen in the more traditional approaches to poverty alleviation exhibited by most multilateral agencies and government assistance programs. Corporate efforts to deal with poverty through aid and philanthropy often mimic these approaches. Most such interventions assume that the cure for poverty is to raise living standards and consumption to levels more in line with those in developed countries. Many of these poverty alleviation efforts are large scale and focus on "one-size-fits-all" solutions. Poverty reduction goals, then, focus on single metrics such as material consumption, medical treatment, or nutrition, which may or may not be appropriate or desired in a specific social, cultural, political, or religious context.

Business has been viewed as an important instrument of poverty alleviation through large-scale investment in factories and facilities, thereby creating jobs and income. Critics of this perspective, however, contend that the poor are reduced to mere factors of production with low wages that do not allow access to adequate goods and services. They argue that the constant search for cheap labor and raw materials compels industry to engage in a "race to the bottom," where the exploitation of people and natural resources drives the very poverty and inequality they are presumed to be alleviating. Rapid urbanization forces rural migrants into squalid conditions where they lack legal standing and become captive to the system from which they seek to benefit.

A second type of intervention is meant to develop capacity within the ranks of the poor. Such interventions view the poor not as factors of production, but as engines for innovation and entrepreneurship that drive economic growth. These approaches seek to build the capacity to mitigate the effects of poverty through private sector, market-based mechanisms. They typically begin with the conception of the poor as capable, productive people.

Capacity-building interventions have led to an increased number of hybrid organizational forms that operate as for-profit entities, but determine success based on social objectives. Such organizations—referred to as for-benefit, third sector, social entrepreneurship, or Base of the Pyramid (BOP) ventures depend on microenterprises that leverage local resources to meet culturally appropriate goals. This private sector, profit-based approach treats poverty as a potential source of business growth, and the causes of poverty provide the foundation for new product and service development. By understanding and meeting the unmet needs of individuals and communities, these interventions depend on complex networks of entrepreneurs, nongovernmental organizations, and community leaders to facilitate innovations meant to generate mutual benefit for both the communities and the firms.

Critics of capacity-building approaches question whether the small scale and the high failure rate of many such enterprises embody the scale and scope necessary to deal with poverty on a global basis. These approaches are also criticized for depending on the ability of firms to convince the poor to aspire to and pay for products and services they do not need. There can be risk that such initiatives become just another way of removing what little wealth exists among the poor as local informal economies become more formalized and institutionalized.

Yet compared with large-scale aid-based activities, these revenue-based interventions hold promise for connecting business to poverty in a way that can recognize its many forms and the important role of the poor themselves. Widespread experimentation and innovation with this approach enables the competitive process of the marketplace to reduce poverty in a way that is sensitive to local interests and needs. Success can then be replicated and diffused, and it can positively affect the tangible and intangible factors of poverty over the long run.

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See also Base of the Pyramid; CSR and CSR 2.0; Development, Sustainable; Development, Rural—Developed World; Development, Rural—Developing World; Development, Urban; Education, Higher; Fair Trade; Green GDP; Health, Public and Environmental; Health Care Industry; Human Rights; Social Enterprise; Water Use and Rights

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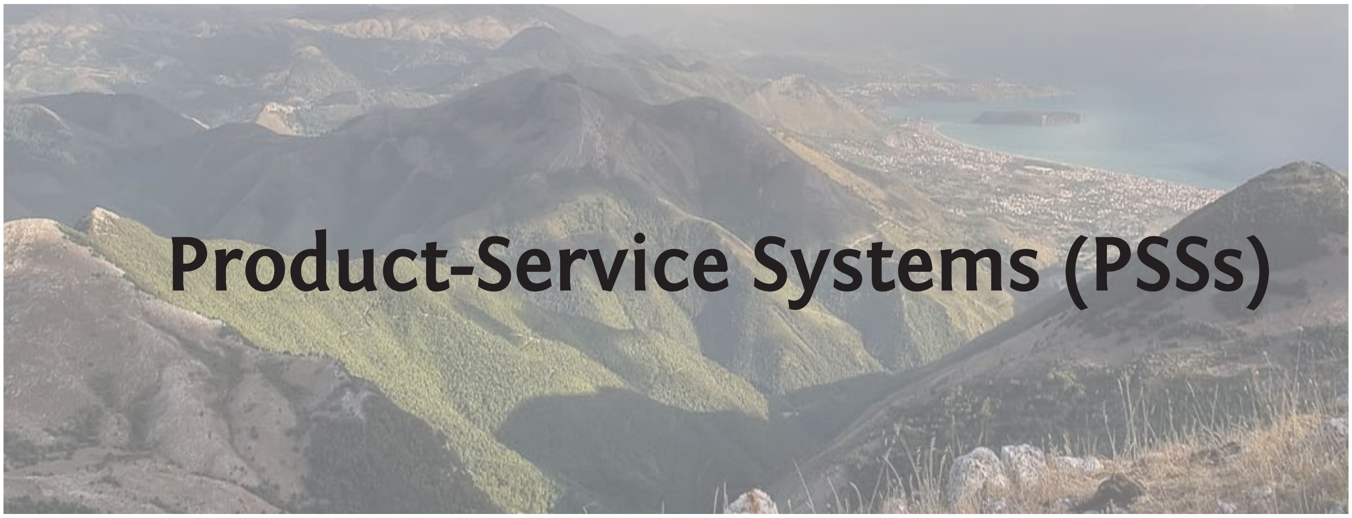

Product-Service Systems (PSSs)

A product-service system (PSS) combines a physical product with services designed to meet consumers' needs. PSSs are often classified by their primary focus, whether they are product-, user-, or function-oriented. Companies that use PSSs often take more economic interest in the full lifecycle of their physical products. By decreasing a product's lifecycle cost, these companies can often increase profit and reduce negative environmental impact.

A product-service system (PSS) typically combines a tangible (physical) product and some type of service that complements the product in order to meet a user's needs. There is a wide range in the extent to which the product component or the service component provides the core of the PSS. In some PSSs, the product provides the majority of the value, with services adding peripheral worth. In other situations, services provide the primary value. PSSs can have a positive impact on sustainable business practices as revenue models shift from the sales of physical artifacts (companies are rewarded for selling more "things") toward models that generate revenue from sales of the service or function. Companies that are able to use the same materials, through long-life products or recycling old products, for example, will have a competitive advantage by not needing to compete for raw materials. So instead of being rewarded for using more materials (with the negative sustainability impacts from obtaining, processing, and transporting those materials), companies will be rewarded for using materials efficiently and thus reducing negative sustainability impacts.

Types and Examples

Many classifications of PSSs have been proposed. They most frequently span a continuum with "product-only" systems at one end and "service-only" systems at the other end. Typically distinctions are made in three main areas, ranging from a high-product / low-service focus to a low-product / high-service focus. The following descriptions are adapted from an article in the journal *Business Strategy and the Environment* by Arnold Tukker (2004):

- *Product-oriented services.* Sales of the product are the primary focus and source of revenue. Product sales are complemented by add-on services provided to enhance or explain the use of the product. Examples include maintenance contracts, supply agreements for consumables relating to the main product (such as toner or ink for a copy machine), and training or support for software.
- *Use-oriented services.* While the product continues to play a central role, ownership of the product remains with the company and revenue is generated through leasing, renting/sharing, or product pooling. Examples include car lease programs, shared washing machines in apartments or self-service laundry facilities, and website hosting of multiple low-traffic websites on the same server. A PSS can maximize product use to meet demand (with fewer products needed to meet the same demand or the same number of products used to meet increased demand) and can motivate a company to extend product life (longer life means more time to generate income by leasing the product).
- *Function-oriented services*. The delivery of a function, not a product, is the focus. Companies that provide the function generate revenue through service management or outsourcing, and are paid per unit of service or functional result. Examples include office cleaning or catering services; copying services (when a business using an onsite photocopier pays for the copies it makes rather than a flat rental fee, while the provider or manufacturer of the copier is responsible for keeping the machine

operational); and voicemail (when companies provide the function of voice messaging without the customer having to purchase an answering machine).

History of the Concept

It is difficult to find an origin for the PSS concept, since business has always involved meeting customers' needs by providing some combination of products and services. The present understanding of a PSS stems from ideas related to a closed-loop system, in which a company reuses or recycles materials or products and therefore does not need to bring in any new raw material, as well as from the concept of extending product life through improved durability, maintenance, or remanufacturing. Prior to the 1990s, these ideas were still focused mostly on the physical product as the primary value offered by a company. (The term *physical product* refers to the tangible artifact, often simply called the "product"; it indicates that a company can also sell a commodity combining a tangible product and a service.)

Initiatives in the 1990s changed from a focus on add-on services based on a physical product to a focus on providing a service to meet the specific needs of the customer. This change was driven from two perspectives: business and the environment. From the business perspective, companies that developed solutions to meet those needs—instead of focusing on selling a product—meant that companies could improve their position in the value chain, enhance the differentiation of their offerings, and open a range of new opportunities for innovation. This change also suggested that the source of revenue—the thing for which a company is paid—should not be based solely, if at all, on a physical product, but rather on the extent to which customers' needs were met. That was where the environmental perspective came in: a company could increase profit by decreasing the lifecycle cost of the physical product, with the assumption that decreasing lifecycle cost (for example, by extending the life of the physical product and reducing energy and material use throughout all lifecycle phases), provided opportunities to dramatically lessen negative environmental consequences and demonstrate how sustainable business practices can lead to economic growth.

PSSs and Sustainability

The extent to which PSSs can reduce or eliminate environmental degradation is a topic of research and debate. In some cases, reasonable evidence exists that overall environmental impacts are lessened when companies take more economic interest in the full lifecycle of a product (for example, with car-sharing programs or pay-per-use washing machines). A slight increase in the inconvenience of a car-sharing program (for example, the need to reserve the car and pick up the car keys from a central office), or the pay-per-use of a washing machine (transporting the laundry from one place to another, for instance), likely reduces the use of these PSSs to some extent, thus making them only incrementally better from an environmental perspective. When companies assume operating costs of products, however, there is potentially greater incentive for use of products with low operating costs and products with longer expected lifetimes—both of which are often associated with reduced environmental impact. For example, a study regarding clothes washing, sponsored by the Netherlands government program on Sustainable Technology Development, states that large-scale clothes-washing services are currently able to achieve a 33 percent reduction in energy use, and by 2025, with measures enacted through additional research, should be able to achieve up to 90 percent reductions in water use while reducing detergent use by 94 percent (van den Hoed 1997).

In other cases, the amount of overall environmental impact of a PSS may be difficult to assess. For example, added services may require additional energy or materials. Still other cases result in a "rebound effect" (when increased availability through reduced cost leads to higher demand, which leads to more overall negative sustainability impacts). Theoretically, PSSs offer significant opportunities to reduce environmental sustainability problems. Practically, significant barriers often prevent them from doing so.

Drivers and Barriers to PSS

Drivers for PSSs can be considered at multiple levels—society, market, company, and customer. From a societal level, growing awareness of environmental issues can lead directly to changing customer demands and indirectly to legislation that often favors the environmental benefits PSSs may offer. For example, consumer awareness of electronic waste has led to legislation that makes manufacturers take back a product at the end of the product's life; a PSS approach enables the company to better control the material flow. Market drivers vary considerably between sectors, and particularly in mature markets with lots of competition and low profit margins, PSSs often offer opportunities for differentiation other than low cost. At the company level, drivers often relate to resource management (for example, minimizing the impacts of increasing costs of materials by maintaining ownership of products and/or materials) and risk mitigation (for example, addressing end-of-life issues of their products before producer responsibility legislation forces them to do so). From a customer perspective, PSSs that offer opportunities to more directly meet their actual needs may thus reduce costs and improve performance.

At a broad level, barriers include the relatively low cost of energy and materials, which are the basis for physical products, compared to the high cost of labor, which is the basis for services, at least in developed countries. Companies often face a lack of market demand for PSSs, especially in high-volume, low-value product markets that have dominant mindset rooted in a "throwaway society" and planned obsolescence. Additionally, companies along a value chain often lack the strong relationships required to put together complete PSS offerings; they may not know how to develop a PSS; or there may be other internal barriers related to costs or organizational structure. Barriers for customers include uncertainties regarding the terms of the PSS offering, lack of knowledge of total lifecycle costs, and unwillingness to allow the necessary access to real or intellectual property. For example, a customer that needs to make copies of confidential documents may not be interested in using an off-site copying service because someone outside the company might see those documents.

Related Concepts / Future Concerns

A number of related concepts, which may also affect the future of the PSS sector, have similar goals or applications to all or part of the PSS concept, including: economy focused on servicing old products; circular economy, which brings together the concepts of cleaner production and industrial ecology; least-cost planning, in which demands for energy services are satisfied with the lowest total cost to society; and functional product development, in which products are developed with an explicit focus on the function the user wants.

Product-service systems have the potential to contribute to the development of a more sustainable society by reorienting the revenue models of companies away from the sales of physical products (with associated resource and energy flows) and toward revenue models based on the sales of service or function. Such a shift could support society's movement toward sustainability by allowing for significant reductions in the material and energy flows associated with meeting consumer needs and wants, as well as increase the ability to better satisfy those needs. A move toward the service- versus product-oriented business model can also support economic sustainability at the company level by providing additional opportunities for differentiation in the market and by driving innovation. PSSs can also contribute to economic sustainability at a global level by encouraging decoupling economic growth and ecological limits.

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See also Design, Industrial; Energy Efficiency; Information and Communication Technologies (ICT); Integrated Product Development (IPD); Lifecycle Assessments (LCAs); Manufacturing Practices; Natural Step Framework, The (TNSF); Performance Metrics; Remanufacturing; Supply Chain Management; Zero Waste

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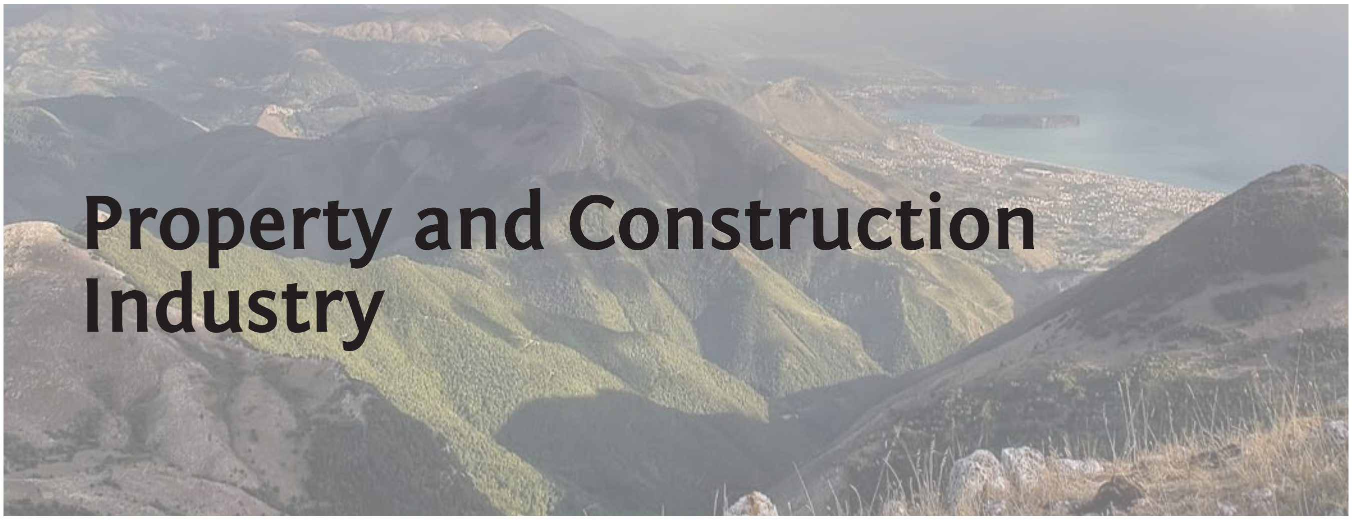

Property and Construction Industry

The property and construction industry faces considerable challenges for developing practices that address "triple bottom line" issues (i.e., environmental, economic, and social concerns) throughout the building delivery process—from land acquisition to design, construction, and demolition or reuse. But pockets of good practice exist on a range of levels, and businesses are being judged on their ability to adapt to the sustainability context, implement new technologies, and move into new markets.

The property and construction industry is often associated with responsibility for a range of impacts on the environment. The creation and operation of towns, cities, and their infrastructure require raw materials to be extracted and energy to be consumed. In some cases, this results in pollution and waste. But in return, the built environment can make a positive contribution—jobs are created, homes are built, and people are able to live safe and healthy lives. As a result, there is a delicate balance between the inputs required and the outputs or benefits gained. In past decades, certainly in industrialized nations, this balance has not always been achieved, so there is growing pressure on the property and construction industry to change.

Within the context of sustainable development, the construction industry plays a major role in the delivery of a built environment that supports existing needs without compromising future generations' ability to meet their own needs. For example, materials should be specified and procured responsibly, energy should be used efficiently, and pollution and waste avoided. But this ethos needs to be applied at all levels—sustainable planning, sustainable design, sustainable construction, and sustainable buildings—a requirement that is proving to be a significant challenge in practice.

Issues to Confront

All the "triple bottom line" issues (that is, environmental, economic, and social concerns) should be considered throughout the building delivery process—from land acquisition to design, construction, and demolition or reuse. These issues quickly become part of a wide-ranging debate that encompasses land use planning, architecture, construction, and facilities management in which several major, crosscutting issues (or impact categories) are generally held to be the most important and relevant to property and construction development:

- Energy and carbon dioxide (CO_2): The heating, lighting, and cooling of buildings typically account for a major proportion of each industrialized nation's energy consumption (up to 50 percent). A clear legislative focus now exists on energy reduction, both in terms of operational energy and embodied energy (that is, energy associated with building material production).
- Resource efficiency: The construction industry is a significant user of raw materials and water, so it must take responsibility for efficient and responsible utilization of Earth's finite resources. There is growing pressure to reduce primary resource consumption, find alternatives, increase recovery and recycling, and reduce waste, with incentives and fiscal penalties in some countries.
- Transport emissions: Materials extraction, processing, manufacture, and delivery all account for many millions of truck miles every year that result in the consumption of fossil fuels and the production of harmful emissions. There is renewed interest in other forms of transportation and more efficient logistics in the industry.
- Ecology and pollution: Both at the factory and the building site, the processes used to construct buildings produce noise and create air pollution (mostly dust); they

can also affect water quality and biodiversity (the range and health of species in an area). There is significant coverage of environmental protection within the law in most countries, but localized problems still exist.

- Development scale: The development scale of the built environment has an obvious impact on a community. It can influence quality of life, social justice, and life chances. Although these social and economic issues are sometimes overlooked because they are difficult to understand and measure, they cannot be ignored.
- Health and well-being: Like any other workplace, health and safety are critical in the construction industry, which accounts for many deaths every year. Enormous legal, legislative, and public pressure continues to be placed on the industry to ensure the safety of its workers. The poor management of other aspects such as human rights is attracting more attention. People's well-being is also affected within completed buildings. In this case, personal health and comfort are influenced by temperature, humidity, and the airborne contaminants that are emitted from building materials. Poor indoor air quality is often held responsible for asthma and other respiratory conditions, so there is pressure to build safe, healthy buildings that are well ventilated.

The relative importance of any of these issues will depend on political pressures, geographical location, building type, and the nature of the organization providing the service or product—the idea of "one size fits all" is not considered to be at all applicable in this context.

Innovations

The construction industry is generally accepted to be conservative and somewhat reluctant to change, and the same could be said for its position on sustain ability. That generalization does not accurately describe the current status of the industry because there are pockets of good practice developing on a range of levels.

First, technical developments have resulted in new products that offer various environmental benefits, such as lower embodied energy in manufacture, lower operational energy, and higher percentages of recycled/secondary content. Other products are guaranteed to satisfy relevant building standards or regulations. Some examples of these developments include:

- new technologies in energy microgeneration, such as wind turbines, biomass boilers, and photovoltaic panels, which are increasingly being specified and are becoming more cost-competitive
- new types of wall panels (with phase change materials that turn from solid to liquid at certain temperatures and are capable of storing and releasing energy), floor constructions (with void formers to create hollow spaces to reduce weight), windows and cladding for façades (with integrated shading), and HVAC (heating, ventilation, and air conditioning) systems (with low energy chillers and fans)
- commonly available building products with high proportions of secondary aggregates such as china clay waste, fly ash, or slag
- straw bales, sheep's wool insulation, and hemp-based concretes, once seen as radical building products, which are now commercially available

The consumer is now faced with a vast array of products that are identified as being "sustainable," but not all labels state exactly what this means. For this reason, attempts have been made to compile lifecycle analysis data for new forms of construction, alongside conventional options, to help people understand in more detail the effect of their choices for, say, a floor or wall construction—an example is the Green Guide developed by the Building Research Establishment (BRE). In this way, a product's sustainability benefits can be made transparent, comparable, and easy to understand.

Secondly, the development of sustainability services and management practices within the property and construction industry has followed a positive, but slightly different path. While there are consultants and specialist contractors that have established expertise on gaining accreditation (for example, ISO 14001, the International Organization of Standard's highest environmental management standards) or on using certain product types, such as HVAC, geothermal heating, or straw-bale construction, some sustainable practices are widespread and well established and no longer require such a degree of specialist advice. Waste management is a good example, with extensive use of materials segregation, recycling, and recovery on many construction sites, particularly in countries with relevant legislation. The adoption of such practices was an easily won point for the industry because contractors and clients could see very quickly the financial benefits of preventing materials from going to waste, saving capital costs, and reducing the risk of litigation.

An example of the effective management of social and environmental issues associated with construction, such as dust and noise, can be found in the widespread use of programs like the Considerate Constructors Scheme in the United Kingdom. In this program, contractors are awarded certificates for maintaining good track records on protecting their workforce, the environment, and the general public. A more recent development to improve material and product supply chains is the use of responsible sourcing programs to try to ensure chain of custody, reduce environmental impact, improve working conditions, maintain management standards, and eliminate child labor, corruption, and bad practices. Still, there is much to do to improve working and welfare conditions around the world.

Finally, a range of assessment tools has been developed for use in the measurement of sustainable buildings albeit they work in slightly different ways; different weightings, for example, may be applied in accordance with national policy or legislative priorities. Although many hundreds exist, two principal assessment tools are used around the world:

Leadership in Energy and Environmental Design (LEED) Green Building Rating System was developed in the United States and is now used extensively. It is based on a single approach within which a range of building types can be evaluated.

BREEAM (Building Research Establishment Environmental Assessment Method) was developed in the United Kingdom and is used internationally. BREEAM has expanded into a large suite of several versions, each of which is designed for a particular building type.

These assessment tools have emerged to help manage the building process and have been very successful. They were not designed to prescribe solutions, but they have been criticized for reducing sustainable construction to something of a "tick / check box" exercise that undermines the integrated nature of the subject.

Barriers to Sustainable Construction

While many innovations exist and continue to be developed, particularly in the area of low carbon technologies, the broader adoption of sustainable practices in the property and construction industry tends to be inhibited by a range of barriers that include technical, managerial, commercial, and structural challenges. Although some are particular to a location or building type, a few, generic barriers are commonly reported.

First, there is a slow rate of change in the building stock in many industrialized nations; that is, only a small percentage of new buildings are completed each year, which means that the built environment today consists of a majority of buildings that are tens or even hundreds of years old. This is a problem because in most cases the performance of this existing stock, particularly in terms of energy consumption, is very poor. Furthermore, most legislation to improve energy performance applies only to new buildings and large-scale refurbishments, so poor performance of existing buildings will remain a problem unless legislation is changed to require the necessary upgrading. Without legislation, any such change is voluntary and less likely to occur, except on a local or individual scale; indeed, building codes and standards are commonly cited as a major obstacle.

Secondly, there is a problem in the process of accounting for sustainable construction—how the cost of innovation is assessed commercially by construction companies and how its benefits are valued by building owners. Although many conflicting views exist on this, the capital cost of implementing sustainable practices in a building appears to be slightly or somewhat higher than "normal" construction. This may be as little as a few percentage points higher, but 10 to 15 percent is also commonly quoted. Figures vary widely; some individual products cost ten times more than conventional options. Despite higher capital costs, most sources acknowledge that the long-term operational savings can reap far greater benefits. As a result, energy payback periods are often cited (for example, a heavyweight masonry house might pay back its initial embodied energy deficit within about ten years of efficient operational conditions, in comparison to its lightweight timber equivalent), but these rules of thumb are not easily transferable from one situation to another. A similar problem is encountered when attempting to account for environmental impacts, for instance in the selection of building materials. A common example is recycled aggregates; the perception is that by crushing and reusing unwanted concrete or stone, the further extraction of virgin raw materials is avoided, which is worthwhile, but the additional processing energy needed to convert the recycled material into an appropriate constituent ingredient, and the extra transport emissions incurred to take it to processing venues and back to site, may outweigh any possible benefits. These difficult calls are termed "trade-offs" and can be very challenging to resolve in practice.

Finally, the structure of the industry itself continues to prove problematic. Here a set of circumstances conspires to prevent widespread adoption of sustainable practices. Professional groups and site workers are often claimed to lack skills and knowledge about new design standards, construction materials, and energy technologies, but this situation is changing over time as education curricula improve. Furthermore, the fact that several different professions are involved in building projects can prove challenging when tough decisions need to be made (for example, a poor understanding of how wind turbines operate can lead to their incorrect placement in a wind shadow on a building and a resultant lack of any actual power generation). Often, specialist consultants do have the right know-how, but some clients are simply not prepared to pay for their services. Indeed, capacity remains a problem in both service provision and product supply—there is a lack of sufficient competition in the market for some innovative products. This can lead to situations in which one supplier dominates the market and controls the price. Difficulties can also be found in the supply chain, where it can be impossible to guarantee chain of custody from one supplier to the next. Responsible sourcing programs (such as that established by an international nongovernmental organization called Forestry Stewardship Council) address this somewhat, but broader issues of ethics and human rights are often entirely overlooked, particularly when sourcing materials from remote locations or working in less well-regulated regions of the world.

Much of this discussion points toward a need for a higher level of change throughout the industry to address these shortcomings. More appropriate accounting methods, improved skills and know-how, and more suitable procurement practices need to be introduced, some of which can be implemented at the organizational level, but some necessitate structural or legal changes. The scope of these barriers is very broad and extremely challenging, but there is evidence of progress.

Successful Sustainability Practices

Despite the barriers to the adoption of sustainable practices in the property and construction industry, the growing awareness and familiarity with the sustainable development agenda, coupled with a genuine sense of urgency to change conventional practices in some countries, have resulted in many exemplars of good practice whether these are manifested physically, as in completed buildings, or evident from management practices.

First, specific buildings or development projects demonstrate successful green practices. Beddington Zero Energy Development (BedZED) in London for example, includes an extensive array of sustainable technologies such as ground source heat pumps, onsite generation, wind turbines, and photovoltaic panels. Its success, however, also has been due to the project's integrated approach to sustainable design and construction and greener standards of living—only electric cars are permitted on the development. The Audubon Center at Debs Park in Los Angeles was the first Platinum-rated LEED building in the United States and is entirely powered by onsite solar energy generation. Recycled materials were used throughout the environmental education center and 50 percent of the building materials were sourced locally.

In Europe, fewer than a hundred major development projects like these exist, but many thousands of individual buildings can be deemed as sustainable in some respect. The most successful and highly publicized projects arise from a range of public or private clients, tend to have highly skilled (often internationally renowned) consultants as part of the project teams, and, in most cases, engage in participatory design processes involving users and other stakeholders. These projects may not always excel in all aspects; some, for example, may contain more effective technical innovations whereas others may facilitate high levels of positive behavioral changes in residents' behavior. What is certain is that there is now a genuine sense of competition on the part of building owners to have the "greenest" building or use the least energy. Many clients now insist on attaining publicly respectable levels of achievement, for instance using LEED or BREEAM. A specific group of examples can also be found in demonstration projects that tend to have a research focus (for example, to analyze energy consumption or test new equipment) or a marketing function for product manufacturers. The benefit is that many of these buildings can be visited—several demonstration houses exist at the Building Research Establishment, the University of Nottingham's "Creative Energy Homes," and the Hockerton Housing Project in the United Kingdom. Further examples can be found across the world, such as the Green City of Tomorrow in Malmö, Sweden; the Masdar City development in the United Arab Emirates; and individual buildings like the Green Building Demonstration Project in Fresno, California.

Secondly, it is possible to describe success in terms of changes to management practices at various levels within the industry. The presence of sustainability or environment directors / vice presidents in most major construction companies is a reasonable indicator of the level to which it is embedded in the industry, as are the plethora of industry awards for best practice in sustainability. Partnerships between construction companies and third-party organizations or pressure groups like the World Wildlife Fund are also becoming more common, as are companies that are choosing to report annually on sustainability, often using external auditing companies to publish credible data on their performance on waste or energy use, for example. The development of sector sustainability strategies for construction and other related industries, such as civil engineering, and particular construction product supply chains is a another positive step in Europe and the United States. These demonstrate commitment to change and a helpful attitude towards policy development to ensure that the whole industry does actually develop the capacity to deliver sustainable buildings.

Finally, consideration must be given to the impact of these buildings and practices. Certainly there is now a much greater awareness and familiarity with the basic concepts of sustainability within the industry. Trade magazines publish articles regularly on new exemplary projects, sustainability conferences attract large audiences, many dedicated peer networks exist, and the professional bodies are publicly supportive. Common terminologies are generally well understood (particularly among professional groups), and in some cases deep subject expertise is developing on new technologies. Public research funding levels have also increased to reflect the changes happening in industry. The level of sophistication in the industry's ability to deal with difficult trade-offs is increasing steadily, but many practitioners complain about the fast-moving policy and legislative environment relating to sustainability. Small businesses are typically finding it very hard to keep pace.

It is very difficult to get a sense of the overall impact of these changes within the built environment as an entity in its own right, particularly because the rate of turnover of building stock is so low. Some evaluative research does exist, often on performance of individual buildings or comparisons between projects. It might be fruitful to analyze the performance of individual companies operating within this industry, although this might only offer a piecemeal depiction of current trends.

Outlook for the Industry

There is no doubt that the industry will continue to experience pressure because of the many environmental impacts associated with building construction and operation, and because of the critical role it plays as an industry in delivering successful, sustainable buildings. This pressure will manifest itself primarily through legislation but increasingly through market demand, particularly if energy costs continue to rise. Decarbonizing buildings will remain a heavy burden on the industry and its customers, regardless of whether legislation actually changes to address the massive millstone of poorly performing older stock. New buildings will have high expectations placed upon them.

In terms of the cost and accounting for sustainability, a tense relationship between sustainability and commercial considerations will continue. Organizations will experience greater pressure to use whole lifecycle costing techniques to weigh up initial capital expenditure and operational running costs. This means that more practitioners will need to familiarize themselves with lifecycle assessment methods, which will also play a significant role in emerging standards and standard assessment tools. While these tools have been broadly accepted so far, there may be a market backlash against them if the "tail starts to wag the dog."

The sustainability agenda is inherently complex, but the industry should not just focus on environmental protection; the social side of sustainability can no longer be overlooked. Indeed, this will prove to be a market differentiator, with successful companies proving themselves by upholding high ethical and human rights standards. For example, ISO 14001 is the benchmark for environmental management, and in the near future, new standards such as ISO 26000 for social responsibility will start to take hold in construction and other sectors. Awareness of corporate social responsibility is rising, and there is significant scope for the industry to improve in this area. Successful businesses in the property and construction industry will thus be judged on their ability to adapt to the sustainability context, implement new technologies, and move into new markets by showing leadership in sustainable practices and influencing others to do likewise.

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See also Building Standards, Green; Cement Industry; Design, Landscape; Development, Urban; Energy Efficiency; Facilities Management; Hospitality Industry; Municipalities; Smart Growth; Triple Bottom Line; Water Use and Rights

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Public Transportation

Well-run mass transit systems are less polluting per trip than individual automobiles, but low costs of motor vehicle use, low-density settlement patterns, and unstable funding are obstacles to sustainable public transportation in countries with widely dispersed populations such as the United States. In developing countries, transit systems sometimes replace "greener" travel modes such as walking and biking. Public transit is used for some 50 percent of all trips in many cities in China.

Public transportation, sometimes called mass transit, refers to a wide variety of transportation services available for general use. Common parlance restricts the term to shared surface transportation services, such as buses, trolleys, light-rail, subways, commuter rail, and ferries. Motorbike taxis, pedicabs, and other human- and animal-powered conveyances are in service in many countries. Vans and other small vehicles are often in use as "paratransit," specialized services that supplement the transit system. In some locations, taxis and other hired cars also serve a public transportation function, offering shared rides.

The public transportation industry is as diverse as the services it offers. The industry includes firms that produce transit infrastructure (e.g., vehicle manufacturers, fuel producers, engineering firms that design and build rail systems, architectural firms that design stations), as well as the suppliers of materials needed for transit construction, operation, and maintenance. The transit industry also includes organizations that plan and deliver transit services, systems analysts who forecast demand and design routes and schedules, service operators (e.g., drivers, maintenance technicians, dispatchers), and administration and finance experts. The transit industry also has connections to urban planning and real estate development and to other transport groups, especially those involved in street and highway development, design, operation, and maintenance.

The public transportation industry offers services in rural areas and between cities, but its largest and most important role is to serve travel within the metropolitan areas that house the majority of the world's population. In developing countries, investments in public transit are greatly increasing transit use, and with it, accessibility to jobs and housing for the working classes. In many cities in China, some 50 percent of all trips are made by transit (Ng and Schiller 2006, 4), and transit ridership is growing rapidly in other developing countries. In advanced economies, transit's share of urban travel is usually far smaller, often no more than 2–20 percent of regional travel (National Research Council 2001b, 28). But even a modest transit share can have a big impact on reducing congestion; for example, a 5 percent reduction in car traffic along a street can make the difference between stop-and-go delays and heavy but flowing traffic. Furthermore, transit is a critical element in "green" urban mobility by helping to reduce energy use and lower environmental impacts.

Transit is a sizable industry. For example, in the United States, public transportation is a $48.4 billion industry involving some 7,700 service providers and employing more than 380,000 people. Almost 11 billion trips were taken on U.S. public transportation systems in 2008. While the numbers were down somewhat in 2009 due to deep recession, growth during the previous decade had been steady; from 1995 to 2008, transit ridership increased by 38 percent, more than double the population growth rate and 80 percent higher than the growth in auto travel over the same period (American Public Transportation Association [APTA] 2009).

In most countries, the government plays a major role in every aspect of providing public transportation: planning, design, construction, operation, maintenance, monitoring, and evaluation. The government may act directly through public agencies (the most common approach in the United States) or indirectly through contracts with the private sector to develop and operate transit systems (the approach usually taken in the European Union). In high- and middle-income countries, capital investments in transit are covered mostly by the government, either by directly paying for them or by facilitating joint transit and land development opportunities where revenues from the latter cover transit costs. In developing countries and some middle-income countries, loans from international development banks are a major source of the capital for transit.

Agencies at all levels of government—national, state, regional, and local—are involved in public transportation, as are private firms. The Federal Transit Administration of the U.S. Department of Transportation funds about half of the country's capital costs of public transportation (more in rural areas and small cities) and provides a small portion of operating costs. State, regional, city, and county governments also contribute to transit finance and plan and regulate transit operations. In most other countries, national governments fund capital expenditures (especially for rail systems). Operating costs are also subsidized in most countries, either directly through taxes or indirectly through mandates and incentives such as employer-sponsored transit passes.

The specific mechanisms for providing transit funding, however, vary widely from country to country. In Great Britain and France, the national government provides transit funding in London and Paris, respectively, but offers very limited assistance to other localities. Services outside London are largely private, unregulated, and unsubsidized except for a limited number of social services. French services outside Paris are subsidized by local governments through employee payroll taxes. In contrast, the Netherlands provides substantial capital and operating funding for transit systems throughout the country. Germany takes yet another approach, offering block grants to state and local governments for the provision of transit services. Until the twenty-first century, Canada had little federal involvement in transit.

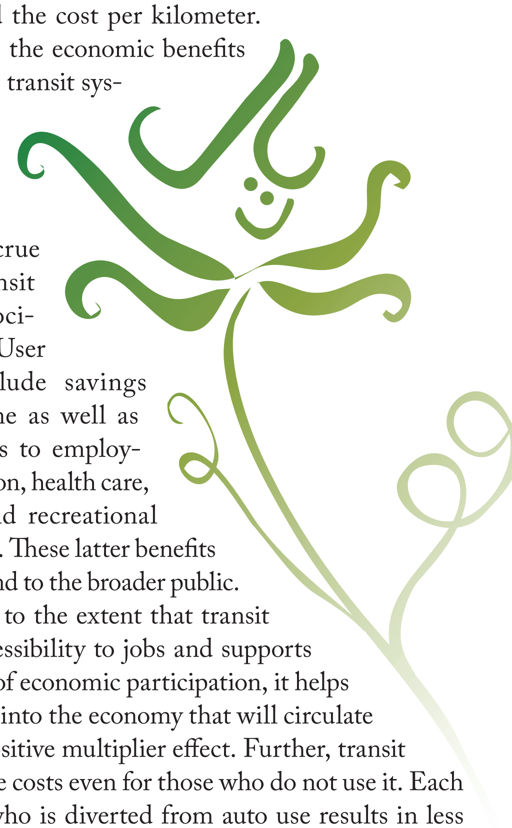
Public transit is playing a growing role in developing regions. Latin America continues to make major investments in transit and has been at the forefront of innovations in bus systems, especially bus rapid transit (BRT). As its urban population grows and incomes increase, China has been building subway systems and light-rail transit in the largest Chinese cities, and it has made major investments in BRT and other bus systems in other large urban areas. With rapid urbanization and some 125 cities with populations over 1 million, China promises to be a major market for transit investment in the coming decades.

Just as financial arrangements vary, so do operations responsibilities. In the United States, transit operators can be special districts, city agencies, county agencies, state agencies, and private contractors. In the European Union, transit services are commonly offered up for competitive bids from private operators. China's rail and BRT operations are government enterprises, but many buses are operated by private employers.

Sustainability and Public Transportation

Public transportation systems are widely viewed as a highly sustainable means of getting people from one place to another. Well-designed and well-operated public transit systems offer important economic and environmental benefits.

The economic incentives for implementing transit systems are hard to quantify because transit projects are often related to real estate development. How long it takes to pay off a project depends on factors such as the technology used and the cost per kilometer. Nevertheless, the economic benefits of established transit systems can be measured in a variety of ways, and they accrue to both transit users and society at large. User benefits include savings on travel time as well as greater access to employment, education, health care, shopping, and recreational opportunities. These latter benefits in turn rebound to the broader public. For example, to the extent that transit increases accessibility to jobs and supports higher levels of economic participation, it helps pump money into the economy that will circulate and have a positive multiplier effect. Further, transit use can reduce costs even for those who do not use it. Each transit user who is diverted from auto use results in less congestion for those who continue to drive.



Public transportation can help produce benefits from urban agglomeration. Transit can facilitate the clustering of urban activities and help produce economies of scale, with higher productivity and lower costs. Transit investments also can help reduce the total costs of public and private infrastructure, including transportation itself.

Infrastructure costs can be lower in transit-oriented areas, which are more compact and therefore require fewer miles of streets, water lines, and sewers.

Lower car ownership and use means that the amount of land and the number of parking structures can be reduced. In addition, because public transportation efficiently uses urban space, communities with people who use transit for many trips may be able to reduce the amount of urban land needed for transport. Transit systems such as subways can operate underground, sharing rights of way with surface streets or traveling beneath buildings. Even when operating on surface streets, public transit systems offer substantial efficiencies, delivering perhaps three to four times the number of passengers per hour as personal vehicles. Finally, transit can deliver cost savings compared with other motorized modes due to lower levels of environmental damage: reduced energy consumption, air pollution, and traffic noise.

The environmental benefits of public transportation can be substantial. A well-designed transit system can reduce energy use and greenhouse gas emissions compared with travel by private motorized vehicles, such as cars and motorbikes. In addition, by helping reduce congestion, public transportation reduces the excess energy use and air pollution associated with stop-and-go driving. Transit systems also have a smaller footprint than highways and so can have a lower impact on natural systems and urban environments.

The American Public Transportation Association (2009) estimates that at current ridership levels, transit saves the United States 4.2 billion gallons (15.9 billion liters) of gasoline annually and reduces U.S. carbon emissions by 37 million metric tons annually. Further, APTA estimates that a single commuter switching from a car to public transportation for the commute to work can reduce a household's carbon emissions by 10 percent; the reduction jumps to 30 percent if the commuter eliminates a second car. Transit use can also improve safety, as its record is far better than that for autos.

Challenges

Despite its great potential, public transportation faces major challenges, whose resolution may be key to its future prospects. Three key issues are financing, competition from the automobile, and suburban access.

Financing

Financing public transportation is a major issue worldwide. As noted, transit systems' capital costs are usually government financed, and many transit systems' operating costs are paid for through a combination of fares, other revenues, and government subsidies. Governments justify subsidies with a variety of reasons, including environmental and energy benefits. Subsidies, however, are controversial, and in many cases their continuation is far from assured. A variety of financing schemes have been used. In the United States, local governments subsidize much of mass transit, often by adopting specific property taxes, sales taxes, or fuel taxes. In several places, notably Hong Kong and Japan, land development around transit stations is a major source of revenue for the transportation system. Some cities in the European Union and the United States have had successes with joint development at and around transit stations, particularly heavy-rail stations, and some have used special assessment districts to capture a portion of the increased real estate value around the stations. Employer taxes and impact fees also have funded transit, as have voluntary programs involving subsidies for services to particular employment centers.

Funding uncertainties make it hard to maintain services, and they discourage innovation, especially innovation that requires risk taking. Thus finding ways to put transit on a more stable financial footing is necessary if it is to continue to be a competitive alternative.

Competition

Competition from the automobile is also a major challenge for most public transportation systems worldwide. In many metropolitan areas in the European Union and the United States, transit has maintained or increased total ridership but has lost market share since the late twentieth century as auto ownership has increased. In the twenty-first century, mass transit is only a small share of overall travel in advanced economies; in the United States, transit mode share rises to double digits only for work trips in a handful of cities. Transit captures a higher share of travel in the European Union and in Japan, but auto use has become the dominant travel mode there as well.

In Latin America, China, and India, where nonmotorized travel still predominates, both transit use and auto ownership and use are growing rapidly as incomes rise. This raises a two-pronged challenge for transit. First, when transit riders are drawn mostly from travelers who formerly used nonmotorized modes of transportation, such as bicycles, pedicabs, and walking, the environmental impacts may be negative (although transit may offer significant benefits in terms of time savings, comfort, and accessibility). Second, transit has to compete with the auto as the basis of transport services in light of its status as an indicator of middle-class success.

It is unclear whether the emerging middle classes in these areas will embrace public transportation or move increasingly toward personal transport modes, such as motorbikes and especially automobiles. The advantages of the automobile are not always apparent, especially when streets and highways are heavily congested. On the other hand, an auto can provide door-to-door service, and the car itself is a comfortable, controlled environment, even if travel is slow. In comparison, transit (even in improved formulations) can entail long walks, waits, and transfers, congested stops and stations, and jam-packed vehicles. (Six-plus passengers per square meter is commonplace in many developing countries.) Thus in many cases, the attractions of the auto and the negatives of transit services are critical considerations for those who have a choice of modes.

Government policies to charge the full cost of automobile use, including externalities such as congestion and environmental damage, are not fully in place anywhere. As automobiles have become more energy efficient and less polluting, however, some of the criticisms of their use have diminished, and the environmental advantage of using public transportation has shrunk. In addition, concerns about pollutant emissions from public transportation systems have grown along with evidence on the detrimental health effects of emissions, especially from diesel fuels. Further, in many countries, including the United States, subsidies for transit are highly visible, while subsidies for the automobile (e.g., parking subsidies) are largely hidden; this makes transit's economic benefits less apparent. Likewise, transit's contribution to congestion relief can be hard to see, especially when buses are stuck in the same traffic as single-passenger automobiles. Thus it is becoming increasingly critical for transit operators to improve their sustainability with improved vehicles, fuels, and operations.

Suburbanization

The third major challenge to public transit is posed by the suburbanization that is occurring worldwide. Transit is problematic in many suburbs in the United States and in some parts of the European Union because low densities and auto-oriented street designs make transit services costly and impractical. Transit must be well used if it is to compete from an economic, energy, or environmental perspective with the private automobile. Systems that run half-empty buses and trains, as sometimes happens in the United States, are not economically efficient and may be less energy efficient than solo driving, and environmental performance also can be worse. (Buses must be both well used and well maintained in order to reduce emissions. Poorly maintained bus fleets, a frequent problem in many developing countries, can be serious sources of pollution.)

When built into outlying areas developed with little land-use planning, public transportation systems can lead to urban sprawl in the same way that suburban highways do. For example, in some U.S. suburbs, transit services attract commuter trips but all other trips are made by auto.

Suburbs in Latin America and Asia are almost always sufficiently dense for mass transit to be an option, but distances from urban job centers, impeded pedestrian and bicycle access to transit stations, and long, slow line-haul travel combine to make public transportation use difficult. As a result, many such locations are seeing rapid growth in the use of motorcycles, motorbikes, and electric bicycles instead of bus and rail systems.

Innovations

Public transportation agencies have sought to improve services, increase sustainability, and become more competitive in a variety of ways, many of which directly address the challenges of environmental performance, markets, and costs. Three important innovations are green vehicles and fuels, bus rapid transit, and transit-oriented development.

Green vehicles and fuels address concerns about emissions from diesel fuels and cut greenhouse gas emissions. Newer vehicles are not only more energy efficient but also incorporate designs and materials that reduce noise, improve longevity, and otherwise reduce lifecycle environmental costs. Clean fuels can be used in both existing and new vehicles and range from natural gas to electric propulsion; they reduce pollutant emissions and greenhouse gases substantially, with the specifics varying with fuel type.

Bus rapid transit is a service innovation developed originally in Curitiba, Brazil, and since implemented in numerous other cities from Bogotá to Boston to Beijing. These systems run buses in exclusive lanes and give them priority treatment at intersections. They also use bus, station, and fare collection system designs that speed boarding (e.g., paying before boarding) and alighting (e.g., either low-floor vehicles or raised platforms).

High-quality stations, vehicles, and information systems provide user comfort and convenience, as do well-designed pedestrian, bike, and feeder bus connections. Together these features produce cost-effective, customer-friendly services. This results in increased bus speed and reliability, providing a quality of service similar to that of light-rail systems at a fraction of the cost.

Bus rapid transit can be used as the principal line-haul transit service for a city or region, as in the case of Bogotá, Colombia, or can be used to complement and connect to rail services, as in Boston, Beijing, and San Francisco. Fast, safe, efficient transit services have attracted many riders, including some who are auto owners. For example, the Bogotá system operates 850 large-capacity buses eighteen hours a day and reports a daily ridership of 1.4 million;

surveys indicate that about 10 percent of the system's users have access to a private motor vehicle but nevertheless chose to ride the bus (C40 Cities 2009).

Transit-oriented development (TOD) builds markets for transit in both city and suburban locations by creating high-density areas of mixed-use activity within walking distance of transit stations and stops. TOD also can increase revenues for transit by providing joint development opportunities and increasing local property and sales tax revenues. It can be located around high-speed or conventional rail stations or along bus rapid transit corridors, and it can include housing, jobs, and services for a variety of income groups. Implemented as a regional policy, TOD can help structure metropolitan growth in ways that support high levels of transit use, biking, and walking.

Taken together, these innovative approaches can help public transportation secure its future. They also can help urban planners build more economical, environmentally sound, and socially equitable and responsible cities in which transit plays a key role.

Future of Public Transportation

Public transportation is an important strategy for sustainable development, especially in urban areas where the majority of the world's population lives. Transit provides both mobility and access, and the world's largest cities literally could not function in their present form without it.

Transit use is growing quickly in China, India, and Latin America, where it serves a burgeoning demand for urban jobs and better housing. In the United States and European Union, transit use is concentrated in large cities, but many small- and medium-sized cities also rely on transit to meet the basic mobility of those who cannot drive and to help reduce congestion and emissions.

Worldwide, transit operators are challenged to put their finances on stable ground, to provide environmentally sound services, to respond to social needs, and to compete with the automobile. But there are hopeful prospects for succeeding on all counts. New technologies, new operating strategies, and new urban development approaches offer opportunities for transit to overcome current difficulties and to grow and thrive from a sustainability perspective.

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See also Automobile Industry; Airline Industry; Bicycle Industry; Development, Urban; Local Living Economies; Municipalities; Public–Private Partnerships; Smart Growth; Travel and Tourism Industry; True Cost Economics

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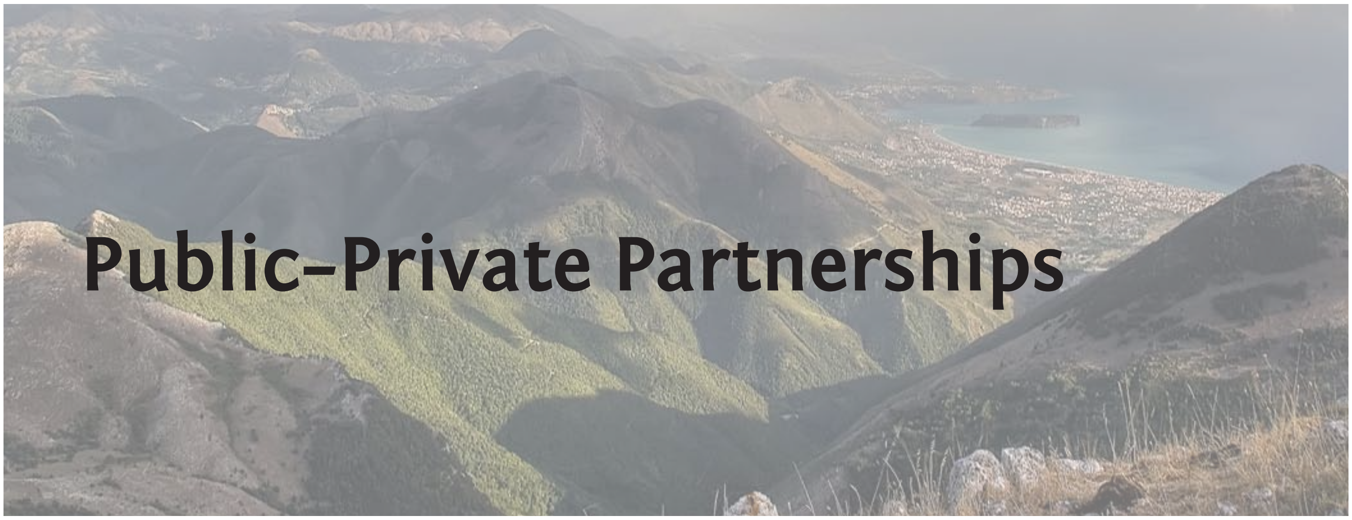

Public–Private Partnerships

The public sector—government—has not always been successful in providing adequate services, especially in poorer, more remote areas. Since the 1990s, the private sector has been used to deliver financing opportunities and improve services in conjunction with the public sector through public–private partnerships. Water and sanitation has been one sector addressed globally through different types of these contractual agreements.

Throughout the world, the public sector is principally responsible for water and sanitation services, operating more than 90 percent of the piped networks in developing countries. On the whole, however, the public sector has not succeeded in improving water and sanitation access and quality in many parts of the world, especially for poorer people, and in more remote areas. Such operators typically suffer from various problems, including low service coverage and quality of service, artificially low tariffs, billing and collection difficulties, lack of capacity, lack of capital investment, lack of operation and maintenance and poor consumer relations. In the 1990s, public–private partnerships (PPPs) began to be promoted as a means to deliver financing for investments and efficiency improvements. Infrastructure (telecommunications; electricity generation, transmission, and distribution; natural gas transmission and distribution; transport; and water) accounted for half of privatization/PPP proceeds in developing countries in 1990–2003 (ADB 2008). By 2000, private operators were serving 93 million people in developing countries (Marin 2009); high profile projects were undertaken in Latin America as well as in megacities including Buenos Aires, Argentina; Manila, the Philippines; and Jakarta, Indonesia.

What Is a Public–Private Partnership?

While there is a large volume of literature relating to public–private partnerships, there appears to be no hard and fast definition. The predominant understanding of public–private partnerships is a general one: public–private partnerships serve to implement projects in which there is some form of collaboration between the public and private sectors; they also finance or otherwise increase resources for the sector (resources include people, skills, expertise, knowledge, technology, equipment, facilities, and spare capacity) in order to expand capabilities.

In general, public–private partnerships have a number of common features:

- A formal or informal agreement. The majority of PPPs are governed by a formal contract, which is generally understood to be a legally binding written agreement. But public–private partnership is also used to describe other types of less formal agreements between governments and private organizations. These "agreements" spell out the responsibilities of each party but stop short of being legally binding arrangements.
- A public- and a private-sector entity. There is a lack of consensus over the definition of what constitutes the private sector in the context of PPP arrangements. For example, a private partner might be a private company (international or local), an informal service provider (international or local), a nongovernmental organization (NGO), or a community-based organization (CBO). The partnership may be a bilateral contractual arrangement or a multiparty arrangement.
- An outcome. PPPs are intended to ensure that services are provided in the most efficient and effective ways possible and usually through joint realization. For

example, the private sector typically contributes design, construction, operation, maintenance, finance, and risk management skills while the government is responsible for strategic planning, regulation, and so on. This sets PPPs apart from other forms of public–private interaction, such as when a private-sector operator or an NGO has essentially been subcontracted to provide a service (or services) independently.

- A degree of risk borne by the private-sector entity. Most definitions of PPPs usually refer to the degree of risk borne by the private sector. There is a distinction between models of PPP with low private-sector risk, such as service and lease contracts, and those with significant private-sector risk, such as concession contracts (Sohail 2003).

PPP Models

There are a number of different types of PPPs in existence. The following is a typical categorization of different contractual arrangements for private-sector participation, but several hybrid arrangements are also possible.

Service Contracts

Under a service contract, the government pays a private entity to perform specific tasks. Service contracts are a long-established practice used for routine operations (meter reading or leak detection), engineering works, and the laying of pipelines.

Management Contracts

Management contracts are contractual agreements between the government and a private partner under which the private partner is given the responsibility for day-to-day management of an enterprise in exchange for a fee; the government, however, retains financial and legal responsibility for delivery of services. These are arrangements in which a municipality or local government purchases management services from a company.

Leasing or Affermage

Under this model, the government delegates management of a public service to a company in return for a specified fee, commonly based on the volume of water sold, while ownership of assets remains with a holding company operating for the government.

Concessions

This arrangement usually gives the concessionaire (the owner or operator) a monopoly service provision for a fixed period of time, during which the concessionaire also assumes any significant investment risk. The model of large concessions has worked in some places, but its suitability to most developing countries has been questioned.

Why Use PPPs?

Public–private partnerships are pursued as a way to leverage knowledge, resources, and capabilities to achieve public goals. PPPs are often used to address non-revenue water reduction (reducing the amount of water “lost” before it reaches the customer and is paid for), billing collection, and labor productivity. While the early models of partnerships focused on the gains from private financing, the most successful PPPs in the water and sanitation sector have largely been based on public financing (leases or hybrid programs) combined with private-sector efficiency. Thus rather than improve access to private financing, PPPs have been used to improve the financial viability of the water and sanitation operators through service quality, access expansion, and increasing cash flow for investment and creditworthiness. In the long term these improvements should translate into broader, more equitable, efficient, affordable, and effective delivery of services. Nevertheless, PPPs may not be selected as an option to improve service delivery on ideological grounds or the basis of public service ethos (Sohail 2002a).

Innovative Solutions

Access has improved by expanding the water network to poor neighborhoods that were previously unserved, as in Queenstown, South Africa; La Paz–El Alto, Bolivia; Manila; and Buenos Aires. In Queenstown, a much smaller PPP covering a population of 22,000 was amended to include an extra 170,000 inhabitants of predominantly low-income areas (Sohail 2005). The renegotiation of existing concession contracts operated in Manila and Buenos Aires led to affordable connection charges for lower-income consumers—benefiting 400,000 in Manila and 260,000 in Buenos Aires. Connection-fee cross-subsidies were used in Buenos Aires; reduced connection costs through distant meter locations and the use of community labor led to 90 percent cost reductions in water tariffs for the poor in Manila (Nickson and Franceys 2001). Nonetheless, there is little evidence of coverage extended to the urban poor as a result of larger scale, formal private-sector companies in PPPs, at least in the initial stages of the contract (Sohail 2004).

In 2000, 80 percent of the water PPP market in developing countries was dominated by five international water companies. Since 2001, however, most new contracts have been signed by private operators from developing countries (these account for 90 percent of the growth in the number of people served by PPP projects). By 2007, local private water operators served more than 67 million people; some international operators have also transferred their existing contracts to local investors (Marin 2009, 9).

Water operator partnerships (WOP) have been promoted by the U.N. since 2006 as a way to strengthen local water and sanitation services by sharing expertise through training and technical assistance. WOPS are defined as "cooperation between water operators," on a "not-for-profit" basis (UNSGAB 2006, 3). Some may not classify them as PPPs, but they are partnering arrangements: the receiving partners are always public undertakings (water and sanitation utilities, drainage and sewerage companies, or wastewater organizations), but their collaboration partners may be well-performing public (foreign public utilities or local public utilities) or private operators (international private operators or local private operators), small-scale water and sanitation service providers, or community-based organizations.

Small, often informal service providers play a significant role by filling in the gaps in service delivery. These service providers, however, are often not officially recognized or involved in PPPs. The potential for these small service providers in PPPs has not been accurately assessed.

Controversies

In developing countries, PPPs haven't met initial expectations: there have been a series of highly publicized contract cancellations, mostly in Sub-Saharan Africa, and in Latin America among concession programs. Doubts still remain over the suitability of PPPs both for improving the performance of water utilities and extending access to water and sanitation to the unserved in developing countries.

Cherry-picking is a particular danger with PPPs, that is, the sites that are most attractive to private investors—large cities in countries with large economies and a large middle class—will be selected rather than areas with the greatest need. Poor areas and people are often seen as unprofitable and difficult to serve, which means that connections and extension of services are typically not made to residents with insufficient funds, insecure tenure, and those living in difficult-to-reach locations such as rural areas (Sohail 2002b).

The pricing of services in general and the design of tariffs for service provision in particular is a significant issue. In most cases, PPP projects have been accompanied by tariff increases (due to more realistic pricing or greed, depending on one's point of view) that put services beyond the reach of the poor. PPPs may also be accompanied by massive lay-offs, depending on extent of "over-staffing."

Some services are less attractive for private-sector involvement due to their more complex nature; neglect in the area of sanitation is a significant trend that has been noted with PPPs. This could be the case for many reasons: sanitation facilities are often more complex and expensive than water facilities; the demand for the service often does not exist; there is an unwillingness by users to pay; or there may be unnecessary bureaucracy or regulation that constrains service delivery (Sohail 2002c).

PPPs require significant government capacity to be effectively managed, however, such capacity is often lacking. Local government officials need to learn not just how to strategically manage PPPs, but also how to renegotiate and implement them to achieve their objectives.

Successes of PPPs

PPPs haven't always worked, but successes have often received much less publicity than failures. PPPs tend to work best for those who can pay and who live in places where the overall demand makes the provision of services a viable option. If a PPP is to improve access and service delivery for the poor, then this has to be specified in the contract documents that will ultimately be the basis for engaging the private sector. Very few PPP contracts contain explicit pro-poor references. Bidding procedures and contract design should allow sufficient flexibility for innovative solutions to water and sanitation supply, such as lower-cost or alternative technology (for example, pipes at lower depth or condominium sewerage), and flexible billing arrangements as well as payment options, particularly with respect to poor neighborhoods (Hemson and Batidzirai 2002). Multipurpose contacts, such as the combined water and electricity concession in Casablanca, offer opportunities to optimize the demand and sources and should be explored further. In Casablanca the larger electricity side of the services was subsidizing investment in the smaller water division (Hall, Bayliss and Lobina, 2002).

Developing a long-term business model for PPPs to work within a given context is a challenging activity and requires further exploration.

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See also Development, Sustainable; Development, Rural—Developed World; Development, Rural—Developing World; Development, Urban; Health, Public and Environmental; Municipalities; Public Transportation; Water Use and Rights

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Remanufacturing

Most of the environmental challenges of our time are related to unsustainable patterns of production and consumption. So-called "closed loop product systems" (in which product waste can be put to other uses) can provide significant value in addressing these challenges, but they can be costly to the manufacturer unless technology exists to address returned products in an economical fashion. Remanufacturing provides the greatest net benefit among any of the existent recycling and resource recovery options.

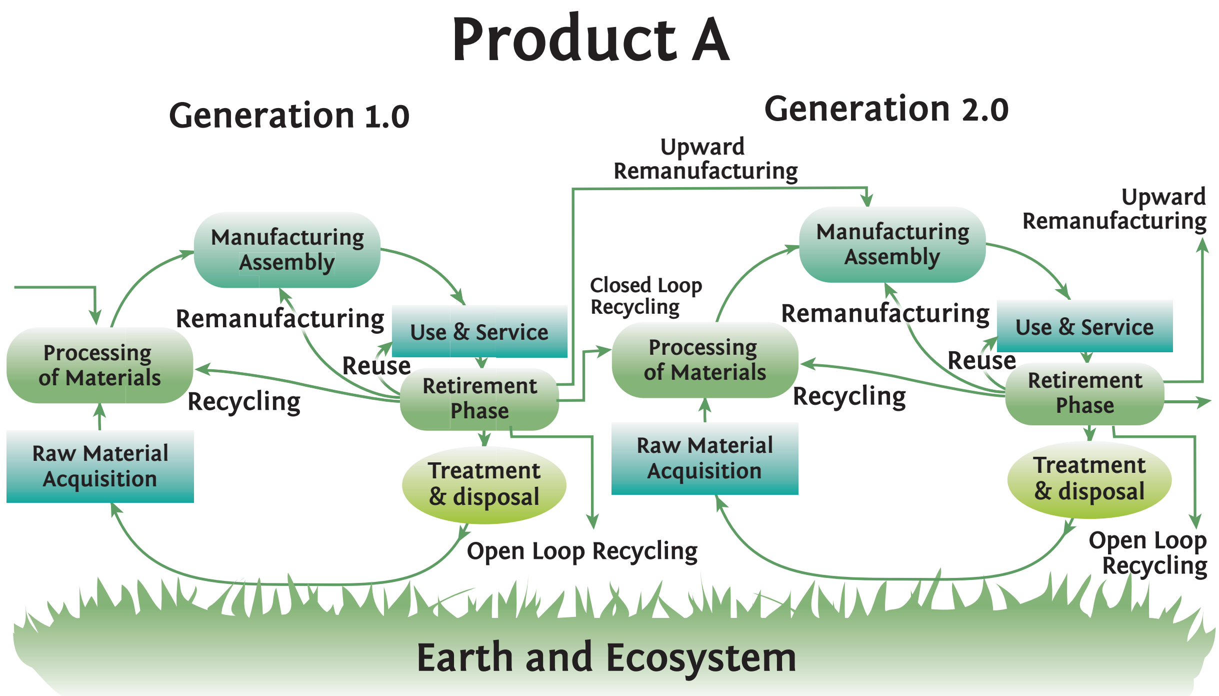
Remanufacturing is an industrial process by which retired or nonfunctional products or modules are processed and returned to "like new" condition. In many cases, however, remanufactured products or modules can be better than new ones because problems that became known during the product's use are not duplicated in the remanufacturing process. For example, parts that prove to be less durable than desired are replaced with more durable parts. Remanufacturing requires the repair or replacement of worn out or obsolete components and modules. Parts subject to degradation affecting the performance and expected life are replaced. Remanufacturing differs from other recovery processes in its completeness: a remanufactured machine or module should match the same customer expectations, performance, reliability, and life cycle as new machines.

In a typical product life cycle, the product begins as raw material. The materials are processed, refined, and fashioned into a usable product through a series of manufacturing and assembly operations. The product is then put into service. At the end of its life in this linear model, the product is disposed of. The disposal phase in most cases returns a product to the Earth's ecosystem in a form quite different from its constituent parts. For example, plastic parts begin as liquid petroleum; these parts can be recycled to make new parts, disposed of by incineration with the gaseous by-products released to the atmosphere, or simply returned to a landfill where they will take decades (or longer) to degrade.

An alternative product life cycle model, as illustrated in figure 1 below, can be depicted as the links of a chain, with each link representing a single generation of a product. This sustainable life cycle approach initially draws upon raw materials and makes use of materials processing to start its product life cycle engine, but it is ultimately much less dependent on these virgin sources of material as the product progresses through multiple generations. Each link is internally supplied by its own end-of-life products and their constituent components, parts, and recycled materials, using new virgin material to complement recovered material. As product innovation progresses, each link provides the bounty of its end-of-life products to the succeeding generation's product life cycle.

The lifecycle model in figure 1 on page 398 suggests six options for disposition of end-of-life products:

- *Reuse:* Removing the component or product from one system and installing it in another system where it performs its original function. An example is the removal of an automobile engine and its subsequent installation, after minor cleanup or refurbishing, in another vehicle.
- *Remanufacturing:* The process of disassembling, cleaning, inspecting, restoring, replacing, and reassembling the components of a part or product in order to return it to like-new condition. The part or product is then returned to service in a system similar to that from which it came. Automotive parts such as starters, alternators, and water pumps are routinely remanufactured at the end of their useful lives and returned to service.



The alternative product lifecycle model is less dependent on raw materials than typical manufacturing approaches as the product progresses through multiple generations, using (and re-using) the same raw materials it was originally made with. Using fewer raw materials clearly has economic as well as environmental benefits.

- *Upward remanufacturing:* The process of disassembling, cleaning, inspecting, restoring, replacing, and reassembling the components of a part or product in order to return it to like-new condition and incorporate it into a new upgraded system or a newer model. This might require that new features be built into the product during remanufacture.
- *Closed loop recycling:* Recycling the material from a part or product and using that material to fabricate the same type of part or product. For example, plastic film canisters are sometimes ground and used to supplement virgin material in the manufacture of new film canisters.
- *Open loop recycling:* Recycling the material from a part or product with no similar product manufacturing process dedicated to the consumption of the recycled material. For example, plastic milk jugs collected from municipal recycling streams are transformed into many different products, including carpet and insulation.
- *Treatment and disposal:* Returning parts, products, or their by-products to the ecosystem because they have no viable markets. Incineration and disposition to landfill are two examples of this approach.

The contemporary global commercial remanufacturing industry is characterized by predominant emphasis on the automotive sector. Present-day remanufacturing activities, however, also encompass toner cartridges; office furniture and equipment; transportation, construction, and electrical equipment; medical devices; machine tools, compressors, and other heavy machinery.

Although it is an enterprise of worldwide scope and significance, remanufacturing (often shortened to "reman") is possibly the industry most neglected by researchers. Only two major surveys of U.S. remanufacturing have been conducted (Lund 1996; Lund and Hauser 2003), and they assessed a limited number of broad indicators including number of firms, total annual sales, total direct employment, and number of product areas served. The 1996 Lund study estimated that U.S. remanufacturing is a $53 billion industry represented by 73,000 firms and 480,000 in total direct employment but cautioned that these estimates "are far from precise" (Lund 1996).

The more recent broad study of the industry found that "firms engaged in remanufacturing are diverse in locations, products, and markets; multifaceted, in that remanufacturing is done in conjunction with a group of related business activities; predominantly small, independent, and privately owned; and competitive with original equipment manufacturers (OEMs), but also dependent upon them" (Lund and Hauser 2003).

These studies also captured only a small portion of the entire remanufacturing industry, most notably independent remanufacturers and some original equipment manufacturers (OEMs), who manufacture products that are sold under the purchasing company's name. The U.S. Department of Defense, the largest remanufacturer in the world, and other government entities and leading OEM remanufacturers were not fully addressed in either study.

Any attempt to survey the full extent of remanufacturing is necessarily constrained by these realities.

History of Remanufacturing

After the Industrial Revolution in the 1800s, remanufacturing emerged as businesses realized that many machines were too expensive to simply discard when ordinary wear and tear made them unusable. Railroad equipment makers became skilled in remanufacturing worn-out steam locomotives to new standards and then reselling them to railroads that could not afford the latest motive power. The automotive industries were also early practitioners of remanufacturing. By 1910, automobile tire remanufacturing ("retreading") was an established industry. Ford Motor Company began to apply remanufacturing principles and practices to the rebuilding of automobile engines in the early 1930s. And in the decades following World War II the remanufacturing concept was adopted by Caterpillar (n.d.), Xerox (King, Miemczyk, and Bufton 2006), and other first-rank multinationals, together with a multitude of smaller operations ranging down to one or two employees.

Remanufacturing entered a new era with the environmental movement of the early 1970s, sparked by awareness of the environmental consequences resulting from the world's industrial appetite, including consumption of fossil fuels, a finite resource that contributes to climate change. Remanufacturing was seen as a preventive step toward a sustainable, low-waste economy.

Recognizing the need to curb resource depletion and waste generation, in 1999 the President's Council on Sustainable Development recommended remanufacturing as a potential means to "close the loops of material and energy flows," citing its cost and energy efficiency for products at the end of their lifecycles (PCSD 1999). There was also growing appreciation by manufacturers of remanufacturing's inherent benefits over recycling. While recycling reduces products into raw material that can then be used again, remanufacturing retains the geometrical shape of the product and so captures both the materials and the value added (which includes labor, energy, and manufacturing processes) embodied in the original product.

Benefits of Remanufacturing

Remanufacturing exists to recapture the value added embedded in a product, and this has important environmental and economic benefits. Remanufacturing is often referred to as the "ultimate form of recycling" because it preserves the embodied energy contained in a product. A remanufacturing strategy not only avoids disposal costs (financial and environmental), it enables the value embodied in the product to be recouped and resources to be used more efficiently (Nasr 2008).

Economic

The economic benefit of remanufacturing is quantifiable. If every part is considered an asset, the recovered value (recovered via remanufacturing, recycling, or energy recovery) is a measure of how much any part is worth at end of its life minus the cost to recover that value (the total of all costs required to take a part out of service and arrange for its end-of-life disposition).

For the consumer, a remanufactured product can offer the same (or better) performance and durability as a brand new product at, on average, half the cost of new products. Infant mortality failures, those generally associated with defective new parts, have already been wrung out and those parts that have begun to wear have also been eliminated. Thus the resulting product has already been broken in, field proven, and refurbished (Nasr 2004).

Environmental

There are tangible ecological benefits to remanufacturing through waste reduction. In 2004 Eastman Kodak Company remanufactured their one billionth single-use camera. The camera was designed so that 77–90 percent (by weight) of the product may be remanufactured and a majority of the nonremanufactured components is recycled. This held back 16 million pounds of mixed plastics and 9 million pounds of circuit boards from entering the waste stream (Eastman Kodak 2004, 15, 23).

Remanufacturing recaptures much of the original value-added (including energy, labor, and raw materials) of the product. For example, when a typical passenger-car tire is retreaded, only 2.3 gallons (9 liters) of oil are required versus almost 9 gallons (26 liters) to produce a new tire; the savings in oil are even greater when retreading larger, heavy-duty tires. Because remanufacturing preserves up to 85 percent of the embodied material and energy used to create new products, remanufacturers are inherently able to compete on favorable economic terms with new-item producers in many markets.

By reducing the amount of discarded material, remanufacturing also lessens greenhouse gas emissions associated with material decomposition in landfills and through incineration. In a typical remanufacturing operation, the ratio of total energy required for original production compared to remanufacture is approximately six to one (i.e., for every kilowatt-hour of energy spent in remanufacturing, about 6 kilowatt-hours are avoided).

Remanufacturing thus lends itself to sustainability practices. Remanufacturing gives products an extended lifecycle due to incremental upgrades. For example, a worn-out vending machine can be remanufactured to better-than-new condition by replacing worn parts as required and equipping it with the latest circuit boards, coin-detection technologies, and exterior graphics panels during reassembly for a fraction of the price of the new unit. This process can be repeated as often as necessary and practical.

Remanufacturing is positioned to leverage its environment-friendly qualities in virtually any location. These qualities apply equally in developed and nondeveloped regions, making remanufacturing an activity of global significance.

Because remanufacturing results in products that are functionally identical to new-built products, the industry is generally held to the same standards as new equipment makers. To cite one example, in 2007, the U.S. Environmental Protection Agency (EPA) proposed more stringent exhaust emission standards for locomotives and marine diesel engines: "With limited exceptions, the[se] regulations would apply to all line-haul, passenger, and switch locomotives that operate extensively within the United States, including newly manufactured locomotives and remanufactured locomotives." (EPA 2007).

Overview of the Remanufacturing Industry

Remanufacturing activities in the United States are broadly divided into two primary U.S. industry segments: military and civilian (i.e., nonmilitary). The nonmilitary segment is further broken down into a number of major industrial product sectors and subsectors.

Military (Vehicle, Aircraft, and Equipment)

The U.S. Department of Defense is the largest remanufacturer in the world. The military remanufacturing includes ground vehicles, aircraft, weapon systems, ships, and stationary equipment. Activities in this area include refurbishment, upgrade, conversion, and complete remanufacturing. It is often referred to as "returning the odometer back to zero" when complete remanufacturing is done.

Nonmilitary Remanufacturing

Remanufacturing not connected with the Department of Defense is currently focused on, and most successful in (though by no means confined to), the following sectors and subsectors:

- *Automotive*: Internal combustion engines (diesel), fluid power cylinders and actuators, motors and generators, motor vehicle parts and accessories, and transportation equipment.
- *Electrical*: Steam, gas, and hydraulic turbines; farm machinery and equipment; power-driven hand tools; electric and gas welding and soldering equipment; pumps and pumping equipment; accessories; and electromedical and electrotherapeutic apparatus.
- *Furniture*: Wood office furniture and nonwood office furniture subsectors.
- *Machinery*: Industrial valves; steam, gas, and hydraulic turbines; internal combustion engines (diesel); machine tools (metal-cutting types); machine tools (metal-forming types); textile machinery; printing trades machinery and equipment; food products machinery.
- *Medical*: Computer peripheral equipment, surgical and medical instruments and apparatus; X-ray apparatus and tubes; and electromedical and electrotherapeutic apparatus.
- *Tires*: Tire retreading and repair shops and motor vehicle parts and accessories.
- *Imaging products*: Printing and copy equipment, toner and ink cartridges, peripherals and modules.

Products from Remanufacturing

Remanufactured products include CAT scanners, printing presses, and marine engines, tires, fuel pumps, fitness equipment, postage meters, and toner cartridges. In the twenty-first century, remanufacturing has expanded into areas formerly dominated by new production, for example medical devices: "The remanufacturing of medical devices is a growing phenomenon within the health-care industry. The types of devices that are currently [remanufactured] range from machines such as neonatal monitors and anesthesia vaporizers to devices used in surgery, such as forceps, endoscopes, and cytoscopes. Many firms are also restoring used disposable devices, such as catheters and surgical cutting instruments and accessories" (Basile and Quarngesser 2007).

Geographic Survey of the Industry

Remanufacturing is positioned to use, or leverage, its environmentally friendly qualities in virtually any location. These qualities apply equally in developed and developing regions, making remanufacturing an activity of global significance. A geographic survey breaks down the locations of reman industries into three main regions: the United States, Europe, and Asia and Australia.

Contemporary U.S. remanufacturing is a major business, with approximately 73,000 remanufacturing firms generating nearly $53 billion in annual sales. The automotive parts segment alone accounts for annual sales of close to $37 billion (Lund and Hauser 2003).

Nations of the European Union (EU) have active remanufacturing efforts, often driven by EU legislation. The Waste Electrical and Electronic Equipment Directive (WEEE), passed by the European Parliament in 2002, sets collection, recycling, and recovery targets for all types of electrical goods from electrical and electronic equipment manufacturers in the EU member states; it affects anyone who does business with European countries. The directive has stimulated interest in practices that improve recovery and recycling rates.

India, China, Japan, Australia, and other Asian nations have less-developed remanufacturing activities. Major corporations such as Caterpillar have invested in dedicated, state-of-the-art remanufacturing facilities in Singapore and China. Asia is also host to numerous smaller recycling operations, notably toner cartridge remanufacturers and suppliers.

Economics of Remanufacturing

The effects of remanufacturing extend far beyond the actual remanufacturing process. According to Robert Lund (1996), "Remanufacturing industry sales are greater than the value of shipments of the entire consumer durables industry (appliances, furniture, audio & video, farm & garden equipment)." Aftermarket automotive parts and tire retreading are two major remanufacturing industry segments.

The aftermarket automotive parts industry is one of the largest and most prosperous remanufacturing segments. "There are nearly 6,000 machine shops in North America remanufacturing engines in one form or another. At $2.5 billion dollars, the engine remanufacturing industry remanufactures approximately 2.2 million engines annually in North America" (PERA 2007).

Within the tire retreading remanufacturing sector, "retreaded tires hold an 80% share of the replacement market for aircraft landing gears, since nearly all air carriers procure retreads when available. Off-road machines, such as earth excavators, are other big users of retreads. Knowledgeable customers of retreaded tires include the US Post Office (20% of its replacement tires), France's La Poste, other express courier companies (FedEx, UPS, etc.) and bus fleet operators" (Ferrer 1997).

Research and Education

Historically the remanufacturing industry has lacked visibility and a strong link to the industrial research community. As a result only limited relevant research has been conducted to advance the state of the industry today; however, this is expected to change as the abundant unexplored opportunities for industry/academic cooperation and mutual benefit become obvious to both groups.

Major centers of remanufacturing research in the United States are located at the Rochester Institute of Technology (RIT), Rochester, New York. These include the National Center for Remanufacturing and Resource Recovery (primarily devoted to research and development) and the Golisano Institute for Sustainability (dedicated to sustainability education and academic research, including economics), both located on the RIT campus.

Research related to remanufacturing has grown over the last decade. The University of New South Wales, Australia; the Technical University of Berlin; and Penn State University are among the universities conducting research in remanufacturing.

Trends and Future Direction

Over the next several decades the remanufacturing industry will confront changing conditions in many sectors. These new economic conditions will compel remanufacturers to adapt existing industrial practices and learn and adopt new practices to remain viable and competitive.

As the automotive and truck market turns from conventional internal combustion engines toward alternative power sources (e.g., hydrogen, hybrid systems, fuel cells, ethanol) in place of fossil fuels, the remanufacturing industry will be presented with new opportunities for remanufacturing of fuel cell components, hybrid vehicle battery assemblies, and other related cores (National Center for Remanufacturing and Resources Recovery 2008).

The increasing cost of new military hardware will further encourage remanufacturing of components, systems, and entire vehicles to prolong their active service lives. Stronger environmental legislation and the rising cost of using landfills may prompt the remanufacture of consumer products previously regarded as not cost-effective enough to be worth the effort. This will present opportunities for formation of innovative niche remanufacturers and new growth potentials for existing firms.

The researcher Robert Lund (1996) has characterized the remanufacturing industry as a "hidden giant" because it preserves the current value of extant goods rather than creates conspicuous new value. Tighter environmental regulations and escalating prices for raw materials and end-of-life product-disposal charges in the future, however, may well present remanufacturing with its overdue recognition as a key contributor to the global economy and a major driver of environmentally sustainable business practices.

Nabil NASR

Golisano Institute for Sustainability, Rochester Institute of Technology

See also Automobile Industry; Cradle to Cradle; Design, Industrial; Green-Collar Jobs; Integrated Product Development (IPD); Investment, CleanTech; Lifecycle Assessments (LCAs); Manufacturing Practices; Natural Step Framework, The (TNSF); Product-Service Systems (PSSs); Steel Industry; Supply Chain Management; Zero Waste

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Risk Management

Risk management includes all efforts undertaken by a business to minimize and control hazards that threaten its operations. In the past, uncertainties about quantifying risk led to difficulties in evaluating perceived threats and their possible impact on a company's finances. But new models exist, allowing businesses to more accurately measure risk and even gain a competitive edge in markets once considered too risky.

All companies seeking success in the modern marketplace need to maintain balance between minimizing risk and maximizing opportunities. Risk is any event or action that can impede an organization's ability to implement its strategies and achieve its objectives. While companies continuously face myriad risks, from project failure to industrial accidents, some of the most complex risks relate to social, environmental, and political issues, and managing those risks effectively lies at the heart of successful sustainability strategy.

Social risks are challenges to business practices that emerge from concerns of society. These may include diseases that curtail the workforce, environmental issues that create tension within local communities or trigger financial penalties, human rights violations that damage a company's reputation or lead to litigation, and objections by stakeholders (i.e., an individual or group directly or indirectly affected by a company's polices or actions) due to negative perceptions of business practices.

Environmental risk, often considered a subset of social risk, includes those issues stemming from environmental issues that can impact a company. These include concerns about climate change and potential legislation to minimize corporate impact. It can also include concerns about pollution, both as a result of production and of discarding products like computers and cell phones. Companies can be fined for the pollution generated during manufacturing, and some are held responsible for the proper end-of-life disposal of a product.

Political risk is the exertion of political power in a way that threatens a company's value. This can include the specter of nationalization or forced partnerships facing companies doing business in Venezuela, Bolivia, and other areas of Latin and South America that are drifting farther to the left. It also includes the changed international political landscape heralded by September 11, 2001, and followed by bombings in London, Madrid, and Mumbai, which have impacted the ways in which business is conducted.

The distinction between social and political risk is often blurred. Issues may be experienced differently by different sectors in varied locations—for instance, concerns about climate change may lead to legislation in one geography that can penalize a company but then spur innovation across its manufacturing practices, leading to market success where legislation is not yet in place.

The widely used terms *environmental risk*, *social risk*, and *political risk* are also known as *above-ground risks* (by the mining, oil, and gas industries), *nontechnical risks*, and *noncommercial risks*.

Risk and Sustainability

Issues such as political corruption, child labor, obesity, global terrorism, predatory governments, and environmental pollution pose both challenges and opportunities for business. In fact, setting sustainability objectives is often a result of identifying and seizing opportunities based on the social and political risks facing a company, industry, or region. Corporate sustainability strategy and social and political risk management go hand in hand.

"Leadership" companies view responsiveness to social and environmental issues as assets that produce increased revenues rather than only as liabilities with their associated costs. They recognize that an investment in structures and systems to ensure strong social and environmental performance often pays dividends in terms of improved processes, production quality, efficiency, yields, reputation, and profitability, as well as lower risk. For example, Toyota's leaders tried to envisage what might transform its industry and threaten future market share. They pinpointed climate change and convened a team in 1993 to create the first great car of the twenty-first century, nearly a decade before that century arrived. As a result of a series of technological breakthroughs, manufacturing innovations, and careful marketing, Toyota has sold more than one million Prius gas–electric hybrid cars since introducing them in 1997. That's five times as many hybrid vehicles as its nearest competitor.

Current Practices in Risk Management

Risk management includes all the activities organizations undertake to minimize or control hazards that threaten their objectives. For businesses, access to or analysis of financial information leads to the most rigorous evaluation of options and effective decision making. Companies continue to struggle, however, to integrate social, environmental, and political risks into financial equations in meaningful ways. Failure to consider these risks in investment decisions leaves out critical elements when it comes to allocating resources. According to a 2007 poll by the American Institute of Certified Public Accountants (AICPA), 84 percent of companies don't formally integrate social, environmental, and political risks into financial calculations. Often, therefore, companies make decisions about these risks based on personal biases, or they arbitrarily assign higher risk premiums to projects in unfamiliar locations, failing to focus management's attention on reducing risk. Why? Many analysts mistakenly believe measuring social, environmental, and political risks is not possible. Historically these risks have also been addressed in more descriptive language rather than a format that reflects their financial implications.

Companies have traditionally taken two approaches toward assessing and managing social and political risk—qualitative and quantitative. Neither approach, however, allows companies to use the same formal techniques they employ to evaluate other types of risk, such as business continuity (the risk of disruption to critical functions after a disaster or other unexpected occurrence), information security, or currency fluctuation.

Qualitative Approach

In the 1970s, multinational firms, particularly in the extraction and banking industries, began creating in-house teams to evaluate political and social risks. These teams looked at risk assessment qualitatively, producing detailed briefings that outlined the challenges of conducting business in various parts of the world. Beginning in the 1980s, consultants were often hired to produce similar reports. While providing sound insights about certain risks, such as the likelihood of a coup or a country's use of slave labor, these briefings did not explicitly connect the identified risks to the company's bottom line. Without an understanding of the costs of these risks, executives had no way to integrate the information into business assessments the way they did for other, quantified, data. As a result, important insights contained in those briefs were sometimes relegated to footnotes in the company's business plan.

Quantitative Approach

Realizing the flaws of a purely qualitative approach, some analysts began to quantify political and social risk to make it more relevant to corporate managers. Various methods were developed and put in use.

Scorecards

Indicators of potential political and social risks—such as judiciary independence, corruption, and government turnover—are evaluated and assigned a numerical value. A final "score" is then generated by aggregating and weighting the values of different indicators to calculate a country's overall risk. Such scoring is helpful because it enables a comparison between countries. But it falls short of being directly useful to business decision makers because the risks are not converted into monetary terms.

Statistical Analysis

The emergence of spreadsheet applications, such as Crystal Ball, an analytical tool that automatically generates equations to capture uncertainty, has contributed to quantitative analysis of risk. Results of such software programs show project managers either the most sensitive issues on which to concentrate—sensitivity analysis—or a cumulative probability curve indicating the potential economic performance of a project. The charts, graphs, and dynamic models produced by these calculations, however, cannot be integrated into financial evaluations because they do not generate a return on investment (ROI) number, a political/social risk beta (an indicator used in financial calculations to compare a company's risk compared to the risk of the overall market), or any monetary results that can be included in financial calculations.

Scenario Analysis

Risk mapping plots the expected degree of exposure to various risks on a graph, with probable frequency on the horizontal axis and expected severity on the vertical axis. Such modeling is beneficial as a communication tool, enabling managers to visualize where to allocate resources, and as a way to measure various types of risk. Mapping as currently practiced does not provide a link to financial statements that are critical for comparisons between competing projects. But, with some modifications, including assignment of monetary values to hypothetical consequences, axis points on such a risk map could correlate to financial data and be integrated into ROI calculations.

Adjusted Discount Rate and Cost of Capital

One method of integrating social and political risks into financial models is to create a discount rate or cost-of-capital calculation that can be used in cash-flow projections. This can be done by creating a social discount rate that employs the weighted average cost of capital (WACC) and the traditional capital asset pricing model (CAPM). (A social discount rate is an important factor in determining the value of contributing funds to a project, such as a school, highway system, or an environmental protection program, that would benefit society in some way.) When dealing with markets that may exhibit hallmarks of social and political risk, this adjusted WACC accounts for social and political factors. Calculations for this risk-adjusted beta, however, have in the past largely relied on the standard country-specific risk-rating methodology generated by political-risk consulting firms, which are too broad to achieve the needed objectives. These ratings are neither industry-, project-, nor company-specific, though social and political risks affect companies and their reputations differently, even those operating in the same country.

Effective Risk Management

Effective risk management involves identifying the sociopolitical and corporate environments that might create risks and then measuring and monitoring them. Reporting these risks in monetary terms is an important step toward integrating them into financial planning and corporate strategies.

One method of monetizing and better managing these nontraditional risks is by including them in slightly modified ROI calculations. Managers commonly calculate ROI, a measure of investment profitability, to make decisions about day-to-day operations and capital investment planning. ROI is the most popular method for measuring corporate performance because it is the approach CEOs and CFOs are most familiar with. To make such analysis more complete and improve operational and capital investment decisions, political and social risks must be included in the conventional ROI calculation through several phases outlined below, which makes the ROI more explicit and relevant for effective risk management.

Step 1: Generate options. The first step in a modified ROI calculation that incorporates social and political risks is to think about the various options that could potentially minimize risk, such as investing in a range of countries or including a range of suppliers in the supply chain. This thinking is known as "real options." While real options calculations aren't used outside financial settings and stock-option calculations because of their complexity, this type of thinking incorporates financial insights at the strategic stage of project planning rather than as afterthoughts. This helps clarify the risks and their potential repercussions.

Step 2: Calculate benefits and costs. Calculating the savings and costs associated with each issue that could generate social and political risks is the second step. For example, if a corporation considered employing child labor, the savings would be calculated by measuring the wage differential between children and adults. The issue benefit, which is generally assigned a positive value, would be the savings. Next the potential costs associated with the risk of child labor should be calculated, such as lost sales after the public discovers this activity. The reputations of several industries have been seriously damaged by the use of child labor in their supply chains, and some companies have attempted to stop the practice. In 2001, major companies in the chocolate industry like Hershey, Cadbury, and Nestle became aware of kidnappings and forced child labor on cocoa plantations in the Ivory Coast, which tainted their reputations and reduced sales. Had companies in this industry calculated these costs in advance, they may have employed mitigation strategies to avoid sourcing from plantations using these practices. The biggest cost of social and political risk is usually to reputation and lost sales due to consumer boycotts and protests.

Step 3: Estimate probability. After calculating the potential costs of each risk, approximate (in percentages) the likelihood that each risk will occur and hurt the company. This is the *estimated probability*. Assign an estimated probability to each risk identified.

Step 4: Calculate expected value. Calculate the expected value of each risk by multiplying the estimated cost of that risk by the estimated probability it will occur.

Step 5: Calculate net present value (NPV). Calculate the net present value of each risk. Note that each issue has risks that emerge at different times. NPV calculations for social and political risk are determined in the same manner as traditional NPV calculations. Discount back using a set discount rate in the traditional manner used in financial accounting. Carry out these calculations for each social and political risk.

Steps 6: Aggregate NPVs for social and political risks. After calculating all NPVs for social and political risks, add together the social risk NPVs and then the political risk NPVs.

Step 7: Integrate the results into traditional ROI calculations. Insert the social risk NPV and the political risk NPV as line items in the normal ROI calculation. Provide schedules that show the calculations for benefits, costs, probability, and expected value for each social and political risk**.** This will allow senior managers to see both the results and the processes by which they were obtained.

Defensive and Innovative Risk Management

Identifying and measuring social and political risks, and integrating them into ROI calculations, provides the basis for establishing a comprehensive risk management strategy. While financial risk can be shared or transferred (to joint venture partners, through insurance, or to other entities), this is often impossible with social and political risks. Companies operate in settings where they can be held liable for the misdemeanors of their suppliers or related businesses operating under the same name.

Managing social and political risk includes devising policies and programs to identify, measure, monitor, respond to, and report on issues that generate risk.

There are five methods for managing corporate risk:

- Insuring against risk
- Avoiding risk
- Mitigating risk
- Innovating around risk
- Some combination of the above

Insuring against risk is one of the most conventional methods for managing it. Many insurance policies, however, do not fully cover some of the biggest crises that may arise from political and social issues, such as total expropriation of property, forced joint venture partnerships with the government, or forced renegotiation of contracts. Avoiding certain risks is another option when approaching social and political issues, and it is best achieved by preemptively

identifying threats and seeking alternatives. For example, to avoid potential political risks, a company may decide to open operations in a less risky geography. To mitigate a social risk like unpaid overtime, it may implement a working-hours monitoring system in the factories from which it sources its products.

By undertaking the exercise of measuring political and social risk, companies become skilled at recognizing, managing, and even innovating around risk and opening up new business opportunities. In fact, by focusing solely on the downside of risk, companies can overlook opportunities that provide significant possibilities for innovation and creating competitive advantages.

Consider General Electric (GE), which in 2005 launched "ecomagination," its commitment to addressing environmental challenges. The company recognized an opportunity where many others saw only risk. While other companies were litigating and lobbying to avoid liability for their environmental impacts, GE capitalized on growing concerns about the environment by developing products such as energy efficient light bulbs and hybrid locomotives. Ecomagination is a business strategy driving the company's growth—2006 annual revenue from this program exceeded $12 billion—and GE is not alone. Many companies are discovering opportunities to make money from issues traditionally seen as too risky.

McDonald's is another example of a company that transformed risk into opportunity. While the fast-food industry as a whole has been under attack for contributing to increased obesity, McDonald's recognized that its customers' preferences were changing and it responded with healthier foods. McDonald's began offering salads that were more appealing, and it partnered with Newman's Own to provide all-natural gourmet salad dressing and premium coffee. It now also provides sliced apples in Happy Meals. As a result, McDonald's sales and share price have increased in an age when other fast-food chains are scrambling to respond to the threats of obesity litigation and changing customer preferences.

Innovation is central to companies that identify and seize opportunities where others see only risk. Innovation can be a breakthrough idea; it can also be a new model for doing business in a seemingly risky or inaccessible market.

Outlook in the Twenty-First Century

In an increasingly globalized world, companies are becoming aware of the need to better identify and manage social, environmental, and political risks. These risks can emerge along supply chains and from regions in which companies conduct business. Sometimes the risks are related to products or methods of production and their effects on the environment. Corporations are simultaneously beginning to look at these risks, once considered only threats, and creating strategies to capitalize on the sustainability issues inherent in them: employee issues (strategies to address child labor, worker overtime); consumer issues (strategies to address and capitalize on obesity and eating more healthily); environmental issues (strategies to mitigate pollution, global warming, etc. through better methods of production and green products). To realize benefits, risks must be evaluated and handled within a system that adequately identifies, quantifies, and mitigates them. An increasingly robust treatment of risk issues has enabled some companies to identify opportunities to help them gain a competitive edge. As these successes become more widespread, so likely will the practice of monetizing social, environmental, and political issues for inclusion in financial reports and project plans.

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See also Accounting; Climate Change Disclosure; Corporate Citizenship; Fast Food Industry; Financial Services Industry; Human Rights; Investment, CleanTech; Investment, Socially Responsible (SRI); Leadership; Marketing; Performance Metrics; Social Enterprise; Supply Chain Management; Sustainable Value Creation; Transparency

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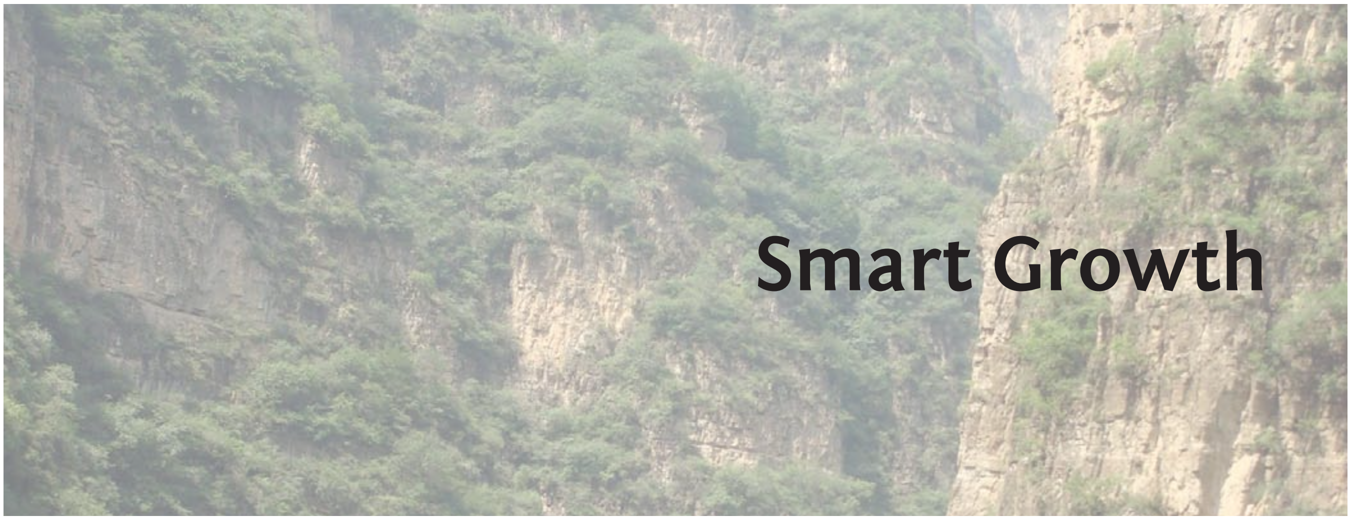

Smart Growth

Smart growth describes development models designed to limit urban sprawl by creating more compact living zones that incorporate all aspects of daily life: residences, business, industry, entertainment, shops, and recreation. Smart growth is considered more sustainable because, in theory, it reduces land use and offers public transportation as an alternative to automobiles, thus cutting down on greenhouse gas emissions.

The term *smart growth* can be understood as a collection of urban planning theories and policies created to counter environmental and social problems linked to urban sprawl (uncontrolled urban growth). Inasmuch as it is reactionary, smart growth is defined by the problems it is intended to affect, and as a result takes different forms and is used to different purposes from country to country, and even from city to city. Similarly, it is often described by different names that are used interchangeably or in conjunction with broad concepts such as the *compact city*, *new urbanism*, and *transit-oriented development*. For instance, since the 1970s growth has been managed in the Netherlands according to a policy called *clustered urbanization*. In Japan it can be found in a national policy called *urban renaissance* and in local initiatives called *machi-zukuri* (literally, "town-making"). In the United States smart growth policies can be found in initiatives to promote walkable neighborhoods and urban revitalization, and it has also been called *land-use control* and *growth management*.

As cities expand, they inevitably consume land, but they also require the investment of a significant amount of new infrastructure, such as roads, sewage systems, electrical power, and gas lines for heating and cooking, as well as a broad range of basic public services, including schools, fire stations, and police stations. When these resources and services are provided at low densities, as in suburban developments, the environmental, economic, and social consequences can be significant. Dependence on automobiles is especially problematic for both environmental and social reasons. Automobiles create congestion, are responsible for the consumption of large amounts of fossil fuels, and can be a barrier to participation in society for those unable to drive if public transit alternatives are not available. This latter is a measurable problem in nations such as Japan, where the population is aging rapidly and residents of older suburbs are already being excluded from a range of activities. Lacking access to a vehicle can make it difficult to undertake simple tasks such as grocery shopping or visiting a doctor without relying on family members or outside assistance.

In order to overcome these issues, smart growth promotes the use of controls on the way cities grow and change over time. Broadly speaking, the intent is to ensure the social and environmental consequences of urban form are given equal weight with financial concerns in the development process.

Origins

The beginnings of smart growth parallel a change in perspective on what constitutes desirable urban form. Its conceptual origins can be traced back to the late nineteenth-century Garden City Movement, the inspiration of the social theorist Ebenezer Howard (Hall 2002, 414–415; Hayden 2003, 202). Howard advocated the creation of self-supporting communities located outside the overcrowded industrial cities of his age, where businesses and residences could coexist in a setting that combined the best of urban and rural elements. Greenbelts and communal ownership of land were included to ensure a degree of social equity and to place a limit on growth. Unfortunately his vision was quickly transformed into one of garden suburbs rather than cities, and the relationship between city center and periphery became one in which functions were segregated rather than integrated. Even in Letchworth, the first Garden City (founded in 1903 in the United Kingdom), which included some industry to support a local workforce, the homes of the varied social classes were carefully separated from each other. More significantly, only a few years later in Hampstead Garden suburb (begun outside London in 1907) there was not even a pretense of including industry or commerce, meaning the development was to be a commuter suburb from the start, dependant for its livelihood on the city. With few exceptions, that was to become the standard pattern of growth on the urban fringe in the decades to follow, especially in the United States.

Nonetheless the concept did have influence. Most famously it formed the basis for the British New Town program begun after the Second World War and exerted a strong influence on similar projects undertaken in Europe and even the United States in the 1960s (Hall 2002). While those developments did achieve some of Howard's goals of well-planned communities (self-sufficient in employment and housing), they were never large enough to accommodate the demand for growth in most cities. In the period following the Second World War, development more typically took the form of suburban bedroom communities, far from places of employment and shopping and increasingly automobile dependent. This was true in Europe, Japan, and the United States, though there was a noticeable lag as result of the time in which cars and trucks became commonplace in each nation.

In the 1960s and 1970s patterns of urban growth in the developed world began to change radically. Cities were dispersed under the influence of suburbanization, and businesses and other functions followed both their workforce and their customers to the urban fringe. The early response to that change was to attempt to manage or limit growth, but by the 1980s focus shifted toward planning to accommodate it. At the same time awareness of environmental concerns was growing, culminating with publication in 1987 of the Brundtland Report, which provided the first modern definition of sustainability: "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987).

It was in this context that urban planners and theorists began to search for policies and urban typologies that would allow them to create a sustainable urban form, but they were unsure how to translate that ambition into actual policies and plans. A number of research projects were begun by academics to test the possibilities, most focusing on the role of energy use in relation to urban form. Typical of research undertaken at that time was a seminal work by the Australian researchers Peter G. Newman and Jeffrey R. Kenworthy (1999), who undertook a global project that showed the least energy-intensive cities in the world were those that combined relatively high density with rail-based public transport. According to their criteria, Hong Kong and Tokyo were the most exemplary. European cities including Paris, Amsterdam, Copenhagen, and London performed well, with American cities, such as Houston and Phoenix, appearing to be the most serious wasters of both energy and land.

Based on these and similar insights, a number of new theories were advanced in the 1980s, many of them reviving and adapting the ideas of Howard's Garden City. In the United States, Peter Calthorpe proposed the *pedestrian pocket* (also called *pedestrian-oriented development* and *transit-oriented development*), a community that mixed both housing and commercial functions and located all homes within 400 meters (a quarter mile) of a transit stop and a commercial area. The careful mixing of land uses and easy access to public transit was intended to make communities more walkable and limit the need for automobiles in daily life. The concept was favorably received and implemented in several cities in the United States, most famously forming the basic structure for the master plan of the city of Sacramento, California.

At the same time the urban planners Andres Duany and Elizabeth Plater-Zyberk launched the New Urbanist movement (sometimes called a *neotraditional development*) with the development of Seaside, Florida (founded in 1979). New urbanism shares the same high-density mix of land use and easy access to public transportation as the pedestrian pocket. Additionally it advocates for the use of a traditional and clear civic structure in its plans and often mandates for traditional architectural styles and materials in its buildings. Seaside proved to be a commercial success, and new urbanism became a model for developments across the United States. In Europe the same movement is called *urban renaissance* and is strongly supported by Prince Charles, who advocated for creation of the new town of Poundbury (begun in 1988) in the county of Dorset, England, according to a master plan by the traditionalist planner Leon Krier. Similar examples were also built across Europe, including Val d'Europe (1995) outside Paris, and Kirchsteigfeld (1993), outside Potsdam, Germany.

The above examples are best understood as design-oriented developments. Policy-driven examples also exist. For example, from the 1980s onward, smart growth policies were officially adopted by several cities, states, and municipalities in the United States (most notably by the states of Florida, New Jersey, Oregon, and Maryland). As policies they are heterogeneous, and each state or city tends to work according to different priorities, but all are grounded in a desire to promote compact development, preserve environmental quality, provide transportation options, support affordable housing, and improve fiscal health of the area (Ingram et al. 2009).

In 1966 the Netherlands adopted the concept of *concentrated deconcentration* as the basis for urban growth for the entire country. It was used as a tool to channel development outside existing cities into relatively dense satellite towns, thereby preserving green space. This early policy for containing urban growth did not focus on curbing automobile use, nor did it contain an environmental agenda. This changed in the 1980s as the nation became more aware of sustainability issues, and policy shifted slightly by focusing on creation of compact cities that were more able to deal with environmental concerns such as reducing the use of automobiles and increasing access to public transportation. The compact city shares the same goals as the examples previously reviewed: high density, mixed land use, and ease of access to public transportation.

Japan too adopted the compact city model as a part of its urban renaissance policy in the 1990s. It is notable that the purpose of this planning policy is related to managing an aging population and is not primarily a tool to govern urban growth.

That smart growth was implemented so widely ensured the development of a number of practical experiments focusing on the creation of sustainable urban form. The focus for researchers since 2000 has been on measuring the successes and failures of those models and proposing alternatives and modifications.

Characteristics of Smart Growth

There are many varieties of smart growth, but most versions share the following characteristics:

- Mixed land use: Residential, commercial, and even some industrial activities are encouraged in close proximity, and even in the same buildings.
- Modal choice for transportation, public and private: Public transportation, in the form of rail or buses, is provided along with infrastructure that encourages cycling and/or walking.
- High residential and employment densities: Jobs and homes are close together.
- Continuous compact development: Leapfrog development is not permitted; growth occurs next to existing communities and without gaps. This ensures connectivity between communities and helps to protect open space, farmland, and other natural resources.
- Limits on growth and policies to encourage development in existing areas: Incentives supporting redevelopment of older sites in a city or town are combined with growth boundaries to set physical limits on expansion.
- Mixing of socioeconomic groups: Policies are used to encourage developments that mix housing types.

Collectively these elements are designed to improve access to the requirements of daily life, from employment and shopping to entertainment and community. There may also be a regional planning component that establishes growth boundaries and land-use restrictions to ensure municipalities tackle the issue of sustainability in a coordinated fashion.

The alternative to smart growth is urban sprawl—defined by leapfrog development (where development takes place noncontiguously, often jumping further and further from an existing city), by lack of control in terms of the direction and shape of urban expansion, and by strict separation of land-use functions. Patterns of this sort are assumed to be unsustainable.

Benefits of Smart Growth

Smart growth is ultimately a tool designed to encourage development of urban forms with a high degree of accessibility for all residents of a community to all the institutions and events in that community. This has environmental, social, and economic benefits.

Environmental Benefits

Studies indicate that smart growth can reduce the number of vehicle miles traveled by urban residents. This is significant because reduced dependence on automobiles (and simultaneous support for walking, cycling, and public transportation) logically leads to a reduction in energy use and a corresponding reduction in consumption of greenhouse gas–producing fossil fuels. Further, by ensuring that development is contiguous and undertaken at high densities, the costs of infrastructure and services can be reduced significantly and the consumption of resources curtailed. Some supporters also claim a health benefit that results from reduced car use and increased walking or cycling.

At the same time open space and green areas including forests and farmland are preserved rather than consumed. In North America, perhaps the best-known example of smart growth can be found in Portland, Oregon, which uses a greenbelt to enforce a limit on urban growth, while simultaneously supporting a public transportation system. More progressive examples can be found in places such as the suburban community of Vauban (completed in 2006) in Germany, where cars are forbidden on most streets, and shops and streetcars are within walking distance of all homes. Residents walk or use bicycles to shop and commute by rail to work, thereby creating a lifestyle that does not require as much energy or resources to maintain or produce as much pollution.

Economic Benefits

Because urban economies are so complicated, isolating the economic benefits of even simple policies is difficult. Studies seem to show, however, that regions and cities that follow smart-growth policies in the United States can perform better economically than those that do not (Cervero 2000; Muro and Puentes 2004). Cities can also save significantly by avoiding the costs of investing in and maintaining inefficient infrastructure and services for low-density areas. The cost of roads, sewers and water lines, garbage collection, postal services, and schools are all affected by land-use patterns and density and can place a strain on municipal governments tasked with providing such services. Some scholars suggest that economic benefits might accrue in settings where businesses are able to trade more easily (because they are closer together) and where residents are attracted to a higher quality of life.

Social Benefits

The social consequences of smart-growth policies are different from country to country. In the United States and in Europe, smart growth is used to eliminate the segregation of social groups by mixing housing types for various economic levels in a single area. In Japan, the focus is instead on ensuring that elderly residents are able to maintain a high standard of living even if they are not able to drive. Encouraging patterns of mixed land use makes both of these ambitions possible.

Issues

Evaluating the impact of smart growth is difficult, first, because the concept is heterogeneous, and second, because agencies other than spatial planning can have a profound impact on urban development. Isolating causes and effects is not always straightforward. Research exists that both supports the claims of smart growth and refutes them. Where problems have been uncovered in most instances, the issue can be understood as a gap between the intent of the concept and its effect after implementation. In the Netherlands, for example, even though planners were able to mandate mixed land-use practices and provide public transportation alternatives, large numbers of Dutch people chose to drive rather than ride. To be fair, the policy was successful on many counts: populations in urban centers were largely maintained, growth on the urban fringe was controlled, and housing was developed in an orderly manner. Nonetheless, planning regulations were unable to stop development of employment centers along highways, and many residents today require a car to commute to work. At the same time a growing demand for lower-density housing has worked against the goals of the compact city, as this has a tendency to produce mono-functional housing areas (Bontje 2001). These developments suggest a failure of policy, but it has also been proposed that such patterns are actually the result of the substantial increase in real wealth of Dutch citizens in the 1980s and afterward (Van der Burg and Dieleman 2004). In response to these deficiencies the Dutch government expanded the scale of its urban planning policies in 2003 to ensure inclusion of the transportation corridors that connect communities in an urban network. While the compact city remains a planning goal, the need for a regional perspective has been acknowledged.

Similar problems can be found in both the United States and Europe. Ironically, in a study of the neotraditional town of Poundbury in the United Kingdom, it was found that car use was higher in the compact development than in the adjacent rural community (Watson et al. 2004). Similar outcomes have been found in other parts of the United Kingdom and in the United States, with the suggestion that compact development does not fit with modern household structure, in which it is now common for more than one family member to be employed, often in distant parts of the city, therefore requiring more than one car to accommodate everyone (Jarvis 2003).

The Future of Smart Growth

A significant amount of research is focused on measuring the effects of smart growth policies as applied to real urban situations around the world. (See, for example, Bontje 2001; Ingram et al. 2009; Jenks and Dempsey 2005). Policies and theories will no doubt be adjusted as results from that work become available. In the Netherlands, as cited above, the focus has already shifted from the compact city to the urban network, which is intended to better reflect the behavior patterns of the country's urban residents.

Some theorists suggest that the best way toward sustainability is to combine the land-use policies of smart growth with financial disincentives to limit auto use, such as increased gasoline taxes and parking fees. These may well come to pass. Nevertheless, the lessons learned from research conducted in the field appear to be that policies need to be flexible, capable of adjusting to changing patterns of behavior as well as to the special needs of each community, wherever it is in the world. While there is little doubt that urban form affects sustainability, it seems likely that the evolution of smart-growth models will continue.

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See also Automobile Industry; Bicycle Industry; Building Codes, Green; Cement Industry; Development, Urban; Energy Efficiency; Facilities Management; Local Living Economies; Municipalities; Property and Construction Industry; Public Transportation

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Social Enterprise

Social entrepreneurs pursue both social and environmental objectives in addition to economic returns on business investments. The resulting social enterprises are not limited to nonprofit businesses; in fact current emphasis is placed on the involvement of the public and private sectors as well. Underdeveloped countries often are ready markets for these social enterprises.

Tackled in the right way, today's economic, energy, and climate crises will lead to tomorrow's solutions, and the size of the potential market opportunities for solutions is staggering. There are an estimated 4 billion low-income consumers, constituting a majority of the world's population, and they make up what increasingly is called the base of the (economic) pyramid, or BOP. A growing body of research is exploring how to use market-based approaches to "better meet their needs, increase their productivity and incomes, and empower their entry into the formal economy" (Hammond et al. 2007, 3). BOP markets are far from small: it is estimated, for example, that the BOP market in Asia (including the Middle East) is made up of 2.86 billion people with a total income of $3.47 trillion, while in Eastern Europe it is estimated at $458 billion; in Latin America, $509 billion; and in Africa, $429 billion. In total, these markets are thought to be worth some $5 trillion.

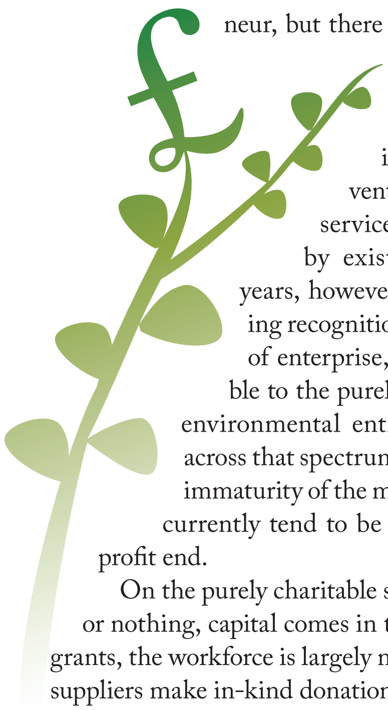
But how can mainstream business, financial, and political leaders best come to grips with these emerging BOP trends in value creation? Three answers immediately spring to mind. First, they can experiment with new business models, as much of the BOP literature suggests. Second, as leading business thinkers have long argued, a can-do attitude is much more likely to succeed than don't-do, won't-do, or can't-do mindsets. And, third, it makes sense to find, study, and work alongside can-do and we-can-work-out-how-to-do-it innovators and entrepreneurs already hard at work developing real-world solutions. In the process, we need to define our terms—particularly the term *social enterprise*. Social enterprises, to quote Social Enterprise London (2009), are "businesses which exist to address social or environmental need.... Rather than maximising profit for shareholders or owners, profits are reinvested into the community or back into the business."

When the Seventh Social Enterprise Conference was held at Harvard University in 2006, co-chair Caitrin Moran spotlighted the accelerating convergence between private, public, and nonprofit sectors in this field. "More than ever, social problems are being addressed not just by nonprofits, but by people and organizations in all sectors," she noted. "Involvement in social enterprise is not limited to those who pursue nonprofit careers. It includes those who work in big corporations, in government, and in nonprofits" (Harvard Business School 2006).

Business Models for Social Change

Anything like global sustainability will be impossible without the engagement—and radical restructuring—of business and markets. As the entrepreneur and philanthropist Pierre Omidyar put it, "I have learnt that if you want to have a global impact you can't ignore business. I don't mean corporate responsibility programs, but business models that provoke social change" (Byrne 2006). So where to look for such change and its agents? Time and again in periods of extraordinary volatility, disruption, and change, it turns out that the best place to look for clues to tomorrow's revolutionary business models is at the fringes of the current, increasingly dysfunctional system. In *Out of Control*, a groundbreaking book on twenty-first-century business models, author Kevin Kelly says, "In economic, ecological, evolutionary, and institutional models, a healthy fringe speeds adaptation, increases resilience, and is almost always the source of innovations" (1994, 468).

Although there is new momentum, this is not a new field of inquiry. Among the books already published are excellent works with titles like *How to Change the World*, *Profits with Principles*, and *Untapped* (which is subtitled *Creating Value in Underserved Markets*). It is clear that there is no standard-issue version of the entrepreneur, but there is a reasonable consensus on what entrepreneurs do. Through the practical exploitation of new ideas, they establish new ventures to deliver goods and services not currently supplied by existing markets. In recent years, however, there has been a growing recognition that there is a spectrum of enterprise, from the purely charitable to the purely commercial. Social and environmental entrepreneurs operate right across that spectrum, though—because of the immaturity of the markets they address—they currently tend to be skewed toward the nonprofit end.



On the purely charitable side, "customers" pay little or nothing, capital comes in the form of donations and grants, the workforce is largely made up of volunteers, and suppliers make in-kind donations. At the purely commercial end of the spectrum, by contrast, most transactions are at market rates. Interestingly however, many of the most noteworthy experiments these days are happening in the middle ground, where hybrid organizations pursue new forms of "blended value"—a combination of social, environmental, and economic value—and where less well-off customers are subsidized by better-off customers.

Against this backdrop, so-called social entrepreneurs develop and operate new ventures (social enterprises) that prioritize social returns on investment. They think in terms of—and aim to measure—social return on investment (SROI). They aspire to improve the quality of life for marginalized populations in terms of poverty, health, or education. One key reason why mainstream business needs to pay attention is that these people try to achieve higher leverage than conventional philanthropy and most nongovernmental organizations (NGOs), often aiming to transform the systems whose dysfunctions help create or aggravate major socioeconomic, environmental, or political problems.

Pursuing the Ideal

While entrepreneurs come from all sorts of geographical, cultural, educational, and religious backgrounds, they share certain characteristics that are immediately apparent the more one gets to know them. These common characteristics color their motivations and influence the kinds of organizations they establish. Social and environmental entrepreneurs share the same characteristics as all entrepreneurs—namely, they are innovative, resourceful, practical, and opportunistic. They delight in coming up with new products or services, or new approaches to delivering them to existing or undiscovered markets. But what motivates the social and environmental entrepreneur is not doing the deal but achieving the ideal. And because the ideal takes a lot longer to realize, these entrepreneurs tend to be in the game for the long haul, not until they can sell their venture to the highest bidder.

One of the burning questions that invariably comes up, particularly when successful business entrepreneurs meet successful social entrepreneurs, is, what motivates you? The implication behind the question is, if you have been so clever in achieving what you have accomplished, why haven't you applied your talents to making money? In response to that question, David Green—one of the world's outstanding examples of entrepreneurial genius involved in creating financial models that deliver quality health technologies to the world's poor—quipped:

> My reasons are purely selfish. I figure I have been put on this earth for a very short period of time. I could apply my talents to making lots of money, but where would I be at the end of my lifetime? I would much rather be remembered for having made a significant contribution to improving the world into which I came than for having made millions. (Elkington and Hartigan 2008, 4)

As interest grows in trying to solve the world's great social, environmental, and governance challenges, definitions—and the boundaries between fields—increasingly blur. In the process, the field of social entrepreneurship has become "a truly immense tent into which all manner of socially beneficial activities may fit," as two board members of the Skoll Foundation (dedicated to supporting social entrepreneurship)—Roger Martin, dean of the University of Toronto's Rotman School of Management, and Sally Osberg, the Foundation's president and CEO—recently put it. Instead, they argue, the real measure of social entrepreneurship is "direct action that generates a paradigm shift in the way a societal need is met" (SustainAbility n.d., 1). What such people do, in effect, is to identify an "unsatisfactory equilibrium" (Martin and Osberg 2007, 32).

Unreasonable People

Any proposed solutions seem improbable given the current consensus that the problems are to all intents and purposes beyond resolution. As a result, many people continue to see the world's leading social entrepreneurs—and, to a degree, those who invest in them—as unreasonable. In fact, a few years ago Muhammad Yunus, the world's leading social entrepreneur, best known as founder of the revolutionary Grameen Bank and winner of the 2006 Nobel Peace Prize, wryly described his breed as "70 percent crazy." (The Grameen Bank, or "village bank," was founded in 1976 and offers small loans to help impoverished people in Bangladesh achieve economic independence through self-employment; in January 2008 the bank opened a branch in the borough of Queens, New York.) It's extraordinary how often these entrepreneurs have been called crazy by the media, by colleagues, by friends, and even by family members. But they are crazy like the proverbial fox. They look for—and often find—solutions to insoluble problems in the most unlikely places.

Many are pioneering and helping map out future markets where most people would see only nightmare problems and risk. Think of it this way: whatever they may intend, these entrepreneurs are doing early market research on some of the biggest opportunities of the century. But they cannot tackle market failures alone. Instead their efforts need to be supported by all levels of government, by business, by the financial markets, and, crucially, by civil society organizations and ordinary citizens—by each and every one of us.

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See also Base of the Pyramid; CSR and CSR 2.0; Development, Sustainable; Investment, CleanTech; Investment, Socially Responsible (SRI); Natural Capitalism; Performance Metrics; Poverty; Sustainable Value Creation; Triple Bottom Line; United Nations Global Compact

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Sporting Goods Industry

The sports industry comprises a multitude of subsectors, one of the largest being sporting goods. Sustainability efforts of major manufacturers have focused largely on improving production methods. Greater impact could be achieved by incorporating sustainability criteria into preproduction methods, such as research and design, and creating enforceable standards along supply chains, where many resources are wasted.

The sports industry encompasses a wide range of diverse subsectors that includes events, manufacturing, facility construction, retail sales, multimedia, advertising, and others. Although these subsectors of the sports industry involve a broad portfolio of overlapping activities, they can be grouped into two main areas: sports services and sports products (sporting goods). The global sports and leisure industry was estimated to be worth more than $500 billion in 2008 while growing at a rate of about 3 percent per year (Hanna and Subic 2008).

Sporting goods comprise sports apparel, footwear, and equipment. This sector has grown significantly over the years while continuously trying to meet the increased demand for new and improved sports products worldwide. According to market researchers, in 2006 consumers worldwide spent more than $250 billion on sporting goods, with the following breakdown by product category: apparel (45.45 percent); equipment (33.93 percent); and footwear (20.62 percent) (Global Industry Analysts 2008). While the global sporting goods market is large and growing, the majority of sales still result from the most economically developed countries, such as the United States and Europe, with emerging markets in Eastern Europe, Asia, and South America slowly catching up.

As in other profit-driven industries, the sports industry is directed primarily by commercial opportunities. New sports products are rapidly developed and brought to market to accommodate the changing needs and personal preferences of consumers. Fashion trends and socioeconomic developments (such as obesity and aging populations) as well as climate change also play a part. To grasp growing commercial opportunities, the industry has diversified by developing and producing lifestyle products in addition to performance equipment such as golf clubs and running shoes. It has also encouraged and supported the creation of new sports and leisure activities (such as extreme sports, crossover sports, well-being activities) that have in turn driven the demand for new types of products. These include, for example, hang gliding, ski jumping, snowboarding, and indoor climbing. All this has resulted in increased production of sporting goods, shorter lifecycles for sports products, and increased disposal rates and waste.

There is growing evidence that global manufacturing industries, including sporting goods manufacturers, are beginning to consider sustainability criteria in their operations (product design and development, manufacturing, supply chains, recycling/reuse) in a more systematic manner. This is due primarily to declining natural resources, increasing government regulations, and growing numbers of consumers who favor more socially and environmentally responsible products.

Sustainability and Corporate Responsibility

In the case of sports products, the greatest environmental impacts are associated with the manufacturing phase as opposed to some other products, like cars, where the greatest impact is in the use phase. In fact, adidas reports that about 95 percent of the company's direct environmental impacts are generated during the manufacturing of its products (adidas 2008). The issues associated with the environmental impact of sports products, however, are more complex than that. First, about 80 percent of the environmental burden of a product is determined during the design stage, when most of the decisions are made regarding the selection of materials and production processes for the new product, so the environmental impacts associated with each stage of the product lifecycle are largely driven by design. Second, contractors of major sporting goods manufacturers may consume as much as 80 percent of the resources used by the supply chain (Nidumoluet, Prahalad, and Rangaswami 2009) through consumption of raw materials, energy, and water. All these resources are associated with the production of the final product. As the sports industry relies heavily on the vast supply chains with manufacturers located worldwide, and in particular in developing countries (especially in Asia), the environmental impact depends to a great extent on how effective large corporations are in inducing their suppliers to adopt sustainable technologies and practices.

Achieving a sustainable framework across the entire business requires a strategic approach that captures all dimensions of sustainability (economic, social, and environmental) and relates these to specific targets and timelines for achieving them. For example, Nike uses this framework, whereby success is measured by the extent to which the company meets milestones for corporate responsibility as well as business growth (Nike 2007).

Similarly, adidas also reports on its commitment to corporate responsibility, including its strategy and associated targets (adidas 2008). Key focus areas include environmental sustainability, supply chain, stakeholder engagement, and employees. The environmental strategy is central to managing and reducing the environmental footprint of business operations, and the core areas of this environmental strategy are products, production, and company-owned sites.

Waste is of particular concern to corporations, including waste arising from their own controlled operations and from supply chains. For example, Nike measured the amount of waste generated across its entire supply chain in its 2005–2006 fiscal year, which enabled the company to calculate the total cost of waste from footwear alone at $844 million (Nike 2007). Reducing waste and hence the cost and environmental impact associated with this waste is clearly of strategic importance. Hence Nike has set specific corporate responsibility targets for waste reduction (e.g., reducing footwear waste 17 percent from its 2007 baseline, equating to 155 grams per pair in 2011).

Adidas (2008) has reported average resource consumption per pair of sports shoes against the following main indicators: energy use, waste water, and average volatile organic compounds (VOC). By measuring resource consumption and also by identifying potential savings and reduction targets, the company is able to realize savings in its own operations as well as assist vendors in its supply chain. For example, after less environmentally efficient Reebok footwear factories joined the adidas Group, adidas reported an increase in energy use and average VOC in 2007 compared to 2006. (See table 1.)

Other major corporations, such as Puma, are also measuring their environmental performance in a similar manner through analyses of resource consumption (e.g., energy and water), waste creation, and carbon dioxide emissions (Puma 2007). The regular measurement of key performance data enables these companies to monitor their environmental performance over time, identify relevant trends, set benchmarks, and identify potential savings.

These approaches to sustainability and corporate social responsibility by the major sporting goods corporations have identified a common concern for reducing volatile organic compounds. VOCs are found in solvents used in manufacturing processes and are a cause of concern because of their toxicity and carcinogenic effects. VOC emissions also contribute to smog and can cause breathing difficulties and other health disorders. The ideal goal is to eliminate all VOCs from sporting goods. A 2006 pilot project initiated by Brucost, a Puma supplier, resulted in a VOC-free sports shoe produced entirely with water-based cements instead of solvent-based adhesives (Puma 2007). In July and August of 2006, Greenpeace recognized this by moving Puma's rating from "amber" to "green" (Cobbing and Hojsik 2007, 9). While a small batch of 1,800 pairs of solvent-free shoes was released in 2006, the

Table 1. adidas Group's Average Resource Consumption/Pair Sports Shoes

Resource	2007*	2006	2005
Energy use (KWh/pair)	2.93	2.36	2.93
Waste water (m3/pair)	0.034	0.045	0.057
Average VOC (g/pair)	20.3	19.3	20.5

*Reebok footwear factories included for the first time

Source: adidas 2008.

Adidas tracks the energy use, waste water consumption, and average volatile organic compounds (VOC) released by the manufacture of its shoes. After the less efficient Reebok factories joined the adidas Group in 2007, average energy use and the release of VOCs increased.

industry has yet to manufacture larger volumes of solvent-free products.

Sporting goods companies have initiated other pilot projects aimed at developing sustainable technologies and practices, but they have had limited impact. For example, the Nike end-of-life footwear recovery program—Nike Reuse-A-Shoe—was established in 1993 to recycle old athletic footwear material (disposed-of shoes and manufacturing scrap) and turn it into artificial sports surfaces and other lower-value secondary products. Since the program began Nike has processed more than 18 million pairs of used shoes, which is barely a fraction of the production volume.

While sporting goods corporations have yet to agree on industry-wide sustainability standards for themselves and their suppliers, there is evidence to suggest that the right strategies and leadership are beginning to emerge in this sector. Still there are many challenges yet to be addressed by the sports industry if sustainability is to become a platform for new business models. More resources are invested into the marketing of sports products than research leading to new sustainable products, materials, and processes. Major sporting goods corporations typically invest between 1.4 percent and 2.4 percent of their revenue on research and development (Hanna and Subic 2008). A fundamental shift is required if sustainability is to truly become the driver of innovation.

Challenges and Opportunities

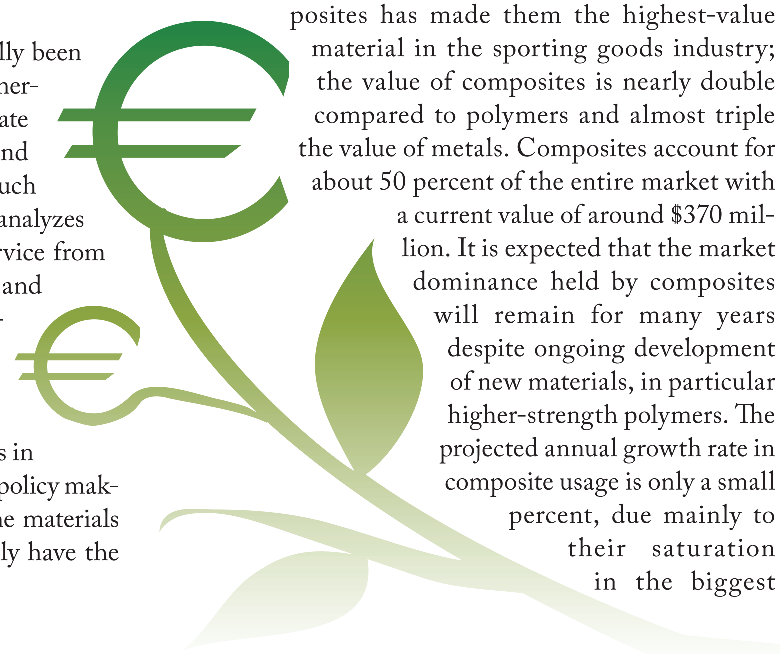
While major corporations have established programs leading to greater environmental responsibility, the same values and practices are not being implemented consistently along their supply chains. The challenge is for the corporations to work closely with their suppliers to make their value chains sustainable.

Advances in sports products have historically been driven by performance requirements and commercial appeal. The sports industry needs to integrate sustainability criteria into product design and development using contemporary methods, such as lifecycle assessment (or LCA, a method that analyzes the environmental impact of a product or service from raw-material extraction to production, use, and disposal), lifecycle costing (LCC), and product sustainability index (PSI) (Subic 2007; Hanna and Subic 2008; Subic, Mouritz, and Troynikov 2009). Interpretation of LCA results may lead to sustainability improvements in areas such as product design and development, policy making, and marketing. Experience shows that the materials and processes used in sports products typically have the greatest impact on the LCA results.

Sustainable design and development is perhaps the key factor for a sustainable sporting goods industry, affecting all stages of a product's lifecycle. The materials and processes used in the manufacturing of sports products are of key concern as they carry with them potential environmental risks. Past innovations have used polyvinyl chloride (PVC)–based materials to make ski boots and sports apparel, and petroleum-based solvents and other potentially damaging compounds, such as sulfur hexafluoride (SF_6) in shock-absorbing and cushioned air bladders, to make athletic footwear (Subic 2007). New materials such as carbon fiber–reinforced polymers are now typically used in tennis racquets, hockey sticks, skis, and other sports equipment but cannot be readily recycled at an acceptable cost or value (and with even greater difficulty in the case of glass fibers). While many corporations state that they aim to increase the percentages of organic cotton and other natural materials in their products, synthetic materials such as polyester are being adopted as the main raw material for sports apparel instead. Synthetic fibers are derived from polymers produced primarily from petrochemicals through energy-intensive processes.

The environmental impact of using composites in mass-produced products is emerging as a critical issue for the sporting goods industry (Subic, Mouritz, and Troynikov 2009). Composites are manufactured using energy-intensive processes that generate significant amounts of greenhouse gas emissions (GHG). They are produced using nonrenewable resources and require the use of chemicals and reagents that are harmful to the environment. Most importantly, composites are not easily recycled and do not biodegrade, which is one of the reasons the European Union banned disposal of carbon-fiber composites in landfills.

The competitive advantage gained by using composites has made them the highest-value material in the sporting goods industry; the value of composites is nearly double compared to polymers and almost triple the value of metals. Composites account for about 50 percent of the entire market with a current value of around $370 million. It is expected that the market dominance held by composites will remain for many years despite ongoing development of new materials, in particular higher-strength polymers. The projected annual growth rate in composite usage is only a small percent, due mainly to their saturation in the biggest



markets such as golf, tennis, and cycling. The use of nanomaterials (nano-sized particles added to composites to improve mechanical performance) is growing at a significant rate due to their rapid uptake in the production of racing bicycles, snow skis, baseball bats, and other sports equipment. While established materials, such as composites, polymers, and metals, are projected to grow in usage by several percent each year, the annual growth rate in the use of nanoparticles is above 200 percent (McWilliams 2006). In 2007, nanomaterials for sporting goods made up 14 percent of the $100 million nanoparticle market (Opportunities for Nano Materials 2009). The presence of these materials in consumer goods raised speculation about the potential for harmful effects on the environment. A workshop cosponsored by the National Science Foundation and the United States Environmental Protection Agency was held in 2003 to identify risk factors of nanoparticle recyclability and biological toxicity (Dreher 2004).

The demand for textile fiber worldwide is increasing along with the demand for high-performance sports apparel. Two types of fibers dominate the market: cotton (natural) and polyester (synthetic). While synthetic fibers are generally perceived as "bad" for the environment and natural fibers as "good," the reality is not so simple (Subic, Mouritz, and Troynikov 2009). Producing synthetic fibers requires significant use of energy and nonrenewable resources, but the cultivation and processing of natural fibers such as cotton can strain water supplies or taint them through the use of pesticides.

Analysis of industry trends indicates a gradual shift toward organic fibers. Research shows that using organic cotton would significantly reduce the lifecycle toxicity of cotton products (Allwood et al. 2006). Nike, for example, aims to incorporate organic cotton to at least 5 percent in all of its cotton materials by 2010.

Millions of tons of textile and clothing waste are generated annually. The United States disposes of 16.6 billion tons of textiles and clothing each year with only 15 percent of it collected for reuse or recycling (Textiles and Clothing 2009, 94). Nevertheless, focus on recycling of sports apparel and clothing in general has increased in recent years primarily due to the rising waste disposal costs, growth of environmental legislation, and the evolution of waste recycling into a more effective commodity industry.

Future Trends and Research Directions

The global sports industry involves complex, geographically dispersed supply chains, with suppliers featuring different capabilities and values compared to the corporations they supply. Hence one of the major focus areas in the future for the sporting goods industry will be to facilitate and develop sustainability standards and practices that can be implemented and enforced along these supply chains. This may require supply chains to be streamlined and simplified to ensure more effective performance management.

The sporting goods industry must approach product design and development from a lifecycle point of view and integrate sustainability criteria into product design and development in a systematic manner. This will require investment in research and development in sustainable materials and processes capable of both meeting performance requirements as well as minimizing environmental impacts throughout product lifecycles.

Finally, the sporting goods industry will be under increased pressure both internally (to reduce costs associated with resource consumption and waste) and externally (to comply with environmental regulations and shifting consumer preferences for more socially and environmentally responsible products). To respond to these pressures, industry leaders will need to adopt a more proactive role and develop business models that integrate sustainability criteria into all areas of operations and not only meet compliance requirements but surpass them.

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See also Biomimicry; Chemistry, Green; Design, Industrial; Consumer Behavior; Lifecycle Assessments (LCAs); Manufacturing Practices; Supply Chain Management; Textiles Industry

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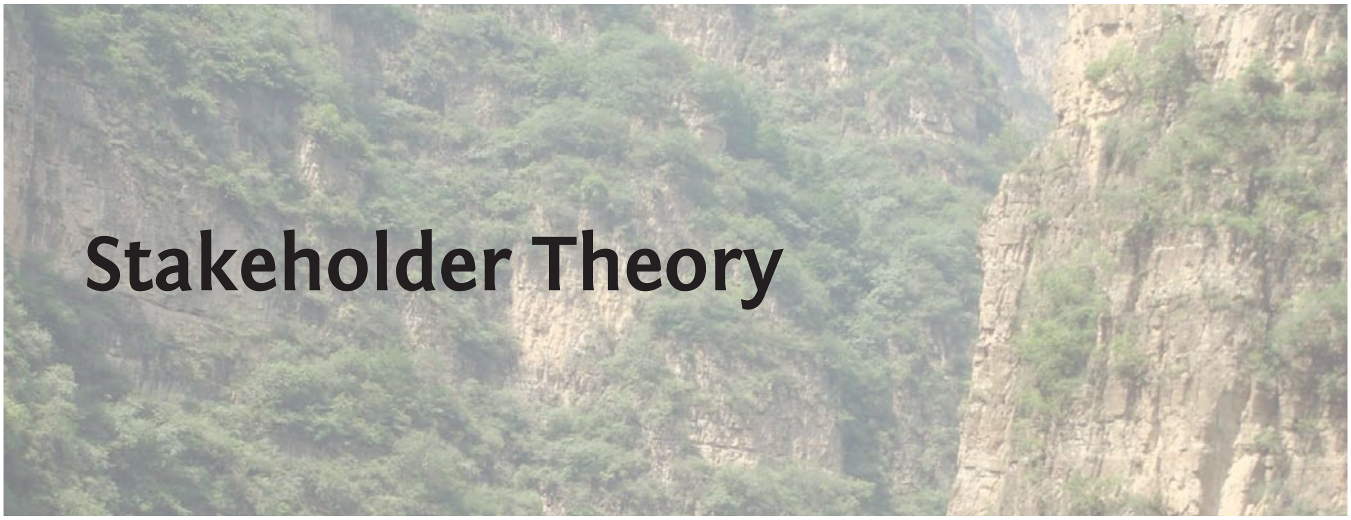


Stakeholder Theory

Stakeholder theory addresses the relationships between businesses and those individuals or groups that affect or are affected by the achievement of their objectives. According to this theory, companies that engage in a network of relationships with multiple stakeholders will improve their performance and viability. These stakeholders include environmental organizations that are increasing pressure on companies to improve their sustainability performance.

The term *stakeholder theory* was initially popularized by the professor of business administration R. Edward Freeman in his managerially oriented book *Strategic Management: A Stakeholder Approach* (1984). He adopted and elaborated on the term *stakeholder perspective*, which seems to have originated at the Stanford Research Institute in 1962. Freeman's original book essentially argued, as did his more current iteration with Jeffrey S. Harrison and Andrew C. Wicks, *Managing for Stakeholders: Business in the 21st Century* (2007), that companies would perform better, and hence be more sustainable over the long term, if they paid more attention to their stakeholders (those who affect or are affected by the actions of companies or organizations). Taking stakeholders into consideration was part of what Freeman considered a strategic approach. This approach was inherently managerial—that is, it was intended to help companies improve their performance and viability and be responsive to the interests, demands, and needs of stakeholders who could affect or be affected by that performance. From the perspective of ecological sustainability, environmentalists are among the key stakeholder groups that companies have to consider. Environmentalists place increasing pressure on companies to improve their sustainability performance in light of concerns about climate change, resource overuse, species loss, and other environmental issues.

In *Managing for Stakeholders*, Freeman, Harrison, and Wicks explained that business is about the interaction of stakeholders—employees, investors, customers, suppliers, and others, such as communities, governments, and the media—who both constitute the business itself and interact in ways that implement the business model. Stakeholder theory stands in contrast to theories of the firm, such as neoclassical economics, that place one constituency—shareholders—as the primary stakeholder of concern. Over time, stakeholder conceptualizations have moved from an initial conception of communication from the company to the stakeholder(s), in which the company held much of the power and was frequently pictured in a spoke-and-wheel pattern (with the company at the center of the wheel), to understanding that there is a more interactive or engaged network of relationships that companies must manage if they are to be effective.

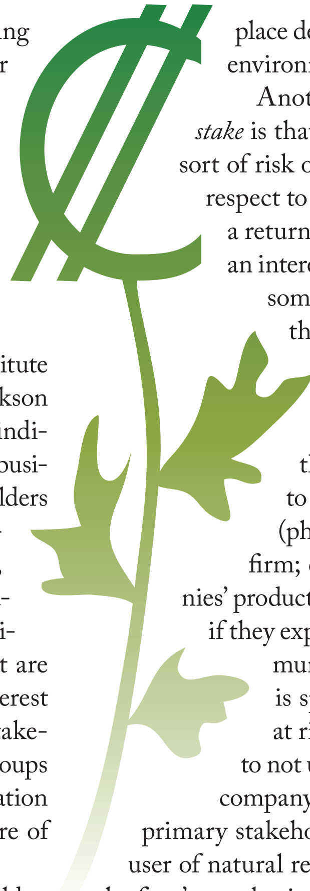
This evolution from a decidedly one-way orientation toward a more interactive stance has resulted in new terminology in both theory and practice around issues of stakeholder engagement. Because of this shift, companies are sometimes willing to find ways to both give and get feedback about their activities from different constituencies that are important to them. The newer conception of stakeholder interactions presents a picture of the organization involved in a network of relationships, some of which are critical or primary, and others of which are less direct or secondary. In the realm of ecological sustainability, this shift has meant that companies more frequently engage external stakeholders, such as environmental groups, to hear their concerns and issues, provide feedback, and sometimes shift their business practices. Some companies, such as major chemical companies that have had significant sustainability concerns directed toward them in the past, have begun to seriously incorporate issues of ecological sustainability into their core strategies. They are building sustainability into what many practitioners calls their company DNA.

What Is a Stakeholder?

For most companies and other types of organizations, there are two main types of stakeholders: primary and secondary. Primary stakeholders of corporations are typically considered to be employees, customers, investors, and suppliers. These groups effectively constitute the firm and directly affect or are affected by it (Clarkson 1995). Secondary stakeholders are those groups and individuals that indirectly affect or are affected by a firm's business model, decisions, and actions. Secondary stakeholders are typically considered to be communities, government, and nongovernmental organizations (NGOs), such as external activists and environmental organizations, that are concerned about the company's activities and practices. Some individuals and groups that are less affected by the company's actions or have little interest in the company can legitimately be considered nonstakeholders for that entity. The specific individuals and groups considered to be stakeholders for any given organization differ by organization type and by the specific nature of the organization itself.

Although the environment is not actually a stakeholder, as it is not a person, it is often treated as though it were a stakeholder, because in some way or another all organizations use natural resources to accomplish their objectives. Natural-resource dependent organizations, such as extraction industry companies, would consider the natural environment a primary stakeholder, while more service-oriented companies would think of it more as a secondary stakeholder.

Stakeholders have a "stake" in the organizations of which they are stakeholders. From one perspective, a stake can be viewed as a claim that gives the stakeholder some sort of say over what goes on in the firm or over its impacts, or it can be viewed as a claim that gives the firm some sort of say over its stakeholders. Thus companies can claim that employees owe them certain levels of performance because they are being paid for their intellectual capital, and employees can claim, at least in theory, some sort of loyalty from the company in return for their loyalty to it. Customers can claim certain benefits related to the products and services they are purchasing based on those purchases, and their input can also affect both the nature and quality of those items. Such claims are sometimes based on expectations that are related to ethical principles such as rights (both legal and moral), justice, or fairness; utility (a form of cost-benefit analysis); or principles of care and character. External regulators, such as environmental agencies and NGOs, frequently place demands on companies to improve their environmental performance.



Another perspective on the meaning of *stake* is that stakeholders either have taken some sort of risk or made some sort of investment with respect to the company from which they expect a return. In this sense, stakeholders may have an interest or "stake" in an organization that is somehow at risk, depending on how well the organization performs. Thus investors put financial resources at risk in the firm and can legitimately claim some sort of return for making that investment. Employees can be said to invest human and intellectual capital (physical and/or mental resources) in the firm; customers place their trust in companies' products and services and put that trust at risk if they experience problems. Suppliers and communities can invest in infrastructure that is specific to a company, which is placed at risk if the company chooses to leave or to not use those resources. Depending on the company's business, these groups can either be primary stakeholders, if the company is an intensive user of natural resources, or secondary stakeholders, if the firm's core businesses are not ecologically demanding.

Typically, stakeholders' investments are tangible in that the Earth's resources are used in some way or other, but sometimes they are intangible, as in emotional bonds or ties that can exist between various stakeholders and an organization. Whatever its basis, the reciprocal nature of the relationship between an organization and its stakeholders is increasingly recognized. This recognition has resulted in new activities and terminology around stakeholder engagement, which implies that there is two-way interaction between the company and its stakeholders and, at least to some extent, recognition that there is a degree of influence or power on both sides, not only the company's side of the relationship. In addition, companies frequently view such stakeholder engagement as a means of creating opportunities for learning about the issues they face in society and, sometimes, as a way of providing insights into potential new business opportunities. Sometimes environmental activists will question a company's use of natural resources, creating a sort of "voice" for the natural environment and a platform for engagement on issues of sustainability.

As the notion of primary and secondary stakeholders indicates, different stakeholders have different priorities with respect to any given firm. Ronald Mitchell, Bradley Agle, and Donna Wood (1997) developed a model of stakeholder priorities based on three core variables—power, legitimacy, and urgency—putting primary stakeholders into the category of "definitive" stakeholders because they possess all three attributes. Other stakeholders, who are missing power, legitimacy, or urgency with respect to the company or an issue facing the company, have relatively less compelling means of getting the company's attention. Companies still need to be aware of all relevant stakeholders and their needs, demands, or interests if they hope to be able to deal with them successfully. For example, an environmental regulator has the capacity to become a definitive stakeholder if a company has a serious environmental problem that has come prominently to public attention and drawn regulatory concern. The situation would be urgent because of the public attention and legitimate because of possible regulatory violations, and the regulator would be powerful because of its enforcement capabilities.

This perspective on establishing priorities among stakeholders has the benefit of raising core issues around stakeholder theory. In particular, it raises the issue of power, which is not always equally shared between different constituencies and the company; the company typically has more power, resources, and clout. The other central issue is that of legitimacy, both for the firm and for different stakeholders with an interest in the firm's actions and decisions. In coping with stakeholder claims, risks, and investments, companies have to consider not only the legitimacy of the stakeholder's interest, but also whether its own legitimacy as an actor in society can be questioned on the basis of a decision or action it is considering. For example, although companies typically are larger than most environmental activist entities or NGOs, they increasingly find it necessary to respond when legitimate issues of the sustainability of resource use are raised by stakeholders concerned about the natural environment. At a broader level, the issue of climate change raised by many scientists and governments has created a context in which some large companies have developed comprehensive sustainability programs and are attempting significant internal change to deal with the stakeholder pressures they are experiencing.

Stakeholder Theory and Economic Theory

Stakeholder theory, or what can be called the stakeholder view of the firm, stands in contrast to more traditional economic views of the firm, such as the neoclassical economics view articulated most prominently by the late Milton Friedman. The economics perspective, or what might be called stockholder theory, argues essentially that the sole purpose of the firm is to maximize wealth for one stakeholder group—shareholders. In contrast, the stakeholder perspective argues for a fair return on the investments, claims, risks, and bonds of multiple stakeholders, contending that the company needs to pay attention to these constituencies in order to perform well.

Stakeholder theory can be viewed as an alternative to the stockholder-based theory emphasized in traditional economics. As a theory of the firm, stakeholder theory argues that the fact that firms can function at all is because of their embedment with stakeholders, and that their performance is directly related to the network of relationships that effectively constitute the firm, the values that are brought to those relationships, and how these relationships allow the firm to carry out its business model. In other words, stakeholder theory recognizes the contributions of multiple stakeholders to firm performance, while traditional economic theory essentially limits those contributions to financial ones, "de-peopling" the firm in a sense.

Values, Ethics, and Stakeholder Theory

Stakeholder theory is frequently associated with ethics, although Freeman intended it initially as a managerial approach with an implicit ethic. The link between ethics, values, and stakeholders occurs in the context of the relationships that are developed through a stakeholder lens. Different stakeholders bring different sets of expectations and values to a given company or organization. Companies and organizations respond to their stakeholders in different ways, and their responses reflect their own values and expectations about the appropriate roles that a given stakeholder group might play.

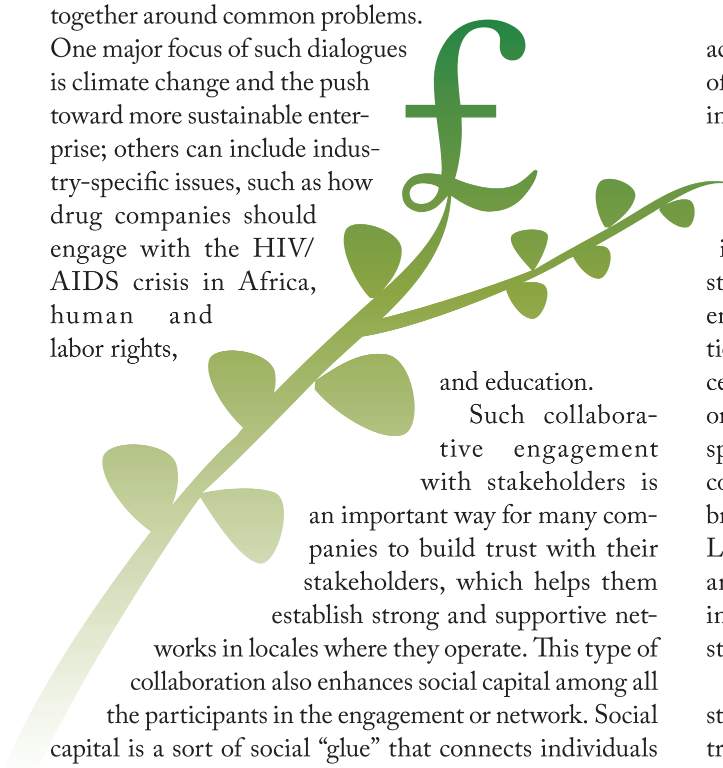
To some extent, managers' decisions and choices always reflect their own and the organization's values. But there is a decided difference between decisions that are made solely with economic or financial considerations in mind, with and for a limited stakeholder set (the shareholders), and decisions that are made with the interests of a wider range of stakeholder considerations. For example, layoffs of employees can seem like the "right thing to do" when only economic considerations are at play, but they may be thought of quite differently when lasting employee relationships, loyalty, and human or ecological costs are part of the equation. Similarly, supply chain relationships may involve arms-length involvement, constant downward price pressures, and resulting sweatshop working conditions, child labor, and serious environmental problems when low cost at any price is the goal. When issues of NGO relationships, supplier relations, and company reputation are taken into account, quite different decisions might be made about what kinds of working conditions are acceptable in suppliers' factories and how the environment is taken into account. The threat of climate change to humanity has made paying attention to sustainability a necessary element of strategy and practice for many companies.

These examples illustrate that stakeholder thinking raises difficult issues about values and objectives that may not always be easily compatible. It is the struggle to find strategies and operating practices that respect fundamental values like human rights and the goal of ecological sustainability that has fundamentally integrated stakeholder theory and the ethics associated with business strategies and practices.

Stakeholder Engagement, Networks, and Social Capital

Companies pursuing stakeholder-engagement strategies develop specific means of interacting with and getting feedback from their stakeholders. Some of these strategies are traditional business practices, such as employee suggestion boxes, employee and customer surveys, and marketing studies. Many companies are involved in collaborative and cooperative endeavors, including multisector alliances, typically aimed at solving social problems, and sometimes called public-private, social, or multistakeholder partnerships or collaborations.

Multistakeholder dialogues are another increasingly popular form of stakeholder engagement. Typically these are forums where stakeholders from different sectors, including government, civil-society organizations, NGOs, educational or academic institutions, and businesses, come together around common problems. One major focus of such dialogues is climate change and the push toward more sustainable enterprise; others can include industry-specific issues, such as how drug companies should engage with the HIV/AIDS crisis in Africa, human and labor rights, and education.



Such collaborative engagement with stakeholders is an important way for many companies to build trust with their stakeholders, which helps them establish strong and supportive networks in locales where they operate. This type of collaboration also enhances social capital among all the participants in the engagement or network. Social capital is a sort of social "glue" that connects individuals and groups in a system, providing a degree of coherence (Putnam 2000). Economist Michael Porter (1998) studied the development and success of companies located within networks or "clusters" of related businesses that were supported by other enterprises. He found that companies in clusters tend to do better than others, providing strong support for the importance of social capital in company performance and further supporting the need for companies to build positive stakeholder relationships of all sorts. Similarly, companies in various industries tend to follow the example of leading companies, thus, for example, when a leading chemical company has instituted a comprehensive sustainability program, it can become important for competitors to follow their lead and also implement sustainability initiatives.

Stakeholder Responsibilities

The relationship between stakeholders and companies goes in two directions, with stakeholders influencing companies and companies influencing stakeholders. The management researcher Jeff Frooman (1999) called the tactics that stakeholders use to change companies "stakeholder influence strategies." Some of these influence strategies come from critical outsiders like NGOs that use tactics like boycotts, letter-writing campaigns, and student involvement to call attention to issues that concern them. Other influence strategies might include the tactics of concerned investors who submit shareholder resolutions calling on management to make specified changes.

For both companies and stakeholder groups, the interaction will be unique to the specific situation and nature of the existing or desired relationships. Stakeholders are increasingly demanding that companies pay attention to issues of responsibility, accountability, and transparency, often with respect to the environment as well as employee, customer, and financial performance. Two important reasons that companies need to respond to stakeholders with integrity are reputation and transparency. There is increasing emphasis on corporate reputation because much of a company's value in the twenty-first century resides in intangible assets like goodwill, human or intellectual capital, and innovative capacity. Companies spend millions of dollars to develop both product and corporate brands, and damage to the reputation of those brands can be significant, very costly, and hard to repair. Listening to stakeholders provides an important mechanism to avoid reputational issues proactively, or even interactively if the company is explicitly engaging with stakeholders.

Another major reason for companies' responsiveness to stakeholders is the increased—and sometimes unwitting—transparency provided by electronic communication technologies like the Internet and other media. Stakeholders sometimes demand that companies be transparent about their decisions and actions, as well as the outcomes of those decisions. Even when companies would prefer that certain things were not publicly known, electronic communication technologies and media make it increasingly difficult to keep things hidden, particularly when critical stakeholders are paying attention to corporate actions. Hence transparency exists whether or not companies themselves deliberately become transparent, simply because it is easier for observers to find out—and communicate widely—what is going on. Today that type of transparency would apply in, for example, the case of a chemical spill or toxic release, or what observers perceive to be excessive or abusive use of natural resources, as happened when an activist publicized Coca Cola's use of India's limited water resources broadly on the Internet; the company was pressured into developing a comprehensive and quite progressive water policy.

Whatever stakeholders do, it is increasingly recognized that they also bear responsibilities for being ethical, proactive, and honest in their engagements with companies. Companies have also come to realize that they are better off understanding what their stakeholders need and want from them, and that sometimes they can forestall problems that otherwise might come as a surprise by directly engaging with stakeholders. With issues of climate change and ecological sustainability now demonstrated to be central to the long-term health and welfare of humanity, many progressive companies are proactively working to build sustainability into their products, services, and operations. These progressive companies are responding to both societal and stakeholder concerns about sustainability and setting an example for companies and other types of enterprise that are slower to respond to these issues.

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See also Activism—NGOs; Corporate Citizenship; CSR and CSR 2.0; Ecological Economics; Ecosystem Services; Education, Business; Financial Services Industry; Human Rights; Investment, Socially Responsible (SRI); Leadership; Public–Private Partnerships; Performance Metrics; Risk Management; Social Enterprise; Supply Chain Management; Sustainable Value Creation; True Cost Economics

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Steel Industry

The steel industry is responsible for 4–5 percent of global carbon dioxide emissions, primarily from ironmaking in blast furnaces; because this is a "mature" process, further reductions in emissions will need to come from breakthrough technologies. Steel has natural sustainable advantages: it has substantial reserves and a high strength-to-weight ratio, it requires low energy to produce, and it is easily recyclable in electric arc furnaces.

Steel is an alloy consisting primarily of iron. It is essential to modern society for infrastructure, transportation, energy delivery, housing, and consumer goods. In 2008 global steel production was 1,327 million tonnes (World Steel Association 2009b; one tonne equals 1,000 kilograms). Steel use is growing in developing countries; from 2002 to 2008 Asia experienced an average annual growth rate of 12 percent, whereas annually over the same period, developed areas such as the European Union-27 grew by only 2.4 percent, and NAFTA (North American Free Trade Agreement) countries' steel use contracted by 0.9 percent (World Steel Association 2009b). Thus, the issues for steel production, use, and sustainability vary throughout the world. One important sustainability indicator is carbon dioxide emissions; the steel industry accounts for 4 to 5 percent of global emissions (World Steel Association 2009a). The issues of sustainability in the steel industry revolve around steel production and use.

Steel Production

There are two major production routes for steelmaking. In integrated steelmaking, iron ore, along with coke (a solid product obtained from coal), is fed into blast furnaces that produce liquid iron, which in turn is converted to liquid steel in basic oxygen furnaces (BOF). The BOF normally accepts 20–30 percent recycled steel scrap. The second route—electric arc furnace (EAF) steelmaking—uses 90–100 percent recycled steel scrap. This process is essentially a melting operation using electrical power supplemented by natural gas-oxygen burners.

In both processes, the steel undergoes some secondary steelmaking operations in the liquid state before it is continuously cast into bars, billets, or slabs for forming into semifinished products for customers. Most of the resource implications, energy use, and environmental emissions arise in the production route before the steel is cast.

Obviously, steel must be initially made in the integrated route before it reappears as recycled scrap for melting in the EAF. Therefore, a balance between integrated and EAF steelmaking is established, depending on relative cost and availability of liquid iron and scrap. Globally in 2008, 67 percent and 31 percent were made in integrated and EAF routes, respectively (World Steel Association 2009b). (The remaining 2 percent was made in the antiquated open hearth process.) Developing countries are short of scrap, so the balance there shifts to integrated steelmaking; for example, in 2008 in China 91 percent of the steel was made in the integrated route. On the other hand, the United States has abundant scrap, so only 42 percent of the steel was made in the integrated route. Scrap is also internationally traded (World Steel Association 2009b).

The Integrated Route

Iron ores, mainly hematite (Fe_2O_3) and magnetite (Fe_3O_4) are widely available throughout the world in grades from 30 percent iron. High-grade iron ores (62–64 percent iron) are internationally traded. Years of supply are usually calculated as the ratio of the reserves to the current consumption rate; for iron ore this is along the order of sixty years

(Norgate and Rankin 2002). (This number refers to proven reserves that are now economically viable, although there are other lower grade or less accessible ore bodies.) This calculation, however, ignores recycling, which was discussed briefly in the previous section. Recycling is expected to be the major route in sixty years.

Carbon can be used easily to reduce iron oxides. (22 megajoules, or MJ, is the amount of energy that must be supplied in the blast furnace and BOF to make a kilogram of steel ingot, compared to the 210 megajoules per kilogram, or MJ/kg, of aluminum ingot that are required in the Bayer and electric-intensive Hall-Héroult processes.) Consequently the blast furnace, using carbon as the reducing agent (or reductant), has evolved as the predominant ironmaking process.

Carbon for the blast furnace is provided in the form of coke. Coke is made by blending various coals and heating them in the absence of oxygen in coke ovens. The coking process drives off volatile hydrocarbons and, after quenching, leaves lumps of coke that are much stronger and larger than the original coal. Coke strength and size are crucial for efficient blast furnace operation. The volatile hydrocarbons are usually sent to a by-product plant that removes tar and oil, sodium phenolate, ammonium sulfate, and naphthalene from the gas for sale. The remaining gas is used as fuel to heat the coke ovens and other processes in the steel plant. The coking operation in older steel plants is a significant source of pollution because of leaks from poorly maintained coke-oven doors and from air and water emissions from the by-product plant. These issues have prompted the development of alternatives in coke production, which is discussed below.

Over centuries the blast furnace has evolved to become a very efficient process to reduce iron ore to liquid hot metal (carbon-saturated iron containing 4 percent dissolved carbon, along with other impurities), liquid slag (a by-product), and blast furnace gas. The blast furnace is a vertical shaft furnace into which iron ore (in the form of lump ore, pellets, or sintered ore) and coke are top-charged in alternate layers. Preheated air is blasted into the lower part of the furnace through tuyeres (water-cooled pipes) around the periphery of the furnace. Thus the coke and iron ore descend while the gas rises through the furnace; countercurrent flow results in high efficiency of heat transfer and chemical reactions. The air blast encounters hot coke in the lower part of the furnace, and the oxygen in the air is converted to carbon monoxide. This produces heat for the process, so carbon has dual roles as fuel and reductant. The carbon monoxide sequentially reduces the iron oxides from hematite (Fe_2O_3) to magnetite (Fe_3O_4) to wustite (FeO) and finally to metallic iron (Fe) as they descend. Heating also occurs, so the wustite is liquid or fluxed with slag, and the iron is liquid and saturated in carbon because of intimate contact with coke in the hearth of the furnace. The liquid hot metal and slag are tapped from the hearth of the furnace. The blast furnace gas leaving the top of the furnace still has approximately one-tenth the combustion energy of natural gas, so it is used to preheat the air blast in auxiliary stoves and for other heating throughout the steel plant.

The coke rate (weight of coke required per tonne of iron produced, measured in kg/tonne) is a key indicator of blast furnace efficiency and one of the main factors determining the carbon dioxide emissions for steel production. Since the 1960s it has decreased from approximately 1,000 kg/tonne to 270 kg/tonne through improvements in raw materials, equipment, and charging practices. In the same time frame, injection of supplemental fuels through the tuyeres has become popular (oil, natural gas, pulverized coal, and most recently, waste plastic particles). Rising prices of oil and natural gas have curtailed their use, but the lower overall cost of injection coals compared to coke has led to the widespread use of pulverized coal injection. The highest injection rates are 210 kilograms coal per tonne of iron, with a coke rate of 270 kilograms coke per tonne of iron, but pulverized coal injection has not dramatically reduced the total fuel rate (Irons 2008). The modern blast furnace is approaching its ultimate level of efficiency, so further reductions in emissions, most notably carbon dioxide, will come from breakthrough technologies.

The hot metal from the blast furnace is converted into steel in the BOF; the carbon content of the metal is reduced from approximately 4 percent to less than 0.1 percent. Silicon and phosphorous are also removed. Commercially pure oxygen is injected at supersonic velocities onto the surface of the metal. The oxidation of carbon and the other elements is so exothermic that no external energy is required; in fact, 20–30 percent scrap is added as coolant. Scrap is usually less costly than hot metal, so practices are adjusted to maximize scrap usage. At the end of the process, the steel is tapped into ladles (open cylindrical containers that hold and transport liquid steel) for further processing.

Electric Arc Furnace Route

EAF production has grown from very limited specialty steel production in the 1940s to today's levels because of the availability of scrap in developed consumer societies and its lower costs (energy, capital, and operating) than the integrated route. The energy required to make steel in this route, 7 MJ/kg, is approximately one-third of that needed in the integrated route because it is essentially a melting operation and does not need the energy for reduction of iron oxides.

The process and equipment are much simpler as well. Steel scrap of various grades is charged into the EAF, a squat vertical cylinder. It usually has three electrodes that are inserted through the roof for three-phase AC (alternating current) operation, although DC (direct current) furnaces with one or two electrodes are also used. The electrical heating is in the center of the furnace, so gas-oxygen burners are positioned through the sidewall to speed the melting. Up to 50 percent of the energy can come from chemical heating in some countries, such as in the European Union, where electricity is very expensive. At the end of the heating process, which takes from thirty to sixty minutes, the steel is tapped into ladles for further processing.

Direct reduced iron (DRI) is an alternative feed material for the EAF. DRI is made by reducing iron ore pellets to solid iron with natural gas–based processes. DRI production (66 million tonnes in 2008) occurs mainly in countries with abundant natural gas (World Steel Association 2009b).

Emissions and By-Products

Air and water emissions from steel plants in developed countries and modern plants in developing countries are well controlled. Lifecycle inventories that measure environmental impact are available for all emissions; only the major ones will be discussed below. In many instances potential emissions are converted to by-products (National Renewable Energy Laboratory n.d.).

Air Emissions

The carbon dioxide emissions in the integrated sector are approximately 1.8 to 2.1 tonnes of carbon dioxide per tonne of steel produced, and 0.1 to 0.3 tonnes carbon dioxide per tonne in the EAF sector, depending on how much carbon dioxide was produced to make electricity (World Steel Association 2009a).

Water Emissions

Approximately 8.5 m^3 of water per tonne of steel are used for cooling and chemical processes in the plant; much of it is internally recycled. Water that is not recycled is treated to be as clean upon discharge as incoming water.

Solid Emissions

Approximately 300 kilograms of blast furnace slag per tonne of iron are produced. In most cases, it is granulated and used as aggregate in roadbeds. Approximately 100 kilograms and 80 kilograms of steelmaking slag are produced in the integrated and EAF routes, respectively (AISE Steel Foundation, United States Steel Corporation, and Fruehan 1998). More treatment of these slags is required, but they are usually used in aggregate applications. Dusts and sludges captured from air and water streams in the plant are usually recycled in the plant. Dust from EAF steelmaking is usually processed by separate companies in Waelz kilns or through the Primus process to recover iron and zinc contents.

Recycling Steel

Steel is by far the most recycled metal in volume; in 2008 475 million tonnes of scrap was used to make the 1,327 million tonnes of steel globally (World Steel Association 2009b). The EAF route, described above, is devoted to recycling and is growing due to scrap availability. Steel has inherent advantages in recycling: it is magnetically separable from other metals, it can be infinitely recycled without loss in properties, and the energy required for EAF steelmaking is low.

One important issue is residual elements in steel, such as copper and nickel. These elements are not removed by oxidation in the steelmaking operations, so they tend to accumulate in the scrap streams. Some steel grades have limitations on these residual elements. Accordingly, scrap with low residual content and iron sources that come directly from ore (pig iron, DRI, and hot metal) are used in these sensitive grades.

Developments in Steel Production

As discussed above, by-products are usually recovered in the coke plant. Nonrecovery or energy-recovery ovens have been developed as an alternative. Instead of recovering the chemicals, they are combusted and used to generate electrical power for use in the steel plant or for sale back to the electrical grid. Sulfur in the gas must be removed (as a gypsum by-product), but most of the cost and emissions of the by-product plant are avoided. An additional advantage of the nonrecovery ovens is that they operate at slightly reduced pressure, so there are no gas leaks from the ovens.

There has been a great deal of development of smelting-reduction processes to replace the blast furnace at a lower coal rate without using coke. This has been difficult because the blast furnace is very efficient. The Corex and related Finex smelt-reduction processes have been fully commercialized, but they have higher coal rates than the blast furnace. These processes produce surplus gas that can be used to generate electrical power to partially offset the high coal rate. The HIsmelt process is operational at a smaller capacity but again has a higher coal rate than the blast furnace.

The international steel community recognized that the blast furnace has closely approached its ultimate efficiency, and that to meet future carbon dioxide emissions requirements, breakthrough technologies will be required. In Europe, the Ultra Low CO_2 Steelmaking (ULCOS) program was initiated to find processes that reduce carbon dioxide emissions by more than a factor of two. ULCOS (2009) has selected four processes, which are in various phases of development, for further study that could reach this goal:

- top gas recycling blast furnace with carbon capture and storage (CCS)
- ISARNA (a smelting reduction process, possibly combined with HIsmelt) with CCS
- advanced direct reduction with CCS
- electrolysis with electricity from a carbon dioxide–free source

Use of Steel

Steel is by far the most used metal in the world. Its major advantages are high strength, low cost (due to high grade ore and low energy production costs), high high-temperature strength, and the ability to tailor the properties (strength, elongation, and creep) through alloying and heat treatment.

The major disadvantage of steel is its density—7000 kg/m^3—compared to aluminum (2,700 kg/m^3) and plastics (approximately 900 kg/m^3). This is most acutely a problem in the transportation sector, where fuel efficiency is directly related to weight. The frame and outer panels of most automobiles are steel because of low cost and high performance, but there is competition from aluminum (although because of the higher cost in purchasing and fabricating aluminum, it is used in smaller quantities for outer panels). The steel industry has been active in reducing weight in automobiles, starting with the UltraLight Steel Automobile Body (ULSAB) project in the 1990s. Through the use of higher-strength steel and advanced manufacturing techniques, the project achieved a 25 percent reduction in body weight, along with improved performance. Further work is continuing on other aspects of vehicle light-weighting.

There is also intensive development of advanced high-strength steel (AHSS) for automotive applications. In steel, and most metals, there are trade-offs in strength and ductility; stronger steels are usually more brittle. AHSS achieves both high strength and ductility that can be tailored for specific applications. Thus the high degree of formability required for automobile bodies can be achieved with strong, lightweight sections. The strength-to-weight ratio of AHSS surpasses that of aluminum alloys in automotive use. AHSS can also be tailored for kinetic energy absorption, which is important for crash protection.

One issue with using aluminum as a replacement for steel in automobiles is that it takes much more energy to make aluminum (see the section above on the Integrated Route), which then must be offset by improved fuel efficiency over the life of the automobile. Lifecycle analysis is used by both the steel and aluminum industries to quantify total energy use and carbon dioxide emissions, but there is controversy over the results because of differing assumptions and methodologies.

Long-Term Sustainability

Steel has natural advantages with respect to sustainability: substantial ore reserves, low energy costs to produce, infinitely and easily recyclable, and high mechanical strength that can be tailored for many applications. The steel industry has ambitious development programs to reduce the environmental impact of both making steel and of the use of steel products, so that steel remains the most important industrial metal in a sustainable future.

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See also Airline Industry; Automobile Industry; Energy Efficiency; Energy Industries—Coal; Energy Industries—Overview of Renewables; Lifecycle Assessments (LCAs); Manufacturing Practices; Mining; Remanufacturing; Supply Chain Management

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Supply Chain Management

Virtually all businesses depend on supply chains to move their products from idea to reality and from point A to point B. Globalization, outsourcing, and increased stakeholder expectations all factor into the question of how supply chains may be managed to be more sustainable in the long run. A comprehensive product lifecycle management approach can help companies to reduce the environmental footprint of their supply chains while protecting the rights of workers in developing countries.

Increased global competition and international sourcing have magnified the importance of supply chain management (SCM) as a core competency for major manufacturing firms. Supply chains are increasingly seen as strategic assets, and companies are placing greater emphasis on collaboration with suppliers and customers that are part of their "business ecosystem." The scope of SCM is expanding to include all of the business processes involved in fulfilling customer expectations, from product development to end-of-life disposition. As a result, companies are assigning supply chain specialists to the cross-functional teams that manage these business processes. This broader "value chain" perspective of SCM encompasses not only physical assets, such as facilities and vehicles, but also intangible elements such as knowledge and relationships. Accordingly, SCM has been defined as "the integration of key business processes from end user through original suppliers, which provides products, services, and information that add value for customers and other stakeholders" (Lambert 2009, 2).

From this broad perspective, there are a number of global trends that have accentuated the importance of sustainability and corporate responsibility in SCM.

- Globalization has raised concerns about inequities between rich and poor countries, as well as adverse environmental impacts such as energy consumption and greenhouse gas emissions (International Monetary Fund 2002). Tensions between economic opportunities and environmental and social concerns can be obstacles to global expansion, while varying regulatory requirements and cultural barriers tend to complicate the acquisition and integration of international businesses.
- Outsourcing has blurred the boundaries of the enterprise, and companies are challenged to assure that their suppliers and service providers are complying with safety and sustainability expectations. Moreover, outsourcing may simply shift environmental burdens such as carbon emissions to less developed nations. Incidents such as discovery of corrupt labor practices and contamination of product constituents have raised public concerns and given rise to renewed emphasis on supplier auditing and due diligence. Companies are increasingly expected to disclose the origins of products, including raw materials, and the conditions under which they were manufactured.
- Government directives in the European Union (EU) and elsewhere have invoked the doctrine of "extended producer responsibility" in the form of end-of-life product recovery requirements, often called "product take-back." For example, the EU End-of-Life Vehicles directive of 2000 is aimed at reducing the waste generated by scrapped motor vehicles, while the EU Waste Electrical and Electronic Equipment directive of 2003 requires take-back of electronic products such as televisions, computers, and cellular phones. These policies have stimulated adoption of "reverse logistics" (Guide and Van Wassenhove 2002) and have prompted changes in product development practices throughout the affected supply chains, including design for recovery, reuse, or remanufacture of obsolete products, components, materials, and packaging.

- The adoption of "lean" manufacturing approaches, such as "just-in-time" replenishment, has made global supply chains more susceptible to business interruption because their buffers and reserve capacity have been diminished. Supply chains are vulnerable to a variety of disruptions, including deliberate threats, technological failures, and natural disasters. These threats call for heightened awareness and rapid recovery capabilities; they also create opportunities for more agile companies to take advantage of openings for market penetration and growth. Advanced information technology now enables global tracking of assets and shipments, using technologies such as radio frequency identification (RFID) tags. The capacity to monitor market fluctuations, communicate seamlessly with suppliers or customers, and control the flow of products and materials enables real-time, "adaptive" responses to changing supply and demand patterns, thus reducing wasted resources and increasing supply chain resilience (Fiksel 2007).

These trends have magnified the importance of corporate commitments to sustainability, social responsibility, transparency, and responsiveness to stakeholder expectations. Aside from reducing their supply chain environmental footprints, corporations are being held accountable for upholding ethical standards, respecting diversity, and demonstrating concern for employee and community well-being. A company's brand image and reputation can be deeply influenced—either positively or negatively—by the perceptions of customers and other stakeholders.

Linking Sustainability to Business Value

Supply chain business processes such as sourcing, inventory management, warehousing, logistics, and distribution are increasingly viewed as strategic levers in enhancing business competitiveness. Thanks to the Dow Jones Sustainability Indexes and similar rating initiatives, financial analysts have recognized that there is a correlation between shareholder value in capital markets and excellence in sustainability, including both social responsibility and environmental management. Specifically, there are two major categories of business value creation associated with improved sustainability performance.

Avoidance of Costs and Liabilities

The traditional approach to environmental, health, and safety management involves compliance with regulations and standards, minimization of product or process-related risks, and stewardship of natural resources. Sustainable business practices such as pollution prevention, reduction in hazardous materials use, waste minimization, and improvements in material logistics (e.g., pallet geometry) are important contributors to reducing both operating and capital costs. Paying attention to social responsibility and stakeholder satisfaction also helps to protect a company's reputation and avoid costly business interruptions.

To avoid costs and liabilities, companies have pursued a number of core business practices, as illustrated by the following examples.

- **Assure compliance** of products and business processes with laws, applicable regulations, and industry standards. Texas Instruments anticipated its customers' needs by developing a systematic process for assuring compliance with European Union (EU) requirements regarding banned and restricted substances.
- **Minimize risks** and maintain business continuity by assuring product and process safety throughout the supply chain. Motorola's distribution managers discovered that they could reduce both occupational injuries and solid waste disposal by controlling the quality of incoming wooden pallets from suppliers, yielding estimated savings in lost time and expenses of over $5 million per year (GEMI 2004, 9).
- **Maintain health** and well-being both for employees and local communities through responsible management of operating sites. Abbott Laboratories reduced contractor safety incidents to well below the industry average by integrating safety protocols into its automated contractor performance management system.
- **Protect the environment**, including public health and natural resources, through waste elimination, pollution prevention, and ecological stewardship. FedEx redesigned its overnight letter packaging to utilize 100 percent recycled fiber, strengthening its environmental leadership without compromising product performance or long-term costs.

Economic Value Creation

A more integrated approach to value creation is evident in the increasing level of collaboration between environmental managers and other groups, working in cross-functional teams. The rate of material throughput in industrial supply chains is the single most important driver of (a) operating costs, (b) consumption of energy, water, and other needed resources, and (c) generation of waste and emissions. There are significant business incentives for companies to embrace sustainable SCM practices that reduce the overall flow of materials through the value chain. New technologies such as process intensification and microreactors have demonstrated the potential for order of magnitude increases in process yield and capital productivity.

There are several actions that businesses can undertake to achieve social and environmental benefits:

- **Raise productivity** through material conservation, energy efficiency, and conversion of wastes into byproducts. Intel has saved millions of dollars annually by developing lighter-weight plastic trays used in the fabrication and delivery of its microprocessor units (GEMI 2004, iii). The company is also working with customers to develop closed loop systems for reuse of the trays.
- **Encourage collaboration** among customers, suppliers, and other stakeholders that influence supply chain effectiveness and license to operate. A global coalition, led by HP, Intel, and others, created a uniform Electronic Industry Citizenship Code for suppliers. The code sets forth principles for managing environmental releases, workplace health and safety, labor practices, and business ethics, and includes supplier assessment and auditing procedures.
- **Support innovation** in products, services, and technologies that enhance product differentiation, customer satisfaction, and stakeholder confidence. Eastman Kodak uses "Design for Environment" principles that have helped reduce the weight of its digital cameras while dramatically improving its products' performance.
- **Enable growth** via acquisition, increased market share, or access to new markets by conforming to market expectations such as ecolabeling and ISO 14001 registration. Owens Corning has achieved rapid growth for Atticat fiberglass insulation, which was Cradle to Cradle Certified at the Silver level. (Cradle to Cradle certification is given to companies with production processes and practices that are sustainable and support the recirculation and reuse of materials.) The product utilizes 60 percent recycled material, contains no toxic binder chemicals, and is highly compressible for superior transportation efficiency.

Thus, rather than sustainability issues placing constraints upon the supply chain, environmental and social performance improvements are often consistent with industry efforts to increase supply chain speed, efficiency, effectiveness, and continuity.

Product Lifecycle Management

The vast majority of supply chain environmental impacts, including resource consumption and waste generation, are invisible to product consumers. Lifecycle assessment (LCA) methods are frequently used to quantify the "cradle to cradle" environmental burdens of supply chain processes. To incorporate sustainability thinking into SCM, it is essential for companies to consider the *full lifecycle* of their products, including all of the supply chain processes involved in sourcing, production, distribution, use, and recovery of the products. The vast majority of supply chain environmental impacts, including resource consumption and waste generation, are invisible to product consumers. In a typical product lifecycle, roughly 95 percent of the material throughput is released to the environment in the form of trash, wastewater, and airborne emissions—mainly carbon dioxide. Overall, about 20 billion tons of industrial wastes are generated annually in the United States, and over a third of these are hazardous wastes. This amounts to about 60 tons per capita, by far the highest in the world (Fiksel 2009, 5). Continuation of these patterns threatens to exceed the capacity of ecosystems in terms of resource production and waste absorption, and also poses potential threats to global climate, vegetation, and agriculture.

Increasing awareness of sustainability concerns has led to the development of various methods for estimating the "environmental footprint" associated with supply chain operations. The term "footprint" may connote a single metric, such as a "carbon footprint," or a collection of indicators representing different environmental burdens (such as energy use, solid waste, and air emissions). To estimate a lifecycle footprint requires careful definition of scope and boundaries. For example, a material footprint may include only feedstock and supplies used in company operations, may encompass broader supplier and customer activities, or may extend to ecosystem goods and services such as biomass (wood, fish) or fresh water. While efforts to measure total ecosystem service consumption are rare, many companies are beginning to assess their water footprints.

According to the World Business Council for Sustainable Development (WBCSD) publication *The Greenhouse Gas Protocol* (2004), the most common indicator is the carbon footprint, which measures greenhouse gas emissions in terms of carbon dioxide equivalents. The majority of carbon footprint estimates, however, only quantify a company's direct use of energy in the form of fuel or electricity. If a typical company considers all of the energy expended in the supply chain to provide purchased goods and services, its overall carbon footprint can be as much as ten to twenty times larger. A number of organizations, including the World Business Council for Sustainable Development, the World Resources Institute, and the Carbon Trust, have launched initiatives to produce international standards for product lifecycle accounting and corporate value chain accounting, expected to be released in 2010.

Having a baseline environmental footprint enables a company to investigate cost-effective opportunities for footprint reduction. Depending on geographic locations and the type of facilities, certain companies in the supply chain may be in a much better position than others to achieve energy and material conservation. The following are examples of such opportunities (Fiksel 2009).

- **Reduce the procurement footprint**—Many companies have begun to examine the environmental practices of their suppliers and encourage greater energy and material efficiency, which also tends to lower procurement costs. The federal government and many state governments have introduced environmentally preferable purchasing guidelines that can be utilized by private-sector decision makers. For example, Walmart has developed sustainability scorecards for packaging and energy use, and has requested environmental performance improvements from all of its suppliers.

- **Reduce the operational resource footprint**—Companies have found a great deal of "low-hanging fruit" (or easily attainable goals) by tightening up energy management practices (heating, cooling, and lighting systems) and materials management practices (maintenance, inventory, and waste management). Newer facilities are being designed with recycled materials and advanced energy-saving features, as interest in "green building" has mushroomed. But the largest gains in resource conservation come from redesigning production processes to reduce throughput requirements and install more efficient equipment. From 2005 to 2007, General Electric conducted a "Lean and Energy" initiative that has yielded over 250,000 metric tons in greenhouse gas reductions and $70 million in energy cost savings.
- **Reduce transportation requirements**—It is common for products or components to go through several shipment stages by various modes before arriving at their ultimate destinations, which adds to supply chain costs as well as packaging and energy consumption. Options for increasing transportation efficiency include shipping outsourced modules directly from the supplier to the final customer; reducing transportation urgency by allowing greater lead times; redesigning the product geometry, packaging volume, or stacking configuration so that less space is wasted; and reducing temperature requirements or other energy-consuming constraints.
- **Reduce consumption of shipping containers**—In many supply chains, disposal of used containers such as shipping pallets is a major source of solid waste. Significant cost savings and material efficiency can be achieved by designing containers that can be recovered and reused for the same application. In some cases, containers can be eliminated. Duke Energy was able to redesign the cable storage and handling systems used for electric power lines so that wooden reels were no longer necessary, saving over $650,000 per year.
- **Reduce waste generation**—Supply chain throughput can be reduced by identifying and minimizing nonproduct output—by recycling pallets, solvents, catalysts, scrap materials, or process water. Lean process design can help to reduce unnecessary inventory, which requires extra resources and can lead to product spoilage and waste.
- **Ensure supply integrity**—The globalization of material procurement has created vulnerabilities in the supply chain for many products, and there have been many examples of product contamination with harmful substances (for example, melamine from China). To avoid such incidents, manufacturers should establish programs to screen and audit their suppliers, and ensure that all product constituents can be obtained from reliable sources.
- **Use refurbished components**—Durable products can be manufactured with refurbished components, resulting in lower costs and reduced material consumption, often with the same level of quality as products manufactured with brand-new components. Ideally companies can develop a reverse logistics system whereby spent materials and used components can be recovered, reprocessed, and recycled back into their supply chain. For instance, Caterpillar has established a profitable Remanufacturing Division that exchanges used engines for new ones.
- **Recover materials at "end of life"**—When products are disassembled, materials and components need to be sorted into different categories for purposes of recovery and recycling; companies can facilitate material identification by means of coding or marking. As recycling technologies and materials science improve, we are reaching the point where recyclable materials can be found for virtually any application. Many industries have formed alliances to support establishment of a recycling infrastructure for obsolete products and packaging.

Generally, there are two different supply chain perspectives that need to be balanced in product lifecycle management—upstream and downstream. The upstream view, focusing on suppliers, is mainly concerned with maximizing operating efficiency, anticipating safety and security risks to assure business continuity, and minimizing the environmental footprint in terms of resource utilization. The downstream view, focusing on customers, is mainly concerned with assuring that the product is used safely, delivers value to the customer, and is properly managed at end of life.

Future Opportunities

Perhaps the greatest opportunity for quantum improvements in sustainability is collaboration between customers and suppliers to jointly explore the redesign of supply chain operations. Collaborative innovation can enable solutions that might not have been possible if the parties worked separately. For example, electronic device manufacturers are limited by the performance characteristics of available materials and components, while chipmakers are constrained by the technologies of fabrication equipment. By lifting constraints and pooling their talents, they can develop innovative technologies that benefit the entire value-added chain, such as developing new fabrication processes that eliminate the use of chemical solvents.

One promising approach is based on mimicking nature through the practice of "industrial ecology." Natural systems generate virtually no waste; dead biomass provides nutrients for microorganisms, which in turn enrich the soil. Similarly, industrial systems can convert waste materials from production or consumption activities into "food" for industrial processes. Rather than discarding their wastes, companies can discover alternative uses in their own supply chain or in other industry sectors, and thus convert them into by-products. By substituting local waste streams for virgin material and energy inputs, companies are able not only to achieve cost savings but also to reduce their supply chain footprints. Over the past decade, the U.S. Business Council for Sustainable Development (2009) has stimulated adoption of this approach, called "by-product synergy," to a number of U.S. metropolitan areas and has inspired the development of a national network in the United Kingdom called the National Industrial Symbiosis Program.

Another increasingly common style of collaboration is the formation of joint sustainability initiatives among companies within an industry sector, often including direct competitors. Examples include the Beverage Industry Environmental Roundtable, the Electric Utility Sustainable Supply Chain Alliance, the Pharmaceutical Supply Chain Initiative, and the Electronic Industry Citizenship Coalition, mentioned above. In each case, the parties have decided that it makes more sense to work collectively on managing environmental and social performance in their upstream supply networks. In addition, many companies and industry groups are forming alliances with nongovernmental organizations that have traditionally been critical of industry. These engagements have helped to promote creative dialogue about potential solutions and have enabled companies to leverage the competencies and credibility of external groups with diverse perspectives. Examples include partnerships of the Environmental Defense Fund with SC Johnson Wax, Sierra Club with Clorox, and World Wildlife Fund with Coca-Cola.

A Global Commerce Initiative/Capgemini study suggested that by 2016, supply chains would be characterized by increased collaboration among supply chain participants, including sharing of information, sharing of physical assets such as warehousing and transport channels, and more efficient consolidation of shipments for final delivery. The estimated benefits of such a supply chain redesign, even without energy technology improvements, include a 30 percent reduction in transport costs per pallet, 20 percent reduction in handling costs per pallet, 40 percent reduction in lead time, 25 percent reduction in carbon dioxide emissions per pallet, and improved on-shelf availability (Global Commerce Initiative/Capgemini 2008, 42). While creating a more efficient infrastructure is laudable, these incremental gains are not sufficient to offset rising demand due to population growth, economic development, and urbanization around the world. Fundamental innovations will be needed to enable sustainable growth, such as "dematerialization" of supply chains by converting physical products into knowledge-based services.

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See also Chemistry, Green; Cradle to Cradle; Design, Industrial; Energy Efficiency; Facilities Management; Integrated Product Development (IPD); Investment, Socially Responsible (SRI); Lifecycle Assessments (LCAs); Manufacturing Practices; Natural Step Framework, The (TNSF); Product-Service Systems (PSSs); Remanufacturing; Risk Management; Stakeholder Theory; Sustainable Value Creation; Transparency

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Sustainable Value Creation

In business, the meaning of sustainability has changed since the 1980s. Originally it indicated the ability to remain profitable over time; it now includes social and environmental issues as well as economic ones. The global context has changed, and, with many major corporations leading the way, businesses that promote sustainability must acknowledge their responsibility to both shareholders and stakeholders to succeed.

In the business world, the term *sustainable* has long been associated with economic viability. *Sustain-ability* is usually taken to be the ability to sustain shareholder returns above the cost of capital. A sustainable company is one that is profitable over time.

The terms *society* and *ecology*, when used in the context of business, have long been associated with compliance to government regulations and the moral obligation of companies to be environmentally and socially responsible. They represent the obligatory costs of doing business.

This backdrop of meanings has contributed to confusion and even rejection by business managers of the composite term *environmental and social sustainability*. Executives everywhere are confronted with it, yet they do not understand what it means for their company, and they certainly don't see it as a source of strategic advantage. They don't see how growing societal constraints can be a matter for the CEO agenda.

Yet the global competitive context has changed to make environmental and social sustainability a huge business opportunity—for those executives who have the right knowledge and competencies. *Sustainable value*, a term coined by Chris Laszlo in his 2003 book *The Sustainable Company*, implies that a company can address the "social and environmental dimensions of their business activities" (Laszlo 2008, 119) and create value for both shareholders and stakeholders. Leading companies are jumping on the sustainability bandwagon: just a few global players who have recently done so include DuPont, General Electric, Walmart, Marks & Spencer, Toyota, Unilever, Danone, Alcoa, Philips, and JPMorgan Chase. They are not only "doing well by doing good," they are doing better as a result (Laszlo 2008).

A New Competitive Context

Since the 1990s, massive changes in the competitive landscape have increased the influence of a broad range of stakeholders, from nongovernmental organizations (NGOs) and activist bloggers to the media and government regulators (Assadourian 2005). Low-cost communications and the sheer availability of information have educated the general public and increased its awareness of environmental and social issues. Corporate disasters from Bhopal to Enron have sown a mistrust of big business, while tougher government regulations and new environmental laws have raised the requirements (and costs) of operations. Companies find it increasingly difficult to hide environmental and social transgressions, even in far-flung markets where the risk of discovery—and subsequent YouTube exposure—is ever present.

As a result of these trends, stakeholders instantly and globally access information about a company, mobilizing against those seen as doing wrong and enhancing the reputation of those seen as leading positive change.

A separate but immensely important development is the rise of intangible value as a component of stock price performance. The economist Baruch Lev (2001) has shown the extent to which accounting value has fallen as a driver of market capitalization—from 70 percent in 1900 to 30 percent in 2000—while intangibles such as goodwill, knowledge, brand value, and strategic relationships have risen accordingly (Low and Kalafut 2002).

A growing number of CEOs understand that their company's environmental, social, and governance performance affect their ability to attract and retain talented employees, drive innovation, and enhance corporate reputation. Such intangibles help in turn to differentiate their company's offering, leading to superior earnings and share price. Today the value created or destroyed for stakeholders carries strategic business risks or opportunities, demanding that business leaders rethink environmental and social sustainability in terms of value creation.

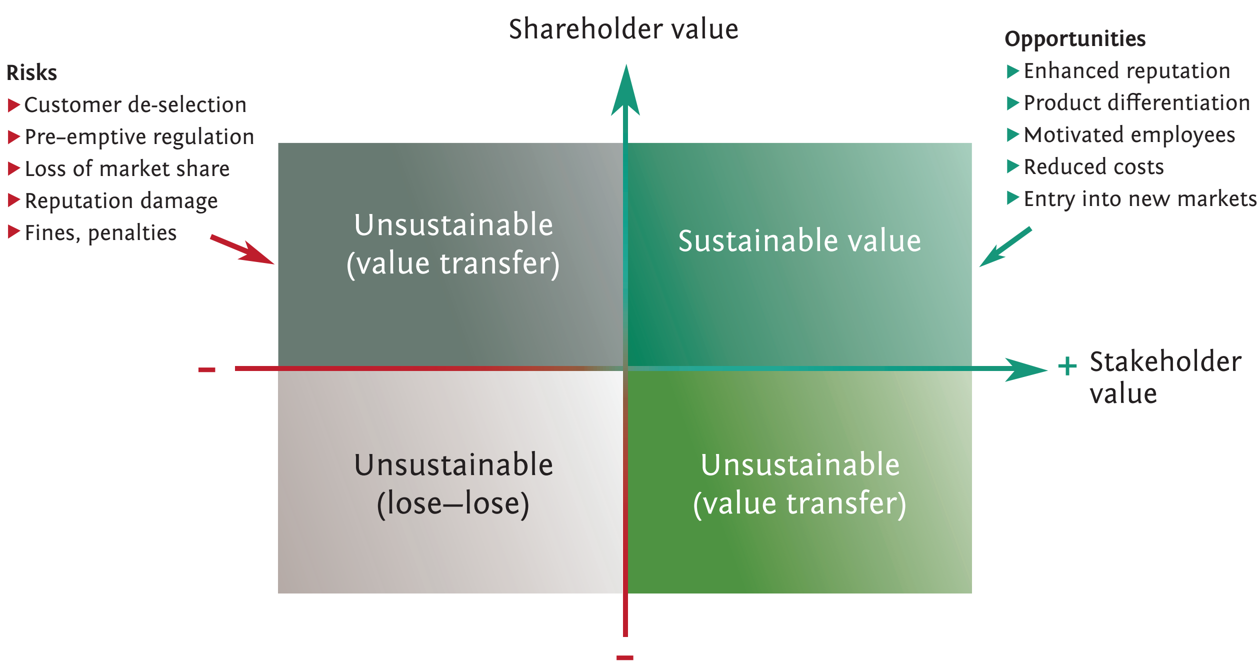
The Sustainable Value Framework

Stakeholder value requires managers to think "outside-in" about how their companies create and sustain competitive advantage. Outside-in thinking, which sees the world from the perspective of stakeholders, is a powerful new lens through which managers can discover new business opportunities and risks. Leaders who engage stakeholders and proactively address stakeholder issues can better anticipate changes in the business environment, reducing the risk of being unpleasantly surprised by emerging societal expectations. Ultimately, stronger stakeholder engagement allows leading companies to discover new sources of value through innovation.

Figure 1 describes company performance along two axes—shareholder value and stakeholder value. Shareholder value is exemplified by increased dividends and stock prices for company "owners"; stakeholder value emphasizes responsibility to all the stakeholders—employees, customers, community, and shareholders—over profitability and "is created when a business adds to the capital or well-being of its stakeholders" (Laszlo 2008, 120). Managing in two dimensions represents a fundamental shift in how managers think about business performance. In this framework, companies that deliver value to shareholders while destroying value for other stakeholders have a fundamentally flawed business model, while those that create value for stakeholders are cultivating sources of extra value that can fuel competitive advantage for years to come. Sustainable value occurs only when a company creates value that is positive for its shareholders and its stakeholders.

Starting in the upper left of Figure 1 and moving counterclockwise, consider the following four cases of value creation.

Figure 1. The Sustainable Value Framework



Source: Laszlo 2003, 126.

Sustainable value (top right) is created only when both shareholder and stakeholder values are incorporated by business, resulting in positive opportunities for all interested parties. Unfocused charity and action by well-intentioned environmentalists (for instance, actions that cause a business to go bankrupt) fall into the bottom right sector. A business that pays no heed to societal or environmental concerns and pays the price in lost customers falls into the top left sector. Actions that benefit neither the shareholders nor the stakeholders (the least desirable situation) fall into the bottom left sector.

Upper left quadrant: When value is transferred from stakeholders to shareholders, the stakeholders represent a risk to the future of the business. Leaded paint and asbestos are historical examples; today, carbon dioxide emissions from coal-fired power plants, phthalates in cosmetics, toxic additives in children's toys, volatile organic compounds in carpet adhesives and paints, heavy metals in fabric dyes, and lead solder and brominated flame retardants in consumer electronics are examples of products that create risks to employees, customers, and society even while they create value for shareholders. Companies that avoid environmental regulations in their home markets by exporting production to countries with lower regulatory standards create similar risks. Also in this quadrant are firms that create shareholder value through a low-cost strategy that tolerates management actions to cut expenses by avoiding overtime pay, undertraining on employee safety, or discriminating on the basis of gender and ethnic background. Shareholder value in these cases is created "on the backs" of one or more stakeholder groups, thereby representing a value transfer rather than true value creation.

Bottom left quadrant: When value is destroyed for both shareholders and stakeholders, this represents a lose-lose situation of little interest to either. Monsanto and its European competitor Aventis lost large sums of money by underestimating consumer and farmer resistance to their genetically modified (GMO) crop products. Before Aventis sold its CropSciences division to Bayer in 2001, it is estimated to have lost $1 billion in buyback programs and other costs associated with its genetically modified corn, StarLink, which was approved only for use in animal feed but was found by NGOs to have contaminated a number of human food products.

Bottom right quadrant: When value is transferred from shareholders to stakeholders, the company incurs a fiduciary liability to its shareholders. Actions intended to create stakeholder value that destroy shareholder value put the company's viability into question. Environmentalists often unintentionally pressure companies to take actions in this quadrant without realizing that the pursuit of activities that generate losses is not sustainable either. It is interesting to note that philanthropy, when it is unrelated to business interests and represents pure charity, is also located in this quadrant. Unfocused philanthropy is implicitly a decision to take financial value from the company's shareholders and transfer it to one or more of its stakeholders (Porter and Kramer 2002).

Upper right quadrant: When value is created for stakeholders as well as shareholders, stakeholders can represent a potential source of hidden business value. Sustainable value is created only in this case. When companies design manufacturing facilities that cost less to build and operate than conventional facilities and that use less energy for heating and lighting, they are creating sustainable value. The same is true when they eliminate packaging waste by rightsizing their products, or when they add environmental intelligence to their products by making them more recyclable, reusable, biodegradable, less toxic, or otherwise healthier. Sustainable value is also created when companies find ways to profitably meet unmet societal needs, for example, by providing nutrition and clean water to the poor. The key is to provide environmental and social benefits to stakeholders without asking customers to accept higher prices or worse quality. Companies that are global industry leaders cannot afford to require their customers to pay the "green premium" that specialty companies have historically charged for their products. Only through process or product redesign and innovation can leading companies create new business and societal benefits without consumer trade-offs.

Managers assessing opportunities to create shareholder and stakeholder value (in other words, opportunities that drive a company further into the upper right-hand quadrant of figure 1) need to make the business case for taking action. Without a clear articulation of business value, managers will be unable to obtain the approval needed to obtain the required resources. The six levels of strategic focus described in the following section is an essential tool used to apply the sustainable value framework.

Six Levels of Strategic Focus

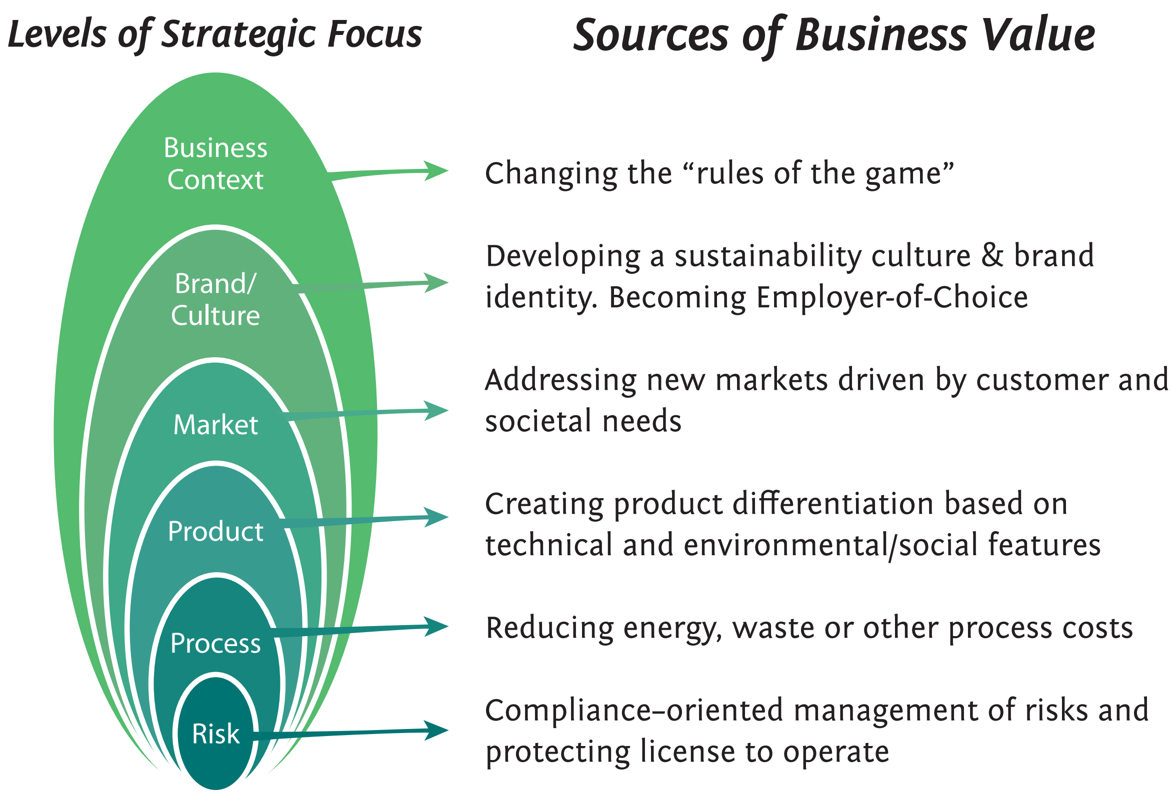
The six levels of strategic focus shown in figure 2 on the following page constitute an important tool for managers seeking to identify how business value is created from sustainability projects. The six levels represent distinct types of sustainability-related business value that can be found in every sector.

Companies have made great strides in compliance-oriented risk mitigation (level 1) and process cost reduction (level 2) through eliminating waste and improving energy efficiencies. Relatively few have focused on top-line (gross revenues) growth based on product or brand differentiation (levels 3 and 5). Even fewer have used stakeholder value creation as a way to drive new markets and business context change (levels 4 and 6). Each of the levels is described in greater detail below.

Level 1: Risk Mitigation

Actions that companies take to comply with government regulations and industry standards (one of the earliest examples being Responsible Care in the chemicals industry, adopted in 1988 by the American Chemistry Council) have historically been seen as a financial burden: they are the necessary cost of doing business and of maintaining license to operate. Yet efficient risk mitigation strategies can create significant value to both shareholders and stakeholders.

Figure 2. The Six Levels of Strategic Focus



Source: Laszlo (2003, p. 140).

Implementing the six types of business value, which are applicable to every business sector, is an important tool in creating sustainable value.

They include the avoidance of penalties and fines, reduced legal fees, and reduced site-remediation costs.

Level 2: Process Cost Reductions

Process cost reductions are often one of the first sustainability initiatives a company undertakes. Reducing energy consumption, eliminating waste, and minimizing materials intensity are all initiatives that save the company money while reducing environmental, health, and safety impacts on stakeholders.

Level 3: Product Differentiation

The growing segment of consumers for whom social and environmental attributes are important criteria provides an opportunity for leading companies to differentiate themselves on a dimension other than price or technical performance. Al Gore's film, *An Inconvenient Truth* (David and Guggenheim 2006), along with a changing political awareness of climate change, is helping to push sustainability issues into the forefront of public consciousness. On the supply side of the equation, mainstream players such as Walmart and General Electric are democratizing green products by bringing unit costs in line with the products' traditional (non-green) counterparts. It is now possible to buy an organic cotton shirt at Walmart for about the same price as one made from conventionally grown cotton.

When consumers are not asked to pay more for environmental and social benefits, and when they are not forced to compromise quality or performance, sustainability attributes become a "plus one." The recent experience of leading companies, including Unilever, Toyota, JPMorgan Chase, and Aviva, shows that consumers prefer green products and services if they do not have to give up anything in return.

Level 4: New Markets

Technological innovation that creates stakeholder value increasingly opens up new markets. Examples include

DuPont's push into soy-based nutritional products and Procter & Gamble's development of water purification products in emerging markets. Aviva, one of the world's largest insurance companies, has begun selling life insurance in rural India for households where the disability or death of the principal wage earner can be devastating. Celanese AG has parlayed its expertise in plastic polymers to develop high-temperature membrane electrode assembly (MEA) for fuel cells suitable for use in cars—itself a new market driven by climate change–related concerns. The French materials giant, Saint-Gobain, is finding new applications for its high-performance materials from particulate filters in diesel cars to solar panel components and windmill tips.

Level 5: Enhancing Corporate Image

DuPont, Walmart, Unilever, General Electric, Alcoa, and many other leading companies are finding that a brand/culture based on creating stakeholder value is rapidly becoming a source of competitive advantage. Among other business benefits, a sustainability image draws in higher-income consumers, attracts and retains talented people, and can ease negotiations with government regulators concerned about industry impacts. It contributes to an image of innovation—in some cases attached to a single product, such as Toyota's Prius—that confers reputation benefits to the entire company.

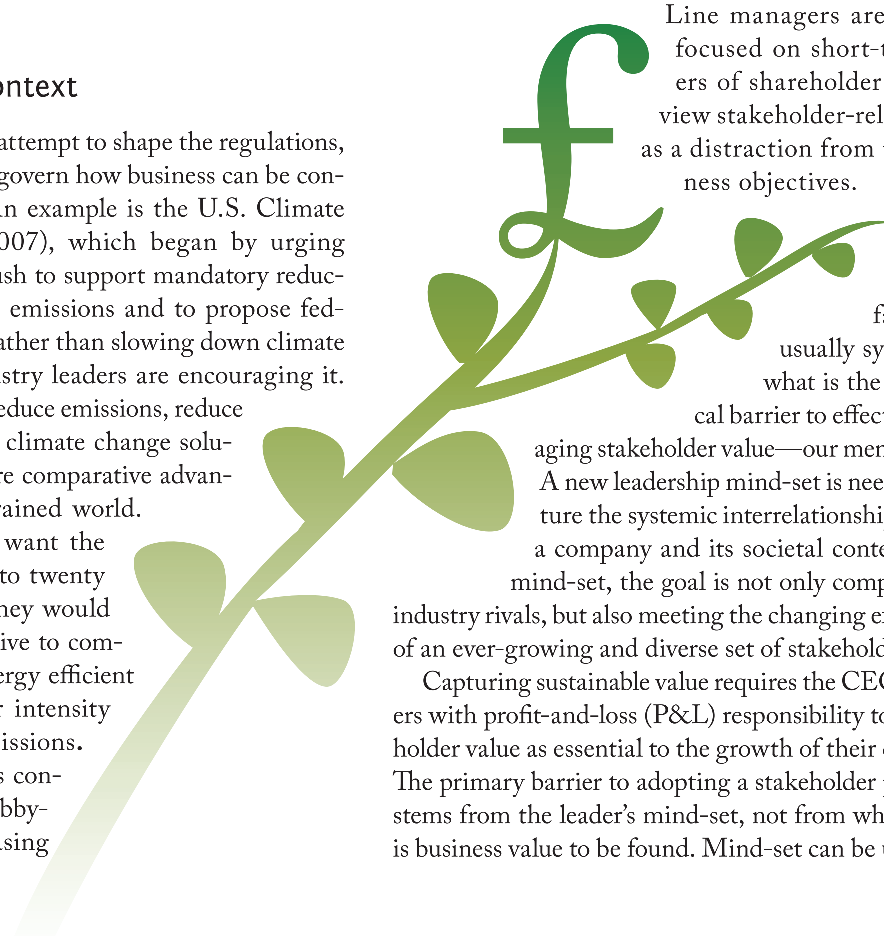
Level 6: Business Context

At this level, companies attempt to shape the regulations, practices, and rules that govern how business can be conducted in their favor. An example is the U.S. Climate Action Partnership (2007), which began by urging President George W. Bush to support mandatory reductions in greenhouse gas emissions and to propose federal reduction targets. Rather than slowing down climate change legislation, industry leaders are encouraging it. They see their efforts to reduce emissions, reduce energy use, and provide climate change solutions as a source of future comparative advantage in a carbon-constrained world. These companies don't want the price of oil to fall back to twenty dollars a barrel, since they would lose that advantage relative to competitors who are less energy efficient and who have a higher intensity of greenhouse gas emissions. Influencing the business context is not only about lobbying government; increasing the overall stakeholder value in an industry can create goodwill for the entire industry. Conversely, negative stakeholder value can shrink the potential market size and reduce the ability of players in the industry to make enduring profits.

Companies can use the sustainable value framework to think in strategic terms about their existing portfolio of products and services. With the framework, managers are able to assess the business value and obtain the resources for sustainability-related initiatives. Perhaps the single biggest obstacle to taking action, however, is not making the business case for the initiatives, but establishing the leadership mindset required to even consider sustainability as a business opportunity.

Leadership Challenge

Sustainability-related business opportunities are often poorly managed in companies that are otherwise global industry leaders, even where a great many strategic business opportunities exist. Several factors can contribute to this situation. An incomplete awareness exists about the company's impacts on stakeholders and how these might in turn affect future business value. Responsibility for social and environmental issues are typically fragmented across the organization and often delegated to those outside the core management team. Line managers are naturally focused on short-term drivers of shareholder value and view stakeholder-related issues as a distraction from their business objectives.



These factors are usually symptoms of what is the most critical barrier to effectively managing stakeholder value—our mental models. A new leadership mind-set is needed to capture the systemic interrelationships between a company and its societal context. In this mind-set, the goal is not only competing with industry rivals, but also meeting the changing expectations of an ever-growing and diverse set of stakeholders.

Capturing sustainable value requires the CEO and leaders with profit-and-loss (P&L) responsibility to see stakeholder value as essential to the growth of their companies. The primary barrier to adopting a stakeholder perspective stems from the leader's mind-set, not from whether there is business value to be found. Mind-set can be understood as the hidden set of beliefs about the individual, others, and the world. Much as computer operating systems allow only certain software applications to run, our mind-sets dictate the range of possibilities we draw upon to solve problems (Senge 1994). For instance, if an executive believes that an NGO's primary commitment is to put his or her company out of business, the actions to engage with them will be very different than if the executive believes both are committed to solving a common problem.

Historically, the mind-set required to rise to the top of a large corporation has run counter to adopting a stakeholder perspective in the process of value creation. Executives have tended to focus narrowly on maximizing shareholder value. They have privileged activities that, often unintentionally, externalize negative social and environmental impacts. They have risen to their positions of power precisely because they are able to create shareholder value by maximizing "efficiencies" that legally drive externalities elsewhere.

The idea that maximizing the value of *all* key stakeholders is of interest (much less essential) for business success is quite heretical to what has made leaders successful in the past. Yet stakeholder power is now a reality in the new global business environment. Business leaders who fail to adopt a new mind-set risk putting their companies and careers at risk.

Outlook for the Future

In the past, managers often felt forced to choose between two perspectives: business has a moral responsibility to society, *or* it has a fiduciary responsibility to its shareholders. Those who believe in the profit motive consider moral questions in the workplace to be a distraction. Those who believe in a societal role for business consider the single-minded focus on short-term profits to be irresponsible.

In the new global business environment, companies can pursue both simultaneously. Indeed, they must if they want to succeed. Companies that deliver profits to shareholders while destroying value for society are incurring liabilities; those that offer solutions to environmental and social challenges are discovering huge profit opportunities. The corporate path to doing well by doing good has become the smart way to do business, if you have the knowledge and competencies required for it.

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See also Base of the Pyramid; Corporate Citizenship; CSR and CSR 2.0; Education, Business; Equator Principles; Financial Services Industry; Leadership; Natural Capitalism; Social Enterprise; Stakeholder Theory; Transparency; Triple Bottom Line

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T

Telecommunications Industry

The rapidly expanding telecommunications industry holds great promise for sustainability by enabling people to work remotely rather than commuting, thus reducing greenhouse gas emissions. In reality, though, the environmental benefits of telecom systems are only as good as the equipment used to run the networks and the mobile devices, such as cell phones, required to connect to those networks.

One might think that software and other virtual products are free from materiality. Such things, it is true, exist in a world of digital pulses and binary numbers, yet they can only be constructed materially through computer hardware. Computers and other electronic gadgets do incur environmental burdens, for example, by depleting natural resources and consuming energy; toxic substances are also used in their manufacture. Whether telecommunications benefits sustainability depends on the network, the device, and the services that device provides (e.g., a phone call or email). Telecommunications is a high-growth sector, especially in developing countries. In 2009, 308.9 million cell phones were sold worldwide; sales of smart phones (which offer multimedia applications) were expected to increase 48 percent by 2010. Overall, cell phone sales were expected to increase 5–7 percent (AFP 2009).

Climate Change Considerations

For the total communication network (TCN), including wired and wireless systems, the main environmental issue is climate change. This is mainly due to greenhouse gas emissions (GHG) from electricity consumption (Forster et al. 2009). For example, current global GHG emissions from information and communications technologies (ICT)—excluding TV systems—are estimated at 2 percent or 800 million tons (Mt) carbon dioxide equivalent (CO_2e). These are expected to grow to 3 percent or 1,400 Mt CO_2e by 2020. Approximately 29 percent of these emissions are from TCN systems (Climate Group 2008). This is comparable to emissions from aviation, although the ICT sector is larger and aircraft emissions are more damaging since they are released into the stratosphere (IATA 2009).

A single average data server results in roughly the same annual GHG emissions as an SUV (Global Action Plan 2007). Since ICT can be used to increase energy efficiency in other sectors, some studies suggest that ICT can reduce overall emissions even if its direct emissions increase (McKinsey 2008). For telecommunications, GHG emissions from cell phone networks are substantial, due mostly to energy consumption for network operations and the production of handsets (Forster et al. 2009). Between 25 percent and 40 percent of the environmental impacts of mobile data transfer are due to the high electricity consumption of the base stations that handle wireless communications (Faist Emmenegger et al. 2003). Environmentally the cell phone is the most significant element of the telecommunication system. Direct data transfer between two cell phones has more impact than data transfer within a fixed network: transmitting one gigabyte (Gb) of data between two mobile phones requires the equivalent of 800 megajoules (MJ-eq)—a unit of energy—of primary fossil energy compared to 640 MJ-eq from a cell phone to a landline. The rate for data transmission between mobile devices is higher because of the intensive consumption of material resources and energy used in production of the handsets. The environmental burdens from using mobile devices are relatively low compared to their manufacture and distribution, a situation worsened by their short product life. For fixed network systems, most environmental burdens are associated with copper cables and telephone centers (Faist Emmenegger et al. 2003; Forster et al. 2009).

Due to its higher capacity, transmitting one Gb of data via a Universal Mobile Telecommunication System (UMTS) is environmentally better than via a Global System for Mobile communication (GSM)—0.94 gigajoule equivalent (GJ-eq) vs. 1.3 GJ-eq. GSM is the main worldwide technology for mobile data transfer, with a capacity of 9600 bits per second; USTM belongs to the third generation technology with faster transmission rates up to 384 kilobits per second. Despite its name, it is not globally compatible (Faist Emmenegger et al. 2003). The history of cell phone technology starts with the analog "brick cell phones" of the 1980s (generation 1 or 1G; nicknamed for their likeness to bricks, the first cell phone sold for nearly $4,000 in 1984); 2G replaced the analog 1G with wireless digital technology working with GSM; 3G technology, launched in 2001, enabled faster data transfer, more network capacity and services; 4G, expected in 2012, will completely replace 3G technology and is seen as the next evolution in cell phone technology—promising even faster data speeds and voice, data, and high-quality multimedia in real time (Fendelman 2009).

For digital terrestrial TV (DTT) and similar devices, energy consumption from the use phase dominates that of manufacture and installation of television systems; this is because the environmental impact is averaged over the relatively long life span of the products—ten to twenty years. DTT networks are fifty to a hundred times more energy efficient than domestic TVs because of more-efficient use of broadcast spectrum signals. This advantage is eroded, however, if both analog and digital systems are operational because services are duplicated. This is also true for devices such as smart phones—there is only an environmental advantage if the device with the combined applications replaces the separate devices (i.e., computers, GPS devices, telephones). Because DTT systems use the broadcast spectrum more efficiently, more systems can be operated using the same amount of spectrum. This can actually increase the overall environmental impact (Faist Emmenegger et al. 2003).

Satellite-based systems have not been fully evaluated. Scenarios for the United Kingdom suggest that switching from DTT to satellite-based systems would have no environmental advantages mainly because (a) DTT and satellite services provide an equivalent service (TV broadcast), therefore duplicating the infrastructure would lead to higher environmental costs; and (b) satellite-based households currently consume around 63 percent more energy than DTT-based households due to the higher energy consumption of the satellite receiver equipment, although this is likely to change significantly in the future (Forster et al. 2009). Compared to terrestrial TV, satellite systems do not need much terrestrial infrastructure from which signals are sent to orbiting satellites. There is a lack of data on the power consumption for the uplinks, however, as well as the total satellite system, system maintenance, and the proportion of uplinks used for TV services and other unrelated services. There are also visual effects on the landscape, for example, satellite dishes on dwellings. (Forster et al. 2009).

The environmental impacts from optical, fiber-based systems are mainly associated with production; cable, infrastructure, and consumer-equipment installation; and network energy consumption during use (Faist Emmenegger et al. 2003). Transitioning from older to newer generations of communication systems can also have environmental effects. The sooner more-efficient technologies are introduced, the better. Shorter transition periods based on set timetables reduce the impact of communication systems once analog networks are switched off (Faist Emmenegger et al. 2003; Boardman et al. 2005).

Raw Materials and Manufacturing

On a product level, production of cell phone handsets carries the most environmental burden because the integrated circuits, silicon chips, capacitors, and printed wiring boards used to build them contain precious metals, such as gold, silver, and platinum. Mining these metals is energy intensive and creates significant environmental damage as large amounts of earth and rock have to be moved to extract small amounts of metal. For example, roughly 350,000 tons of rock and ore have to be mined to obtain one ton of platinum (Douglas and Lawson 1997, 1998).

The manufacture of these electronic components is also energy intensive. Typically, of all the components (electronics, plastics, carrying cases, etc.) used in products such as cell phones, electronics have the highest carbon footprint. Since most electronics manufacturing sites are located in Asia, and consumer demand is so time sensitive, aircraft emissions from shipping is also significant (Faist Emmenegger et al. 2003).

Up to 90 percent of the environmental burden of cell phones occurs at the production phase. From this perspective, a cell phone should be used for ten years before being replaced. (Frey 2002; Frey, Harrison, and Billett 2006; Faist Emmenegger et al. 2003). But in practice, cell phones are replaced every one to two years (Faist Emmenegger et al. 2003; Forster et al. 2009), and while the manufacturing of cell phones has become more resource efficient, the number of subscribers to cell phone services has soared. Between 1991 and 1996, the weight of cell phones decreased tenfold, but the number of users grew eightfold, offsetting gains from reduced product weight (Jackson and Clift 1998). Demand for mobile 3G high-data rate services has created pressure to expand those networks (Forster et al. 2009). This is a major dilemma of eco-efficiency: improving resource efficiency does not automatically lead to conservation but can actually accelerate resource depletion as lower prices made possible by efficiency gains lead to increased consumer consumption. This is known as the "rebound effect" (Jaccard 1991). To achieve absolute conservation in energy and materials, improvements in technological efficiency must not be outweighed by increased overall consumption; rather, they must be accompanied by behaviors that actually conserve resources (GUA 2000; Brezet, Bijma, and Silvester 2000; Hinterberger et al. 1999), but this has not happened yet (GFN and WWF 2007, 2008).

There may also be other environmental, ethical, and political issues if metals or other materials are not sourced sustainably. For example, the metallic ore *coltan* (columbite-Tantalite) is the source for the precious metal tantalum, which is used in capacitors. Coltan has been illegally mined from wildlife reserves in the Congo, which further diminished both the endangered mountain gorilla and okapi, and led to civil warfare (WWF 2005). Comprehensive and stringent supply chain management is necessary to ensure that materials are sourced responsibly.

E-Waste

Compared with the environmental impact from cell phone production and use, the impact from the disposal of electronics plays a lesser role, even if the waste is partly incinerated (Faist Emmenegger et al. 2003; Frey, Harrison, and Billett 2006). In Europe the recycling of electronic products is regulated by the Waste from Electrical and Electronic Equipment (WEEE) directive; the presence of hazardous substances is regulated through RoHS (Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations) and REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals). (REACH is a directive of the European Commission, which acts as the executive branch of the European Union.) Harmful exposure to hazardous substances (i.e., certain metals and flame retardants) does not occur during the normal use of cell phones, but these substance can be damaging if they are dispersed into the environment. This can be a problem in countries with less stringent regulations governing production and disposal of electronics because cell phones are often discarded (Müller et al. 2005). Although some people are concerned about health risks from a cell phone's radio waves, there is no scientific consensus on the ecological and health effects from nonionic radiation.

Wider Implications

Numerous sources say that teleworking can reduce environmental impacts. For example, studies by the WWF (2008, 2009a) found that employee travel accounts for at least 50 percent of a nonmanufacturing company's carbon footprint; thus virtual meetings could improve business efficiency and reduce costs and GHG. In a "smart world" teleworking scenario for the year 2030, 1 billion tons of carbon dioxide emissions could be avoided—according to the World Wildlife Fund, equivalent to the total current CO2 emissions from the United Kingdom and Italy combined and almost 3.5 billion tons in year 2050—almost as much as the total CO2 emissions in the European Union or more than half of the U.S.'s current CO2 emissions (WWF 2009b, 7).

Several studies suggest that in an ideal teleworking scenario, 80 percent of energy could be saved if unused office space and equipment were decommissioned and commuting was eliminated (Hop Associates 2002; Boardman et al. 2005). A 2009 survey by Cisco Systems of 2,000 of its worldwide staff states that the rollout of online communication technologies, such as instant messaging tools and video conferencing, had achieved $277 million in productivity gains, saved $10.3 million a year in fuel costs (a direct result of telecommuting), reduced travel-related carbon emissions by 47,320 metric tons, and achieved greater job satisfaction among employees (BusinessGreen.com 2009). In 2002, the Confederation of British Industry (CBI) identified poor and congested transportation infrastructure as putting major costs on industry and listed teleworking as one of its top solutions (CBI 2002).

Studies gathered in a joint report by the European Telecommunication Network Operators Association and the World Wildlife Fund (ETNO and WWF n.d.) present several conclusions:

- 22.3 million tons (Mt) of carbon dioxide could be saved if 20 percent of business travel in the European Union (EU) was replaced by video conferencing.
- 2.2 Mt of carbon dioxide could be saved if 50 percent of EU workers replaced one meeting with one audio conference a year.
- 22.17 Mt of carbon dioxide could be saved per year if 10 percent of Europe's workforce became "flexi-workers" (on-call employees with full benefits and guaranteed hours).
- 109,100 Mt of carbon dioxide could be saved if 100 million customers switched to online phone bills.
- 195,000 Mt of carbon dioxide could be saved if the inhabitants of the EU did their tax returns online.

Unknowns

One concern is how teleworking changes travel modes and associated energy consumption (Boardman et al. 2005). For example, it is not clear if, in the long run, ICT will encourage people to live farther from their work places, thus increasing travel distance despite reducing the frequency of travel. And if a car previously used for commuting becomes available to someone else in the household, will this increase the number of miles driven by that particular vehicle rather than reduce them?

The carbon footprint of global spam emails—a veritable plague of modern life—is 33 terawatt hours per year—as much as the electricity use in 2.4 million homes in the United States (McAfee 2008). To combat this, the ICT industry needs to comply with strict data protection standards and transparency in the use of personal details and to educate clients on spam and the safety risks associated with broadband connections.

Outlook

Video conferencing, "telepresence," IP collaboration, and telecommuting have come a long way over the last few years and present solutions that are affordable and easy to use. (Telepresence refers to technologies that allow a person to feel as if they were present, although they are somewhere else; videoconferencing and videotelephony are forms of telepresence, the latter to a higher degree due to better audio and video fidelity. IP collaboration is the networked collaboration in an organization converging video, voice, and data channels.) Online banking, shopping, learning, entertainment, email, and teleconferencing can also to some degree replace the need for physical items such as DVDs, books, bills, memo pads, letters, manuals, and company circulars. Sharing electronic files rather than sending folders through the mail can enable staff to work more collaboratively. It also allows better communication with suppliers, contractors, employees and other shareholders through the Internet, extranets, and other forms of communication such as Electronic Data Interchange (EDI), a protocol for the electronic transmission of information between different companies.

Telecenters (centers that provide communities with access to information and communications technologies) are based on the premise that access to information will lead to empowerment, which will eventually lead to economic development. These and other community technology efforts can help people worldwide join the "knowledge society." They provide the essential infrastructure with ICT applications in health care, local economic development, rural e-commerce, education, and e-governance, and can reach people who need them most. Telecenters exist now in almost every country, sometimes under different names, such as "village knowledge centers," "infocenters," or "community multimedia centers" (The Hindu Business Line 2005; UNESCO 2004).

Conclusion

On the one hand, current emissions from ICT (of which telecommunications are a big part) match those of the aviation sector and could soon outstrip these; on the other hand, ICT has the potential to save GHG and costs in other sectors and thus contribute to an overall conservation of energy and resources (which is not the same as just becoming more energy efficient).

Another conclusion is that technology itself is neutral—new technologies are a double-edged sword that can reduce travel and energy consumption, or not—the same ICT can make an attractive substitute for travel or increase it; it can help to achieve the elusive paperless office or it can produce more paper (Flexibility 2009; Boardman et al. 2005; Mokhtarian 2007). ICT can make things possible, but there are both sustainable and unsustainable choices to be made.

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See also Consumer Behavior; Data Centers; Energy Efficiency; Facilities Management; Information and Communication Technologies (ICT); Manufacturing Practices; Mining; Supply Chain Management

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Textiles Industry

Expansion in the production and consumption of textiles will create greater negative impacts on the environment unless all industries along the textile and apparel supply chain commit to environmentally sustainable practices and products. Although legislation will increasingly demand sustainable industrial processes, many companies are voluntarily pursuing green strategies, such as the reduction of waste and the use of renewable energy and organic or recycled materials.

The textile and apparel supply chain affects the environment at all stages—from fiber production to the disposal of textile waste to consumer activity. This effect, or "ecological footprint," also represents the amount of land associated with the production and use of a given amount of textile products. If unchecked, growth in the ecological footprint resulting from expansion in the production and consumption of textiles will contribute to air and water pollution, depletion of fossil fuels and raw materials, and climate change.

Textile consumption—and its impact on the environment—has increased as the world's population has grown. Consumption per person has also risen at a rate almost four times as fast as world population growth between 1950 and 2006 (Textiles Intelligence 2008c). The two most common textile fibers, cotton and polyester, both cause serious environmental problems during their production. Cotton cultivation, which accounts for only 2.4 percent of the world's arable land, consumes around 11 percent of its agrochemicals including pesticides and fertilizers (Kooistra, Termorshuizen, and Pyburn 2006, xi). In addition, irrigation of cotton crops can lead to water shortages and environmental damage, such as the catastrophic shrinking of the Aral Sea in Uzbekistan, which has been reduced to 10 percent of its original size following the diversion of rivers for cotton irrigation systems (Micklin and Aladin 2008). Polyester, the most widely used human-made fiber, is manufactured from oil, a nonrenewable resource. The manufacturing process requires high levels of energy input and generates large quantities of poisonous atmospheric emissions. Relative to cotton and polyester, other human-made fibers that have a minimal impact on the environment account for only a small percentage of the world's fiber consumption.

Within textile production, textile finishing is the most environmentally hazardous stage. Old textile-production plants create a great deal of dust and high noise levels while modern fully automated production processes use huge amounts of energy. Enormous amounts of water and energy are consumed during finishing processes, and the resulting effluent (wastewater) can contain high concentrations of harmful substances, which expose workers to a number of potential health hazards.

Apparel production is the most environmentally friendly stage in the textile and clothing supply chain. But recent shifts of manufacturing to China and other Asian countries have increased the amounts of energy required to transport products to big markets in the United States, the European Union, and Japan.

Many consumers remain relatively unaware of the effect that the manufacture of textiles and home furnishings has on the environment. Western consumers continue to buy large quantities of "environmentally unfriendly" clothing and other textile products, as do increasing numbers in developing countries who are encouraged by falling prices. The significant drop in the price of new clothing in recent years and the often inferior quality of recycled fibers have kept the recycling of used textile and clothing products at a low level.

Voluntary "Ecolabels"

Some clothing retailers are voluntarily attaching "ecolabels" onto garments. These labels indicate to customers either that the item has met certain environmental standards during manufacturing or that a company has been given an award for "best practice" in its manufacturing techniques. Although the type and scope of environmental criteria can vary, these awards are especially important when they have been granted by a credible third-party organization. Each of the following labeling schemes has met with varying levels of success in the marketplace.

The EU Eco-label, administered by the European Union Eco-labelling Board (EUEB), indicates a limited use of toxic substances during fiber production, a reduced risk of allergic reactions, and a guarantee that the product is not more likely to shrink or fade than conventional products. About seventy companies worldwide, most of which are European, have successfully applied to use this logo for textiles and clothing.

The certification "made in Green" was created by Aitex, a Spanish textile technological institute. It indicates a product that is free from harmful substances and has been made in factories where the environment and the rights of the workers are respected.

Some labeling schemes assess the full lifecycle—or "cradle to grave"—environmental impact of the textile or garment. This often includes social aspects of an item's production, such as labor conditions, and information about every stage of the supply chain, including the processing of raw materials, production, distribution, consumption and maintenance, and disposal. One example is the "bluesign standard," launched in 2000 by the Swiss company Bluesign Technologies. It examines consumer safety, occupational health issues, and environmental impact in the whole textile and apparel supply chain. Many key players in the chemical industry, the retail sector, and in fabric production support this standard.

Other labels focus more on a single attribute, such as organic production of source materials, labor conditions, and production facilities. An example is the Global Organic Textile Standard (GOTS), which was developed by the International Working Group (IWG) on Global Organic Textile Standard and introduced in May 2008. This label for textiles shows that a product complies with one of two organic classifications. The first, "organic" or "organic in conversion" (cotton grown on land which has only recently been converted to organic methods), refers to a textile product in which 95 percent or more of the fibers can be certified as such. The remaining 5 percent can be made from nonorganic fibers (including defined regenerated or synthetic fibers but not blended fibers). The second subdivision, "made with x percent organic (or organic in conversion) materials," indicates a product of which 70–95 percent of the fibers must be certified organic. The remaining percentage can be made from nonorganic fibers.

Worldwide Responsible Accredited Production (WRAP), an independent nonprofit organization based in the United States, focuses on certifying ethical manufacturing in factories around the world. These factories, many of which are contracted to produce apparel for brand managers and retailers, comply with WRAP's principles and standards under the Apparel Certification Program, which was introduced in 2000.

The international Öko-Tex consortium has developed three different certification programs for textiles: Öko-Tex 100, Öko-Tex 1000 and Öko-Tex 100plus. Öko-Tex 100 certifies that products do not contain any substances which are harmful to human health. Öko-Tex 1000 sets requirements for the final product, the complete production process, and an environmental management system. Öko-Tex 100plus certifies that products meet certain criteria relating to human health and the environment. The Öko-Tex Standard 100plus certificate can only be awarded to a company that has already received the Öko-Tex Standard 100 and Öko-Tex Standard 1000 certificates. Furthermore, Öko-Tex Standard 100plus certifies that the company is committed to using suppliers who have been certified as complying with Öko-Tex Standard 100 and Öko-Tex Standard 1000.

Regulations and Mandatory Labeling

The European Union's Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) legislation requires all companies with operations in the European Union to register production, use, and importation of chemical substances with the European Chemicals Agency (ECHA). Unlike previous similar regulations, REACH places responsibility for the safe use of chemicals on companies rather than on the authorities, and it involves the entire supply chain from the manufacturer to the retailer. Complying with these standards may have a negative impact on competitiveness, especially for small- and medium-sized enterprises. On the other hand, REACH compliance could also provide companies with a competitive advantage in the growing global market for safer and cleaner products.

Since 1976 in the United States, the Toxic Substances Control Act (TSCA) has enabled the Environmental Protection Agency (EPA) to track industrial chemicals that are produced domestically or imported into the country. If EPA scientists feel that a chemical poses an environmental or human health hazard, they can request detailed reporting or testing of the chemical, or they can ban its manufacture and importation.

The Shift to Organic Cotton

Organic cotton fiber production has grown at dramatic rates since its beginnings in the 1980s. In order to be classified as "organic," a crop must be cultivated in soil that has been free from the use of toxic pesticides and fertilizers for at least three years. According to Textiles Intelligence (2008c), organic cotton fiber production rose by an average of 41 percent per year (from 6,480 to 25,394 metric tons) between 2000 and 2005. Between 2005 and 2007, it rose by an annual growth rate of 51 percent and reached 57,931 metric tons in 2007. Output more than doubled between 2007 and 2008 to reach 160,796 metric tons. Growth has been driven by increasing consumer demand, the changing strategies of large retailers, public efforts to increase environmentally friendly textiles, and specific cooperative development programs.

One of the main problems faced by organic cotton growers is poor yields. Because of crop rotation programs and the absence of synthetic fertilizers, organic cotton yields are 20–50 percent lower than nonorganic yields. Additional costs, incurred at each stage of processing, increase the price of the final product to a level that deters many consumers.

Despite higher prices, sales of organic cotton products (some of which are made of blended fibers) reached a value of approximately $3.5 billion in 2007, and Organic Exchange expected that sales would soar to $4.5 billion in 2009 and to $6.8 billion in 2010 (Textiles Intelligence 2008). The use of organic cotton has become widespread due to the efforts of a number of well-known international retailers and brands, such as Walmart, Nike, and Woolworths.

Selected Green Strategies

Many companies in the textile and apparel supply chain, such as dye houses, fiber manufacturers, retailers, and fashion houses, claim to pursue green strategies. Because of the absence of a single set of global industry standards, it is difficult to assess how green these companies really are. Furthermore, the long and varied supply chains of many retailers make it difficult to measure the total impact of their activities on the environment. Nonetheless, it is evident that a number of companies are making solid efforts to reduce the adverse impact of their operations on the environment.

Numerous large clothing retailers in the United States have demonstrated a commitment to green strategies. American Apparel boasts excellent performance in all areas of sustainability. The company claims to pay the highest wages in the industry while offering its workers year-round job security. In addition, it implements efficient and

renewable methods in its operations, including the use of organic and domestically grown materials.

According to the nongovernmental organization (NGO) Climate Counts, Gap, which is based in San Francisco, is second only to Nike in its efforts to reduce its carbon footprint. In 2005, Gap joined the Better Cotton Initiative (BCI), a collaborative global process which aims to promote sustainable cotton cultivation. Gap reduced energy usage in its U.S. stores by 8.7 percent between 2003 and 2006 (EPA 2009). In 2007, its stores in North America started to carry garments made from organic cotton.

Since 1985, the clothing and sportswear manufacturer Patagonia (2010) has contributed over $34 million in cash and in-kind donations to grassroots environmental activists through its Environmental Grants Program, and in 1993 it established an Environmental Internship Program which allows its employees to work for environmental groups while they continue to receive full pay. The company introduced polyester-fleece clothing made of recycled beverage bottles in 1993, and it has since recycled more than 90 million bottles into fleece clothing. Since 1996, it has used only organically grown cotton for its sportswear line. By 2010, Patagonia aims to manufacture only products that are recyclable and made of recycled materials.

Several companies outside of the clothing sector have also been noted for their environmentally friendly strategies. Among those with strong and effective environmental policies is Interface, a manufacturer of carpet tiles. In response to its customers' concerns about the environment, the company vowed to eradicate Interface's environmental footprint. Since 1996, it has reduced its energy consumption per unit production by 44 percent, its water use by 72 percent, and its landfill use by 67 percent, and it has saved more than $405 million in avoided waste costs (Interface 2009). With a self-imposed deadline of 2020 to achieve environmental sustainability—which company chairman Ray Anderson defines as "taking nothing from the earth that is not rapidly and naturally renewable, and doing no harm to the biosphere"—Interface has set itself apart from other companies in the industry (Todd 2006).

In Tirupur, India, the knitwear-producing company MaHan is building a new plant to produce ecologically dyed products. MaHan claims that the plant will be the first environmentally friendly dyeing plant in India with zero tolerance for water pollution. All the polluted water will be gathered, cleaned, and reused for another dyeing process, which will save 95 percent of all water used by MaHan and eliminate some of the 44 billion liters of polluted water from local dyeing facilities that contaminate the groundwater and farm land annually (MaHan Eco 2010).

Based in Heerbrugg, Switzerland, Rohner Textil is an environmentally friendly producer of high-quality upholstery products. In 1995, it launched Climatex Lifecycle compostable upholstery fabrics, which are made from wool and ramie. These fabrics were environmentally sound and passed all industrial standards, but they complied with few fire regulations. In 2000, Rohner added flame-resistant capabilities to its upholstery fabrics without using hazardous chemicals. Marketed as Climatex LifeguardFR, these flame-resistant fabrics were designed to meet standards in public buildings and for air, train, and water transport.

Although the retail giant Walmart was described as a "reactive leader" in the field of environmental initiatives in a 2007 report by the Switzerland-based research firm Covalence, it has been remarkably quick to implement green policies throughout its supply chain. After being the target of a number of critical campaigns by politicians and business publications, in 2005 the company committed to complete reliance on renewable energy, zero-waste creation, and selling products which sustain Walmart's resources and the environment. It also pledged to buy only organically grown cotton and the alternate crops farmers need to grow between cotton harvests. In 2006, Walmart became the world's largest buyer of organic cotton (Gunther 2006). An immediate but unexpected benefit of Walmart's organic cotton certification was full visibility of the supply chain and the opportunity to eliminate intermediaries. Formerly Walmart had purchased cotton from Turkey, shipped it to China for spinning and knitting, and then shipped it to Guatemala to be cut and sewn. Walmart was able to save time and money by eliminating the shipment to China and having all processing done in Guatemala.

Outlook

It is widely acknowledged by analysts and consumers that the global economy must be made sustainable, and that companies will be subject to laws and regulations that increasingly discourage unsustainable industrial processes. Governments are likely to shift taxation away from labor, income, and investment, and towards pollution, waste, and loss of primary resources.

While it is in the common interest that companies adopt and implement green policies in all textile-related activities, "green" does not necessarily mean "profitable." It is possible that some companies that engage in this endeavor will lose money or go out of business. The successful ones, however, will gain a competitive edge.

In order to make significant improvements to environmentally friendly products, all industries along the supply chain must be involved, including those concerned with crop and fiber production, polymer manufacture, fiber supply, spinning, weaving, dyeing and finishing, garment manufacturing, design, retail, and logistics. It is especially important for manufacturers and retailers to understand and supply information to the consumer about a product's environmental impact, especially information on the production processes used, the amount of water and energy consumed, and the use of chemicals.

It is unlikely, however, that the consumer will lead the trend toward green fashion. According to a 2006 survey by Cotton Incorporated's *Lifestyle Monitor*, 30 percent of consumers consider environmental friendliness when purchasing apparel, whereas 87 percent of consumers consider price to be the most important factor. In fact, the importance of environmental friendliness appears to have decreased significantly since 1995, when a similar survey determined that 36 percent of consumers considered environmental friendliness to be important (Cotton Incorporated 2007).

In addition, an increased "throwaway" mentality among many consumers encourages clothing consumption and production, leading to more pollution, depletion of nonrenewable resources, and waste disposal problems. Young consumers in particular are keen on the concept of "fast fashion"—as pioneered by stores such as Old Navy, Primark, Target, and Zara—since it allows them to change styles quickly on a low budget. One of the greatest challenges for the sector is to create new business models that encourage sustainable production and consumption.

According to the report *Well Dressed?* (Allwood et al. 2006), which was partially funded by Marks & Spencer, clothing—and fast fashion in particular—is a major and increasing contributor to global warming because it is not produced or cared for in an ecofriendly way. The report suggested that consumers should buy more expensive and durable clothing and that clothes could be leased and then returned at the end of the month or season. It is unlikely that many fashion-conscious consumers on a low budget will heed such advice, especially in the short term.

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See also Agriculture; Consumer Behavior; Ecolabeling; Manufacturing Practices; Sporting Goods Industry; Supply Chain Management; Sustainable Value Creation; Water Use and Rights; Zero Waste

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Transparency

Transparency, as it relates to sustainability, entails the disclosure of information. Transparency increasingly has been seen globally as an essential component in efforts to hold governments and private industry accountable for their actions on environmental issues. But the lack of definitive research about whether or not such disclosures reach their targeted audience raises questions about transparency's effectiveness as a sustainability tool.

In the search for sustainability, the idea of *transparency* has gained increasing favor as a means to achieve desired results. More and more it is being looked upon as an essential component for holding both government and private industry accountable. Transparency means many things to many people—general openness, "opposite of secrecy" (Florini 1998), greater flow of information. Here it means *information disclosure*, a phenomenon increasingly central to a diverse range of sustainability initiatives.

Accompanied by freedom of information legislation, the "right to know" movements spreading across the globe reflect an embrace of transparency (Florini 2007). In the context of industrialized countries, transparency underpins what foreign policy expert Ann Florini (1998) calls "regulation by revelation" to address issues such as air pollution, food safety, and vehicle safety. The most prominent example of regulation by revelation is the Toxic Release Inventory (TRI), a chemical release registry established by the United States Emergency Planning and Community Right to Know Act of 1988. The act mandates that companies disclose information about their toxic emissions, with the goals of informing communities exposed to pollutants, holding the companies accountable, and eventually leading to reduced emissions. The TRI has been hailed as a successful sustainability initiative and served as a model for other countries, resulting in a spread of pollutant emission registries across the globe, not only in Europe but also in Mexico, South Korea, and China (Fung, Graham, and Weil 2007; Graham 2002; Stephan 2002; Weil et al. 2006).

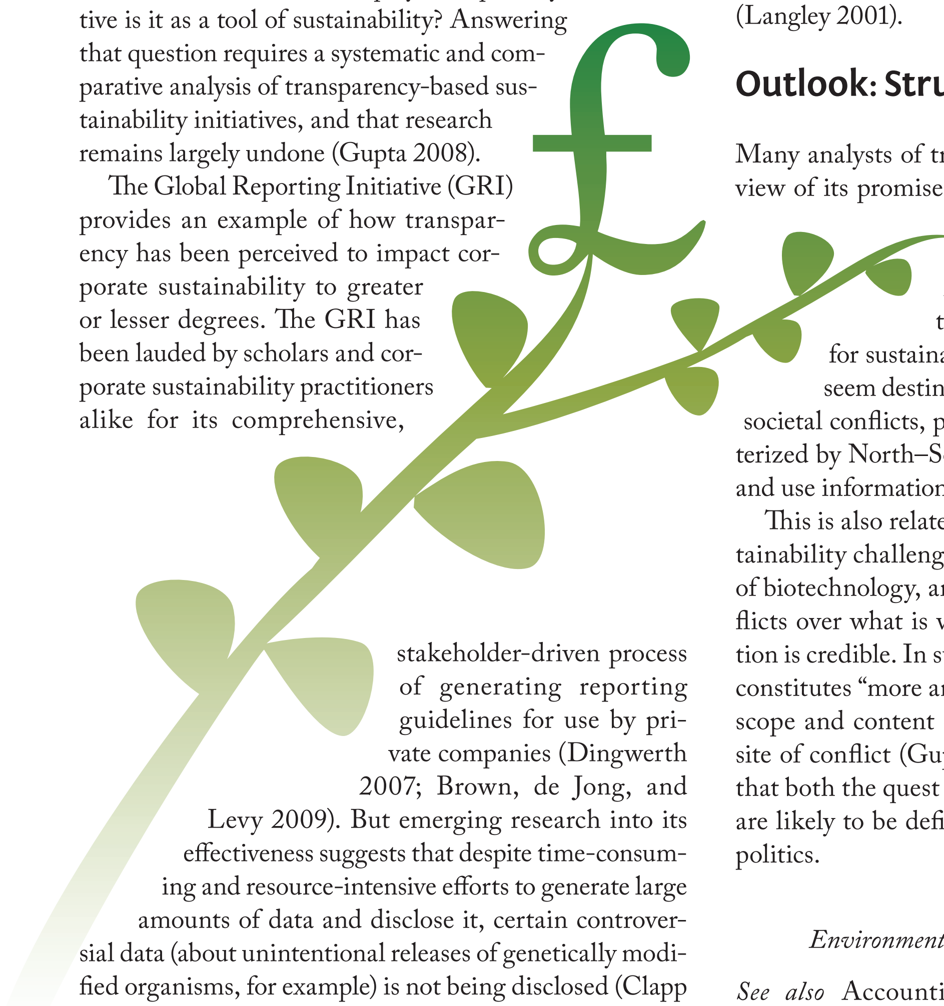
In the context of global sustainability, information disclosure as a means of governance includes both mandatory state-led and voluntary private initiatives (Gupta 2008; Langley 2001). For example, a belief in the power of transparency underpins the June 1998 Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (the Aarhus Convention), negotiated under the auspices of the United Nations Economic Commission for Europe (UNECE), which is intended to enhance citizens' right to know about environmental decisions (Mason 2008). Transparency is also central to various multilateral treaties governing trade in pesticides, hazardous waste, and genetically modified organisms, such as the Cartagena Protocol on Biosafety under the Convention on Biological Diversity, and the Basel Convention on Trade in Hazardous Waste. Privately initiated ecolabeling programs in forestry, fisheries, and organic foods, such as the Forest Stewardship Council and the Marine Stewardship Council, also rely upon information disclosure as a way to promote sustainable choices and enhance sustainable resource use. Various efforts to promote corporate sustainability also rely on information disclosure and transparency, for example: the Global Reporting Initiative (calling for sustainability reporting by private corporations); the Carbon Disclosure Initiative (calling for disclosure of carbon emissions); or the Publish What You Pay initiative (calling for disclosure of earnings from extractive—oil, gas, and mining—industries operating in resource-rich developing countries).

As evident from this range of examples, transparency can be invoked to help fulfill a variety of sustainability-related aims. This suggests that there are multiple architects of transparency in a global and national context: those in the private sector, for instance, who voluntarily promote transparency to further corporate sustainability goals, improve their public image, and/or avoid government intervention; and those in the public sector who, while promoting transparency to remedy perceived and real deficiencies in their environmentally related decision making, aim to ensure political accountability and greater citizen participation. The diverse motives underlying transparency can thus range from a desire to extend the regulatory reach of the state to scaling back its reach; and from furthering a moral "right to know" (thereby holding government and private sectors accountable) to promoting individual lifestyle choices and market-based solutions (Mason 2008).

Impact on Sustainability

Given diverse reasons to deploy transparency, how effective is it as a tool of sustainability? Answering that question requires a systematic and comparative analysis of transparency-based sustainability initiatives, and that research remains largely undone (Gupta 2008).

The Global Reporting Initiative (GRI) provides an example of how transparency has been perceived to impact corporate sustainability to greater or lesser degrees. The GRI has been lauded by scholars and corporate sustainability practitioners alike for its comprehensive,



stakeholder-driven process of generating reporting guidelines for use by private companies (Dingwerth 2007; Brown, de Jong, and Levy 2009). But emerging research into its effectiveness suggests that despite time-consuming and resource-intensive efforts to generate large amounts of data and disclose it, certain controversial data (about unintentional releases of genetically modified organisms, for example) is not being disclosed (Clapp 2007) and therefore never reaches its intended beneficiaries. Or alternately, disclosed information is inaccessible and/or irrelevant for those it is intended to benefit, hence resulting in few users of disclosed information (Brown, de Jong, and Levy 2009).

Such findings can relate to various components of transparency-based reporting, ranging from *design of disclosure*, such as the means by which information is to be disclosed (whether electronic or otherwise), to the *attributes of information* disclosed, such as whether it is standardized, comprehensive, and comprehensible. Those with alternative motives sometimes turn the standard intent of transparency on its head by overwhelming reporting authorities and the public with information, a practice called "drowning in disclosure" (Gupta 2008; Mason 2008; Graham 2002; Fung, Graham, and Weil 2007). Finally, newly emerging *intermediaries of transparency*—auditors, verifiers, and certifiers of disclosed information—are becoming more important, and their degree of involvement can vary depending on the potential ramifications the disclosure. These intermediaries are likely to be increasingly significant in shaping the impact of transparency in sustainability governance (Langley 2001).

Outlook: Struggles over Transparency

Many analysts of transparency begin with an optimistic view of its promise only to subsequently highlight various perils in relying on disclosure in the quest for sustainability (Mol 2008). While most would concur that transparency is no panacea in the search for sustainability, discussions about transparency seem destined to take place in the context of larger societal conflicts, particularly in a global context characterized by North–South disparities in capacities to access and use information.

This is also related to the fact that pressing global sustainability challenges, such as climate change or safe use of biotechnology, are characterized by fundamental conflicts over what is valid knowledge and whose information is credible. In such areas, therefore, agreeing on what constitutes "more and better" information, that is, on the scope and content of transparency, will itself become a site of conflict (Gupta 2008). In short, we can conclude that both the quest for transparency and struggles over it are likely to be defining features of future sustainability politics.

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See also Accounting; Climate Change Disclosure; Corporate Citizenship; Financial Services Industry; Global Reporting Initiative (GRI); Performance Metrics; True Cost Economics

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Travel and Tourism Industry

Sustainability awareness in the travel and tourism industry has grown to such an extent that sustainable tourism has almost become an industry in itself. Major players in the industry have discovered that they can cut costs and make more money by redesigning systems to conserve water and fuel, reduce waste, and protect the natural environment that is often part of the appeal of vacation destinations.

The travel and tourism industry is the largest industry in the world, according to the U.N. World Tourism Organization (UNWTO 1999). Its scope is evident in the following statistics from the UNWTO:

- The number of international arrivals has increased from 25 million in 1950 to an estimated 806 million in 2005, an annual growth rate of 6.5 percent (2009a, 2).
- Figures from 2008 suggest that the number of international arrivals reached 922 million (2009a, 2).
- In 1950 total receipts from international tourism equaled $2.1 billion; in 2005 they rose to an estimated $682.7 billion (2006); by 2008 receipts were up to $944 billion (2009b, 3).
- In its *Tourism 2020 Vision* report, the UNWTO (n.d.) forecasts 1.6 billion international arrivals by 2020; of these, approximately 1.2 billion will be intraregional (within the same continent) and 378 million will be long-haul travelers (between continents).

International travel is forecasted to grow in every region in the world, with Asia growing the fastest. The same forecast predicts Europe will maintain its position as the region with the greatest number of international arrivals, though its share will continue to decline. Data from the World Travel & Tourism Council (2009b) further underlines the economic significance of tourism as it estimates that worldwide tourism employs 220 million people and generates 9.4 percent of global gross domestic product (GDP).

Measuring tourism is not so straightforward, and any tourism-related statistic may be questioned. This is because many countries have permeable borders (as in Europe), count day travelers as tourists, and have other varying methods of measuring tourists. Progress has been made, however, at an international level in the adoption of tourism satellite accounting approved by the United Nations. Tourism satellite accounts analyze the demands for goods and services from tourists and link these to other economic activities (UNSD 2008). The unique situation of tourists is that they are temporarily in a new environment for reasons unrelated to employment or residence. In 1993 the System of National Accounts suggested that since tourists differ from other types of consumers, satellite accounts should be annexed to deal with the situation (UNSD 2008). Nonetheless, this method does not include indirect and induced tourism expenditures (i.e., a tour guide receives a paycheck and spends a portion of this on dining out or other living costs in that destination), which may double the value of tourism to a destination. Furthermore, it is far more common for residents of a country to travel domestically during vacations than to travel abroad. Estimates suggest worldwide expenditures for domestic tourism may be ten times greater than for international tourism (Cooper et al. 2008). It should therefore be acknowledged that tourism is an activity with fuzzy boundaries, with direct and indirect influences on other economic sectors.

In addition, the global tourism economy is three times the size of the tourism industry itself, which only considers tourism's direct impact (Weaver 2006). (It is important to note that tourism as defined by the UNWTO and the World Travel & Tourism Council [WTTC] includes business travel, which accounts for about half of the international trips taken and their economic impact, with higher daily expenditures but for fewer nights.) The number of international flights has also increased because annual two-week vacations are no longer the norm; vacation travelers often take international trips of shorter duration spread throughout the year. Since the greatest environmental impact from travel and tourism is from flying, this is a cause for concern.

Sustainable Tourism

The concept of sustainable tourism grew out of the recognition that human behavior has both positive and negative impacts on the natural environment. Because tourism is often regarded as a tool of economic development, its link to the notion of sustainable development is strong. A key idea in the debate about sustainable tourism is expressed in the so-called Brundtland Report, which claims sustainable development is "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, 8).

The concept of sustainable tourism continues to be debated. Though there is no universally accepted definition of the term *sustainable tourism*, the sustainability agenda in tourism is not new. For example, the *Journal of Sustainable Tourism* was founded in 1993, and early research in this area stretches back to the 1970s (Bramwell and Lane 2008). Most tourism academics and practitioners would agree that sustainable tourism should, first, recognize tourism's environmental impacts and, second, try to manage its impacts in a way that recognizes conflicts of interest. Beyond this, there is no universal agreement. Certainly sustainable tourism has become institutionalized in that supranational organizations, such as the UNWTO, WTTC, United Nations Environment Program (UNEP), and the World Wide Fund for Nature (WWF)—also known as the World Wildlife Fund in the United States and Canada—have endorsed the concept and are trying to support it through various initiatives.

That tourism sometimes has undesirable consequences has not always been readily acknowledged. In fact, travel and tourism have benefited from a glamorous "smokeless industry" image in the past. Often the negative impacts of tourism (resource consumption, biodiversity loss, and changes to local cultures) have been overlooked in favor of its more positive effects (income and job creation). This can be attributed to what the scholar Jafar Jafari (2001) terms the "advocacy platform" stage of tourism development during the 1950s and 1960s, which indicates that tourism was largely championed as an economic activity because it brought with it employment and infrastructure development, for example. Social benefits often derive from the effects of the economic benefits, such as rising living standards, improved health care, and education. Most governments encouraged tourism as a means of economic diversification largely because it attracted foreign money (particularly important to developing countries), created more jobs with less investment than other industries, was highly deregulated, and helped boost the image of tourist destinations (Cooper et al. 2008; de Kadt 1979).

As environmental awareness grew during the late 1960s and 1970s, the advocacy platform of tourism was challenged by a cautionary platform that stresses the often-negative impacts tourism can have on destinations, particularly as a result of unplanned and rapid development (Jafari 2001). Tourism often depends on an environment that is pristine and unsullied; it is in a tourist destination's own interests to protect its natural and cultural heritage to keep attracting visitors. Leisure tourism often takes place in unspoiled areas featuring lush biodiversity, where the construction of tourism-related infrastructure—hotels, second homes, harbors, marinas, and recreational complexes—can cause irreversible damage to environmentally sensitive areas, displace native communities, and obstruct access to scarce natural resources. In the Spanish Costas, for example, rapid and largely uncontrolled development has led to image problems and a subsequent decline in visitor numbers (Andreu, Bigné, and Cooper 2001).

Tourism and Climate Change

The Second International Conference on Climate Change and Tourism, held in 2007 in Davos, Switzerland, acknowledged that climate is a key tourism resource, and thus the travel and tourism industry is highly sensitive to climate change. As a result, the tourism sector must respond to climate change if it is to develop in a sustainable manner.

While the concept of sustainable tourism emphasizes environmental issues, it also recognizes economic and social implications. For example, the presence of tourists, foreign ownership of tourist attractions, and foreign workers all contribute to negative social impacts (Doxey 1975; Wall and Mathieson 2006). Differences in host and guest behavior may cause conflicts or lead to locals emulating foreigners. An increase in land prices can displace communities in favor of second homes for wealthier foreigners, and nonlocal workers often take a short-term utilitarian view of the destination. These influences have been evident since the emergence of mass tourism after World War II, but they have become an even greater issue due to the massive increases in international travel. Consider that Morocco and Egypt each plan to add 300,000 bed spaces (in hotels and second homes), both in desert environments. As of 2009 Egypt's and Morocco's tourism development plans proposed combined hotel and villa developments, where the sale of second homes would finance the overall real estate project, and the hotel would serve as the hub of the second homes' residential needs. The attraction of these developments would not be for their convenience and proximity to local cultural attractions, but for their good value and as relief from the hot climate in remote locations.

The long-term impact of tourism, and therefore its sustainability, will depend on the management of tourist facilities. Water and energy consumption of hotels, for example, is often exponentially higher than consumption rates by the indigenous communities around them. Waste-treatment systems are often insufficient to cope with demand, and the discharge of raw sewage and overuse of landfills are commonplace. Importing food and merchandise is also common, leading to increases in waste packaging, fuel consumption, and fuel emissions, together with a loss of potential earnings for local suppliers. The reverse is also true. Exploitation of local resources (typically for items such as fresh fish) can deplete those resources and cause price inflation. To encourage growth and foreign investment, it is typical for developing countries to offer land for free or discounted prices and to subsidize land sales with incentives such as tax credits and profit repatriation deals, which allow foreign investors to return profits to their home countries. Land usage invariably increases land prices, which affects the ability of locals to live in popular regions, causing further displacement and the creation of migrant-worker communities in, for example, hotel compounds. Coupled with seasonal fluctuations, this creates high staff turnover and poor job security.

Accommodations Impacts

Hotels and other accommodation providers, together with transportation, constitute the largest subsectors of the tourism industry. The Intercontinental Hotels Group alone manages more than 600,000 rooms worldwide. The vast majority of hotels, though, are small or medium-sized establishments. For example, according to the U.K. Department for Business, Enterprise and Regulatory Reform (BERR), in 2007, 98.4 percent of hotels and restaurants in the United Kingdom had fewer than fifty employees and 22.4 percent had no employees at all, meaning the establishment was managed and staffed by the proprietor (BERR 2007).

Dedicated networks for responsible hospitality are now established within mainstream international hospitality associations, such as the International Hotels & Restaurant Association (IH&RA). Meanwhile there are also smaller, specialized associations dedicated to this issue (such as the Green Hotels Association). It is also not uncommon for the biggest players in the hotel sector to have corporate social responsibility programs. For instance, Accor, a leader in the hotel and global services industry, has its Sustainable Development Programme. The realization that substantial cost savings can be achieved through more efficient use of resources is driving sustainability in the hospitality industry. This is not to say that the concept of social responsibility in the hospitality businesses focuses solely on the environment. The larger accommodation providers, such as Marriott, also recognize the social impacts their operations have on the communities in which they are situated, as evidenced by its Social Responsibility and Community Engagement initiative.

The Airline Industry

The airline industry receives a lot of attention related to sustainable tourism. Concerns about climate change have heightened awareness about the impact of aircraft on the environment, yet there are no indications that demand for flights will decrease. Despite widespread acceptance that current levels of global warming are the result of human activity, atmospheric concentrations of greenhouse gases (GHGs) continue to grow. Tourism's share of carbon dioxide emissions is estimated at 5 percent (Davos Declaration 2007). Transportation accounts for about 75 percent of tourism's share, and aviation contributes some 40 percent of transportation's total GHG emissions (UNWTO and UNEP 2008). (These figures can vary from source to source, depending on how the terms *transportation*, *tourism*, and *aviation*, are defined, as well as on the measurement standards used.)

While tourism's 5 percent contribution to global GHG emissions may seem small, the growth trend in international travel is expected to continue, thereby exacerbating tourism's contribution to anthropogenic climate change. Airbus (2009) estimates that passenger numbers will grow by 4.9 percent between 2007 and 2026. The growth of tourist markets in Asia and the rapid expansion of low-cost airlines are expected to play a key role in this expansion.

Views differ about what should be done to reduce airline emissions. Airlines point to advances in technology that would provide alternative fuels and increased fuel efficiency of aircraft. The International Air Transport Association (IATA) suggests that fuel efficiency has increased by almost 20 percent since 1999 (IATA 2009a) and that new aircraft produced by 2020 are expected to reduce fuel burn and carbon emissions by 25 to 35 percent compared to the aircraft they will replace (IATA 2009b). Environmental groups such as the WWF are less sanguine about technological solutions and call instead for reductions in flying.

Cruise Lines

Cruises are an important and growing sector of the tourism industry. According to *The Cruise Report 2009*, the number of cruise passengers from the United Kingdom is expected to reach two million by 2012 (Carnival UK 2009). This represents a doubling of passengers in just eight years. Despite a troubled economic climate, the overall cruise market grew by 12 percent in 2008, further testimony to the strength of the cruise industry. The negative impacts associated with the cruise industry relate to the development and upgrading of land-based facilities and operational aspects such as the discharge of fuel, solid waste, and antifouling paint, which keeps barnacles off the bottom of ships. The International Convention for the Prevention of Pollution from Ships, also known as MARPOL (short for "marine pollution"), regulates the disposal of waste; most solid waste now should be discarded at shore-reception facilities (although small Caribbean islands struggle to cope with the volume), but cruise liners can still dispose of food waste at sea. Changes in this sector have been slow and linked to the design of more modern ships, which take time to build and generally increase carrying capacity, rather than simply replacing older ships as they are decommissioned (Endresen et al. 2003; Johnson 2002). The cruise industry is aware of its impacts, both positive and negative, and is beginning to address some of the less salubrious ones. For example, the Center for Environmental Leadership in Business (CELB) partnered with the Cruise Lines International Association (CLIA) in 2003 to launch the Ocean Conservation and Tourism Alliance (OCTA), a joint initiative to protect biodiversity in top cruise destinations and promote industry practices that minimize the cruise industry's environmental impact.

Controversies and Challenges

Carbon offsetting is often proffered as a means to reduce tourism's carbon footprint. Carbon offsetting is the purchasing of carbon credits, or offsets, equal in amount to the carbon dioxide emitted. These credits then contribute to carbon neutralizing projects such as hydroelectric plants, foot-powered water pumps, or reforestation programs (IIED 2009; The Carbon Consultancy n.d.). The role of carbon offsetting has been questioned by some, however, and remains controversial. Possibly the greatest criticism is that, as we are faced with what many see as the greatest challenge of our time, carbon offsetting leads to attitudes of complacency because there is essentially no net decrease in carbon dioxide emissions; one party pollutes less while another pollutes more. Furthermore, carbon calculators (the means by which the amount of carbon emitted is calculated) are crude, and discrepancies exist between them, meaning different carbon calculators may provide different estimates. This is important if carbon offsets are then calculated on the basis of these estimates.

The "shadow price" of carbon is also much higher than the typical calculation for a unit of carbon because it represents the full cost to society of the environmental damage of carbon emissions. For example, in September 2009, ClimateCare U.K., which is part of J. P. Morgan's Environmental Markets group, calculated the price for offsetting a ton of carbon dioxide at £8.64 (approximately $14.07). A round-trip flight from London Heathrow to New York's John F. Kennedy International Airport would produce 1.53 tons of carbon dioxide per person and cost £13.22 to offset (approximately $21.52) (J. P. Morgan ClimateCare 2009). But the *Stern Review on the Economics of Climate Change*, the largest and best-known report on the subject, calculated a shadow price of carbon at £26.50 ($44.25) per ton of carbon dioxide (Stern 2006). According to this figure, the return flight to New York should have cost £40.55 ($66.01), more than three times the J. P. Morgan figure.

Another critique of carbon offsetting is that it often does not involve those communities most affected by climate change, and that credit accounting has often resulted in the same carbon credits being sold multiple times (IIED 2009).

Another challenge facing sustainable tourism is the deceptive practice called "greenwashing," using the "green" label to sell a product, service, or experience as environmentally friendly when it is not. The growing interest in experiential vacations has been exploited through inappropriate and unregulated marketing claims. For example, a hotel might promote itself as an "ecolodge," a term that suggests the facility contributes to the well-being of its natural surroundings, yet this is often far from the truth.

The idea of ecotourism or sustainability certification has developed as a way to combat greenwashing claims. These efforts have been led by the Rainforest Alliance in their attempts to mirror the success of other sectors. Funding from the U.N. Foundation has led to the worldwide development of sustainable tourism criteria such as the Global Partnership for Sustainable Tourism Criteria (GSTC Partnership), composed of over forty organizations. The

U.N. Foundation has also proposed accrediting sustainability certification programs with the intention of including these in sustainable supply-chain management for large tour operators. These will also be a quality mark for direct consumer marketing (Rainforest Alliance 2010). The challenge for tourism is transferring practices developed for commodities industries to the service sector, where the cost of certification may be too high compared to the value added to small businesses, and the criteria for achieving certification may not be meaningful to the consumer (Font 2007).

Sustainability Innovations

Due to the highly diverse nature of the tourism industry, the sustainability innovations being adopted vary widely, but three in particular typify the sector. The hotel industry, for one, has developed eco-efficient systems mainly in the areas of energy and water management, followed by solid and liquid waste management (Webster 2000). This is due to the importance these controls have on operational efficiency (the second largest operational cost after personnel). The international hotel chains have managed to make the greatest improvements here, retrofitting in-house engineering systems, developing design guidelines for new construction, and managing them using internal benchmarks (Bohdanowicz and Martinac 2007). While these back-office improvements are important, they might not be as visible or as meaningful to consumers as hotels offering experiential vacations that emphasize respect for the local cultures and customs and promote responsible travel.

Second, Internet use by suppliers of goods and services that cater to tourism and travelers has allowed what is known as "disintermediation" (elimination of an intermediary) and "reintermediation" (reintroduction of an intermediary). The result has been a complete change of distribution patterns whereby the customer can go directly to suppliers of products and services all over the world, while also fueling the growth of specialized suppliers of diverse products. This is good news for sustainable tourism, allowing niche markets to grow and encouraging more experiential forms of tourism. For example, many underdeveloped parts of the world are now able to promote their destinations directly through the Internet while retaining more control over the type and volume of tourism they receive. The International Finance Corporation has financed an online retailing platform to allow small hotels, previously not online, to have a real-time, bookable presence, and payment systems on the Internet. This is something that only larger properties have had in the past. The franchise in Vanuatu, for example, has 80 percent of the country's accommodation online (previously only two hotels had an online presence), has developed links with carriers and a range of ancillary services, and has contributed to increasing occupancy rates at smaller hotels (GSTC Partnership 2009). At the same time the Internet has enabled the development of distribution channels such as responsibletravel.com, an ecofriendly travel agency.

Finally, just as eco-efficiencies have been achieved in the accommodation sector (unpublished data from Hilton Europe show they saved $20 million on energy and water management in three years, $9 million of which came from staff behavioral changes), technological developments in cruise and aircraft design have led to more fuel-efficient flights as measured by per capita emissions. New fleets at Royal Caribbean Cruises have reduced emissions by 50 percent compared to ships built ten years ago (Telegraph.co.uk. 2009). The IATA claims that new aircraft are 70 percent more fuel efficient than those built forty years ago and that airlines are aiming for a further 25 percent fuel efficiency improvement (compared to 2005 levels) by 2020 (IATA 2009a).

Successes

Much has been done to raise awareness of the environmental impacts of tourism. For example, the UNWTO has written a *Global Code of Ethics for Tourism* to guide stakeholders in the tourism industry. Tourism Concern is a London-based nonprofit that campaigns for ethical tourism. Since 2007, World Travel Market has organized an annual World Responsible Tourism Day, a day devoted to promoting awareness of responsible tourism. Despite the continued growth of sex tourism, groups like the Ecumenical Coalition for the Protection of Children (ECPAT) continue to campaign against the sexual exploitation of children and have been successful in raising awareness, conducting monitoring reports, and lobbying for legal reforms.

The Federation of Tour Operators' Travelife Sustainability System allows stakeholders to enter and access sustainability data for the travel industry over the Internet. While this creates a single set of standards for competing tour operators, the data is not strictly audited and participation is not compulsory (Schwartz, Tapper, and Font 2008). By the summer of 2009, more than two years since the system started, over 9,000 international hotels had entered their data.

The skiing industry has often received bad publicity due to mountain clearing and leveling during construction projects and the consumption of energy and water used to create artificial snow during regular operations. Several sustainable initiatives are in place, such as one from the U.S. National Ski Areas Association called Sustainable Slopes, an environmental charter and self-assessment tool that produces guidance notes and advice to ski resorts on how to reduce their contribution to climate change.

The golf industry has received equally bad press due to its considerable water consumption and impact on ecosystems. The Golf Environment Organisation was created to develop more environmental awareness in the industry and has been working to introduce sustainability criteria into the selection of golf courses for major tournaments. Alternatively, ecotourism vacations have been a niche but fast-growing market in recent years, reflecting the desire for more experiential holidays. Examples include Lapa Rios in Costa Rica, which has protected a tract of rain forest and offers employees financial support for real estate purchases or loan acquisitions, and Uxlabil Atitlan in Guatemala, where emphasis is placed on supporting local suppliers. The number of these types of companies is growing exponentially, as is the idea of promoting sustainability as an integral part of the vacation experience.

Outlook

The outlook for the industry is complex as a multitude of factors and pressures influence tourism and its development. What is clear is that concerns about tourism's impacts are now widely acknowledged, and the sustainability agenda is gaining traction. Measures taken by airlines, hotels, and tour operators to improve their corporate social responsibility performance are testimony to this. But there is still a lot that can be achieved.

Consumers clearly have a role to play, although demand is sending mixed messages. Surveys show a significant increase in concern for the state of the planet and the desire to travel more sustainably, yet there is an increasing gap between survey results and behavior. For instance, climate change travel (visiting places quickly disappearing due to climate change, such as glaciers) is growing. But consumers must fly less, either by taking fewer but longer trips or changing their form of transport. They need to be more informed about the places they visit and travel with an understanding of local cultures and customs. They need to ask travel companies what they are doing to protect the places they promote as destinations.

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See also Airline Industry; Consumer Behavior; Development, Sustainable; Ecosystem Services; Energy Efficiency; Facilities Management; Greenwashing; Hospitality Industry; Property and Construction Industry

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Triple Bottom Line

Triple bottom line reckoning is a form of business reporting that accounts not only for return on investment (the traditional reporting model) but also for environmental and social values. It has become an important tool for businesses pursuing sustainable growth.

The late 1990s saw the rise of the concept of the triple bottom line (TBL). The TBL underscores the fact that companies and other organizations create value in multiple dimensions. Given the nature and focus of modern accounting, the financial bottom line is generally an inadequate (and often misleading) expression of total value. In addition, the TBL concept aimed to help business people think through the question of how to make corporations more sustainable in the context of major emerging economic, social, and environmental challenges, among them corruption, human rights, and climate change.

TBL and the Three Ps

The term *triple bottom line* was coined in 1994 by John Elkington, countering the narrower focus on the then-fashionable term *eco-efficiency*, which focused on the financial and environmental dimensions of performance. TBL thinking, by contrast, extended to social impacts and to the wider economic impact issues rarely captured in the traditional financial bottom line.

The TBL approach was introduced in detail in *Cannibals with Forks* (Elkington 1997) and has been further elaborated in hundreds of company reports aligned with the Global Reporting Initiative (GRI) and in a growing number of books. A linked phrase, "People, Planet, Profit," or, alternatively, "People, Planet, Prosperity" was also coined by Elkington. This phrase was adopted by Shell in its early public sustainability reporting, following the company's Brent Spar and Nigerian crises in 1995. Known as the three Ps, it became central to the sustainable development discussion in countries such as the Netherlands. It sparked debate about the double bottom line (combining social and financial performance, as in social enterprise) and, variously, quadruple and quintuple bottom lines, in which issues such as ethics and governance were added.

Corporate Lifecycles

The average life expectancy of a company is relatively short. When the oil crises of the 1970s spotlighted the finite nature of fossil fuels, for example, Shell wondered whether there would be life—or at least industrial life—after oil. It investigated how other long-lived firms had addressed earlier market discontinuities. In most cases companies simply died or disappeared. They merged, were taken over, or went out of business. Of the original thirty constituents of the *Financial Times* Ordinary Share Index, an indicator of stock prices on the London Stock Exchange launched in 1935, just nine had survived more or less intact by the late 1990s. And the U.S. corporate death rates turned out to be even higher. Nearly 40 percent of the 1983 *Fortune* 500 companies had dematerialized, as had 60 percent of those so designated in the 1970s, and of the twelve companies making up the Dow Jones Industrial Index in 1900, General Electric (GE) was the only substantial survivor (Visser et al. 2008).

Although the average corporate life expectancy might be in the region of forty to fifty years, there may be several hundred companies around the world that have been operating between 100 and 150 years. This imbalance among the broad mass of companies and the long-winded few is a reflection of many factors, but perhaps the most important is the fact that in a capitalist world, companies that fail to deliver stockholder value are starved of capital and die. To date, sustainability factors have only rarely affected capital availability, but understanding of the relevant linkages is likely to grow rapidly.

Corporate Sustainability Challenges

Corporate sustainability is probably better understood not so much as the discipline by which companies ensure their own long-term survival—though that is clearly part of the equation—but as the field of thinking and practice by which companies and other business organizations work to extend the life expectancy of ecosystems and the natural resources they provide; societies and the cultures and communities that underpin commercial activity; and economies that provide the governance, financial, and other market context for corporate competition and survival. By paying attention to such wider issues, it is often argued, companies are better placed to ensure that their own business models remain valid and adaptable.

As for the corporate sustainability agenda, recent decades have seen sustainability issues gradually forced up through corporate hierarchies. They started on the fringes, handled (if at all) by professionals in such areas as site security, public relations, and legal affairs. Through the 1970s, as new techniques such as environmental impact assessment evolved, new groups of professionals became involved, among them project planners, process engineers, and site managers. Then, during the late 1980s, the spotlight opened out to illuminate new product development, design, marketing, and lifecycle management. As the triple bottom line agenda of sustainable development spread through the 1990s, with an inevitable growth in the complexity and political impact of key issues, the agenda was driven up to top management and boards. In the next round, in addition to those already involved, expect to see new ventures people—chief financial officers, investment bankers, and venture capitalists—included.

Over time, the agenda has opened out profoundly, increasingly embracing challenging issues such as transparency, corporate and global governance, human rights, bribery and corruption, and global poverty. The key text in this area has been 1987's Brundtland Commission report, *Our Common Future*. Its definition of sustainable development is now widely accepted. It was brought into greater focus in 1994 with the introduction of the TBL concept, which has subsequently been widely adopted—for example by the GRI. The concept has also been adopted by leading companies, most strikingly perhaps by Denmark's Novo Nordisk (2009).

As the agenda has morphed, several other factors have conspired to increase the challenge for business. First, business has increasingly been expected to do things that governments would once have done, if they were done at all. Second, the processes of globalization have enormously extended the areas and timescales over which companies are held accountable while the processes of outsourcing and "offshoring" mean that corporate value chains have become increasingly extensive, complex, and vulnerable to challenge. (Examples are Nike and Gap.) And third, the spread of the Internet and the introduction of search engines such as Google have subjected business to ever-growing levels of scrutiny.

The Impact of Globalization

The TBL agenda played into a period of intense globalization, with growing concerns about the lack of governance and regulatory systems at the global level. As sustainability and corporate citizenship agendas have evolved, the calls on the time and resources of business have increased almost exponentially. In 1999, for example, U.N. secretary-general Kofi Annan called on business leaders "to join the United Nations on a journey." He commented that business was already well down the road with a journey of its own, globalization. At the time, globalization appeared like "a force of nature," seeming to "lead inexorably in one direction: ever-closer integration of markets, ever-larger economies of scale, ever-bigger opportunities for profits and prosperity" (Annan 1999).

Ten months before the Seattle protests against the World Trade Organization (WTO), however, the secretary-general also felt it necessary to warn that globalization would only be as sustainable as its social foundations. "Global unease about poverty, equity and marginalization," he stressed, "is beginning to reach critical mass" (Annan 1999). These issues are no less important today, although some focus has shifted to political and security concerns in the wake of 9/11, the war in Iraq, and the Madrid train bombings of 2004, all of which, some would argue, are intimately connected to unresolved problems of poverty and inequity. In tackling such challenges, business is being told it must pay more attention to the need for new forms of global governance.

"Governance" became a buzzword in the 1990s. "Corporate governance," although not a new concept, began its rise in the public agenda in 1992, for example, with the publication of the Cadbury Report in the United Kingdom. That same year the United Nations held its Earth Summit in Rio de Janeiro, spotlighting the urgent need to shift the global economy toward more sustainable forms of development, and the World Bank released its report *Governance and Development*, making the case that governance failures lie behind the poor progress of development efforts to date. A decade later the spotlight had opened out, with those seeking "responsible globalization" now calling for further meaningful "global governance."

But there is a paradox here, and it has two main dimensions. First, the voluntary corporate responsibility (CR) movement has evolved as a pragmatic response to pressing environmental, community, or human rights issues. Companies are asked to address problems and even deliver public goods because governments have been unable or unwilling to do so. But second, because of the weakness—or absence—of appropriate governance systems, CR initiatives are generally disconnected from wider frameworks. As a result, they are at risk of amounting to little more than drops in the ocean when compared to the scale of the challenges. At worst, they may even undermine long-term solutions.

Progress Report

Nevertheless, huge progress has been made. From the defensive stances adopted in the heyday of government-driven responses, companies have begun to explore ways forward with an expanding range of external stakeholders. There has been acknowledgment of the legitimate—and critical—role of companies. While there are still skeptics, there is also an emerging consensus among civil society, government, and business that, in principle, companies play an important role in developing and implementing solutions to pressing sustainable development problems.

In addition, there has been engagement of a significant number of leading multinationals. For example, some 180 companies are members of the World Business Council for Sustainable Development. Nearly 1,000 companies use part or all of the GRI guidelines to report on their social and environmental performance. Business in The Community, a U.K. business association focused on CR, reports a membership accounting for one in five private-sector employees in the United Kingdom and a global workforce of more than 15.7 million people. Similarly, membership of Brazil's Ethos Institute accounts for more than a quarter of the country's gross national product (GNP). A key question remains: how can this potential critical mass be used to drive forward sustainable development even more powerfully?

Finally, there has been a clearer understanding of the "business case" (and its limits). The business case clearly has limits in driving CR to scale. But the extent of the business case for CR and the links with investment value drivers such as reputation, risk management, corporate governance, and management quality are increasingly recognized both by business and key stakeholder groups (e.g., government and the investment community).

While these certainly reflect accomplishments and progress, and individual companies can also claim substantial performance improvements, the fundamental question is whether the CR movement as a whole has made a real difference in addressing longer-term sustainability issues. The conclusion must be that current CR initiatives will increasingly run up against system limits. As former president Bill Clinton argued at a World Economic Forum summit, the scale of the challenges the world faces is such that systematic change will not be enough. Instead, he said, systemic change is needed, changes to the system itself.

But these problems are not new. Professor John Ruggie, responsible for Harvard's Corporate Social Responsibility Initiative and a key architect of the Global Compact, explains: "We in the industrialized world were slow to learn the lesson that markets must be embedded in broader frameworks of social values and shared objectives if they are to survive and thrive. Before we got to that point, we had struggled through the collapse of the Victorian era of globalization, a world war, the rise of the left wing revolutionary forces in Russia, right wing revolutionary forces in Germany and Italy as well as the Great Depression." When the lesson did finally sink in, Ruggie continues, "we called the new understanding by different names: the New Deal, the social market economy and social democracy" (Ruggie 2004, 2). The basis of these social bargains was that all actors agreed to open markets, but they also agreed to "share the social adjustment costs that open markets inevitably produce." And governments played a central role in the process, "moderating the volatility of transaction flows across borders and providing social investments, safety nets and adjustment assistance—but all the while pushing liberalization" (Ruggie 2004, 2).

One of the most striking recent trends has been the formation of new forms of partnerships and alliances, linking business with nongovernmental organizations (NGOs) and other civil society actors. But if future corporate efforts and alliances are to bridge the challenge–response gap, the scaling issue will need to be addressed more seriously and effectively. More thought also needs to be given on how to scale geometrically where the challenges are particularly serious. One answer here is to change market conditions to favor particular outcomes, which is where governments have a key role to play.

That is why two additional challenges evolving in the corporate sustainability space have to do with lobbying and tax policy. On corporate lobbying, there is growing concern that companies that give every surface sign of being committed to sustainability are often—directly or indirectly—lobbying behind the scenes to slow progress. The question here is not only how to make such lobbying more transparent but also how, over time, corporate lobbying can be swung around to support initiatives designed to tackle major problems such as climate change. Second, given the growing importance of government in dealing with so many of the challenges that have landed on the business agenda in the early twenty-first century, there is a real question about how government can be properly funded. As a result, the ability of companies in a globalizing world to manage down their tax burdens is coming under growing scrutiny.

The Four Bs

Work on implementing the TBL agenda has shown that there are many points at which it potentially engages with and influences business thinking, strategy, investment, and operations. TBL-oriented organizations, such as the Global Reporting Initiative (2009) and the Dow Jones Sustainability Indexes (2009), provide insights into current practice. Meanwhile, the corporate work of organizations such as SustainAbility (2009) and Volans (2009) have suggested that a potentially powerful way of approaching TBL-focused corporate change is to think in terms of four Bs.

This often starts with external challenges targeting *brands*, often led by activists, NGOs, and the media. Few things stimulate corporate action faster than threats to brand value, with the result that the TBL agenda cross-cuts the world of brand management. Over time, corporate leaders are then encouraged to adapt their management, accounting, disclosure, communication, and external engagement strategies (*balance sheets*). Some companies can hold the challenge at this level, but, increasingly often, the issues have a sufficiently intense political spin so that they are forced up to *boards*, cross-connecting with the world of corporate governance. If the pressures are sustained, presenting new forms of risk and opportunity, then we may see companies adapting their *business models,* as General Electric (already mentioned as a long-term corporate survivor) has begun to do with its ecomagination strategy. This turn of the wheel brings us back to branding, a point underscored by the success of GE's initiative (2009).

The TBL agenda has spawned a broad range of management tools, ranging from auditing and reporting processes to new thinking about how to blend the different dimensions of value creation. (See, for example, the blended thinking of Jed Emerson—the foundation fund manager famous for popularizing the concept that the value of an organization is based on economic, social, and environmental criteria—and other like-minded analysts, at the Blended Value [2009] website.) In the end, however, there are few drop-in TBL solutions. Indeed, GE founder Thomas Edison's comment about his protracted efforts to find a workable electric lightbulb may be a good way to think of the intense period of experimentation that business is embarking on in pursuit of something like sustainability. Faced with yet one more failure, Edison said something to the effect of, well, now I know 10,000 things that don't work. Given that single-dimensional solutions to complex problems are more likely to fail, the hope is that TBL and blended value mind-sets will shorten the odds of hitting gold with the 10,001st attempt.

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See also Corporate Citizenship; CSR and CSR 2.0; Development, Sustainable; Equator Principles; Global Reporting Initiative (GRI); Human Rights; Investment, Socially Responsible (SRI); Natural Capitalism; Social Enterprise; Stakeholder Theory; True Cost Economics

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True Cost Economics

Traditional economics doesn't account for prevailing business practices' collateral damage to the health and well-being of humankind and ecosystems; critics think the free market / cost-price system is detached from these realities and undermines sustainability. True cost economics attempts to incorporate environmental and health damage into product pricing, which could influence consumption patterns and allow the burden to be borne more equitably.

As prepared by the anti-consumerist, not-for-profit organization AdBusters, the "True Cost Economics Manifesto" begins: "We, the Undersigned, make this accusation: that you, the teachers of neoclassical economics and the students that you graduate, have perpetuated a gigantic fraud upon the world" (Bauwens 2009). The alleged fraud consists of conjuring the illusion of perpetual progress and endless growth from theoretical abstractions that obscure a real world of accelerating ecological decay and widespread human misery. One possible wake-up call is the reality check implicit in true cost economics.

The theoretical debate around true cost economics has been simmering for decades but has now begun to boil over. Its proponents believe that the neoclassical (or neoliberal) economics that has dominated the world for at least the past fifty years is hopelessly flawed. Neoclassical free-market models are detached from physical or social realities. They float disdainfully above the ecological, cultural, and ethical contexts within which the real economy is embedded and thus undermine the quest for sustainability.

Neoclassical economists have traditionally been content to allow the prices of goods and services to be determined solely by the law of supply and demand. However, in unregulated markets, only direct producer costs (for rent, labor, resources, and capital, for example) are reflected in consumer prices. The prevailing cost-price system does not account for the collateral damage to ecosystems, human communities, or population health caused by many production processes. These external (outside the market) costs are born disproportionately by third parties or society at large—and, of course, the ecosphere. Because negative externalities represent real costs, the goods and services inflicting them enter the marketplace at prices below their true cost of production. Such underpricing leads to overconsumption, inefficient resource use, and pollution—all classic symptoms of market failure.

True Cost Pricing

By contrast, in a true cost economic system, consumer prices would incorporate environmental, health, and other welfare damage costs of production. When prices "tell the truth" about costs, consumers adjust their consumption patterns accordingly, purchasing fewer ecologically costly goods. Markets would operate more efficiently, producers would innovate and adopt cleaner production processes, total production/consumption would decline (a good thing in a resource-stressed world), pollution and health costs would be would be reduced to insignificance, and third parties would be relieved of an unfair burden.

With so much going for it, why hasn't true cost economics become standard economics? As we shall see, the answer is complicated but, for starters, consider that the true cost approach would result in steep increases in prices for many goods and services that are today within reach of even lower-income groups. For example, some analysts suggest that true cost economics would raise the price of an average car by many thousands of dollars at current production practices. Who would vote for that? Ours is a global consumer culture accustomed to getting more and more for less and less. Correcting for market failure requires government intervention, and any policy that spawned dramatic price increases would spell electoral disaster for the governing party.

Incentive-Based Instruments

Economists have long argued about how best to internalize wayward external costs. By the 1960s, two main schools of thought had coalesced around the competing theories of Arthur Cecil Pigou and Ronald Harry Coase.

Pigovian Taxes

The English economist Arthur Cecil Pigou (1932) argued in *The Economics of Welfare* (first published in 1920) that the existence of externalities justifies government action. He advocated that pollution charges or taxes be applied to offending activities, to better reflect their true social costs and reduce consumption of the relevant goods. (Pigou also suggested that government subsidize private activities generating positive externalities. This would encourage private engagement in those activities and enhance the gains to society at large.)

The mechanics are simple. Imagine an economy in which a number of polluting industries are imposing unaccounted "pollution avoidance costs" on other industries (such as extra expenses for air and water treatment) as well as various "welfare damage costs" on the public (health costs, aesthetic losses, and forgone recreational opportunities, for example). A reasonable public policy objective would be to "internalize these externalities," keeping in mind that, in a total social-cost framework, any solution that imposes pollution-prevention costs on the polluters greater than the anticipated benefits (avoided costs) to other firms and the public would be inefficient.

Government could, in theory, meet this objective through a flat pollution tax per unit of contaminant emitted. The tax would force each polluting firm to decide between treating its wastes and paying the tax. Acting rationally, firms would opt to treat their emissions to the point where their rising, marginal unit-treatment costs just equal the tax. Beyond that, it would be cheaper to pay the tax.

Since different firms have differing "marginal cost of treatment" curves, each will treat a different proportion of its wastes. However, since the tax is uniform, the marginal cost at which firms switch to paying the tax will be the same for all. This ensures that low-cost polluters do most of the cleanup and minimizes the total costs of treatment (a necessary condition for maximum efficiency).

Note that pollution taxes bring the maximum amount of private information to bear on cleanup strategies. Government need not know the internal processes or cost structures of affected firms. Taxes also pay for their own administration and enforcement. But there is a major problem: in the absence of perfect knowledge, setting the tax rate is just an educated guess. If set too low, the tax will not induce sufficient waste treatment; if too high, firms will inefficiently overtreat their emissions (that is, marginal treatment costs will exceed welfare gains). Subsequent corrective adjustments to the tax are both materially—and politically—costly.

Coasian Bargaining

Despite such drawbacks, the logic of Pigovian taxes charmed most economists until 1960, when it was seriously challenged by the economist Ronald Coase, who argued that if property rights to resources (including sink capacity, or nature's ability to absorb humanity's output and wastes) were clearly defined, then government intervention to correct for externalities was unnecessary, and society could avoid the administrative and enforcement costs of antipollution taxes.

In the absence of significant transaction costs, both polluters and affected parties have a financial incentive to reach an efficient solution through bargaining, regardless of who owns the contested resource. Suppose you, as a papermaker, hold the right to pollute a stream from which I, as a food processor, draw my water. Then I have an incentive to pay you to treat your waste water as long as the cost to me is less than the cost of treating my intake water. Similarly you have an incentive to accept payment because you can profit from treating your wastes. This is because the marginal cost to you of decontaminating your relatively concentrated wastewater is less than the marginal cost to me of cleaning up my more diluted intake water. Of course with more intensive treatment your marginal costs rise to the point where I would save money by shifting to treating my intake water. We bargain around this point—you to maximize receipts, me to minimize pollution avoidance costs.

Now assume I hold the rights to the stream. You have an incentive to pay me to let you pollute as long as my unit price is less than your marginal wastewater treatment costs; I would profit by selling you pollution rights, but only to the point where your payments just cover the cost of treating my now-contaminated intake water. Again, we negotiate an agreement that internalizes costs with no government involvement.

But what if there are thousands of competing firms and myriad other social entities with interests in the negotiated outcome? In the real world, the initial allocation of property rights does matter, and total transaction costs (for research and information, negotiation, administration, and so on) balloon astronomically. Moreover, it is naïve to think that any collection of narrowly "self-interested utility maximizers" will arrive at a solution that is optimal for nature or society at large. As ecological economist Herman Daly constantly reminds us, the "self" in which we are primarily interested is not an isolated atom, but is defined by its relationships in community and by diverse biophysical connections that are affected, but not acknowledged, in economic transactions. This negates any possibility of achieving an efficient or effective solution through private bargaining alone—community (or government) must be involved.

Cap-and-Trade Systems

Government does have one attractive policy option that capitalizes on financial incentives and the allocative efficiency of competitive markets to take the guesswork out of pollution pricing. So-called cap-and-trade schemes also combine fixed emission levels with tradable pollution rights and thus separate the public-policy issue of what constitutes acceptable environmental quality from the legitimate economic question of efficient allocation. The U.S. Clean Air Act was based, in part, on caps and tradable permits, as is the early Obama administration's proposed climate change policy (the Waxman-Markey bill).

In an ideal cap-and-trade scenario, government solicits scientific advice and public opinion to set desirable environmental quality objectives and place a firm limit (cap) on allowable emissions that reflects regional assimilation capacity. The allowable emissions are then divided into a fixed number of shares or permits and distributed by some fair means to existing polluters. After initial distribution, subsequent allocation is determined by trading in an open market. The price per share is thus set by the usual law of supply and demand, except that supply is fixed. If demand increases, prices rise, inducing market participants to invest in more efficient (cheaper) production or waste-treatment processes and reduce their need for pollution rights. New businesses, or firms needing additional shares, purchase them from businesses that no longer require their full quota. Inefficient players are forced out of the market.

In theory then, a tradable permit scheme could achieve ecological and social objectives with certainty, using multiple sources of public and private information to set limits and prices while internalizing erstwhile externalities with market efficiency. And if government charged for the initial distribution of permits or demanded a royalty on subsequent trades (environmental capacity is, after all, a public good), the system would pay for its own implementation and monitoring.

Invisible and Intangible Costs

We have already shown that, despite their theoretical appeal, standard Pigovian and Coasian approaches have serious practical weaknesses. We now consider a fundamental problem that plagues all formal instruments for true cost economics—identifying and monetizing intangible and invisible costs.

Direct production costs and external property damage costs are readily determined from current market prices. But there are no markets for numerous indirect use, nonuse, option, and existence values associated with ecosystems and communities. The market price for a truckload of logs, for example, is mute about the flood control, water purification, biodiversity, carbon sink, and aesthetic and spiritual values sacrificed in clear-cutting the forest. This is why the consumer purchasing a board foot of lumber—or just about anything else—doesn't come close to paying the full social cost of production.

One problem is that assigning a valid money price to something assumes the ability to compress all the values associated with that thing into a single metric. Arild Vatn and Daniel Bromley (1994) identify three theoretical obstacles to such inclusive pricing of environmental (or social) entities:

- A ***cognition problem*** always exists in the absence of perfect knowledge, and the simple fact is that many critical functions of species and ecosystems are cognitively invisible. This "functional transparency" means that the cost of losing any important element of an ecosystem may be unknowable until that element has been destroyed. We obviously cannot place any value on that which we cannot know.
- An ***incongruity problem*** exists when the values associated with an ecologically significant good are incongruous or incommensurable with dollar values. How can we conflate the market price of duck breast with the sheer aesthetic rush experienced from witnessing a wedge of mallards in full flight over the marsh?
- A ***composition problem*** arises because in ecosystems the whole may be dependent on each of its fundamental parts. This means that value of any single component (for example, a species or nutrient) cannot be interpreted independently of the value of the whole.

These and related barriers mean that mainstream efforts to derive accurate, unambiguous *money* values for complex ecological entities (such as contingent valuation) are doomed to failure—we cannot compute costs. Our assumed ability to commoditize nature and basic life support is an arrogant fiction (and in any event, may not be such a good idea).

Transcending Benefit-Cost Analysis

All important decisions involve weighing the relative gains and losses associated with the various options under consideration. As we have seen, pollution charges, one-on-one bargaining, and cap-and-trade schemes all force the affected parties to compute private self-interested benefit-cost ratios as the basis for their internal waste management decisions ("Do we treat our wastes or pay the tax?").

More generally, formal benefit-cost analysis (BCA) purports to provide a comprehensive comparison of the discounted future benefits and costs associated with different development options. The efficiency goal is to maximize any positive difference between gains and losses. Because of its conceptual simplicity and theoretical elegance, many economists regard BCA as the definitive tool for both private and public policy decision making. In an ideal world BCA would therefore be critical to true cost economics.

But this is not an ideal world—there are practical flies in the theoretical ointment. Missing data and irreducible uncertainty combined with limited resources and ideologically tainted analyses explode any claim that BCA produces a socially optimal true cost outcome. The fact is that comprehensive true cost economics is beyond our analytic reach.

This is no minor glitch. Ignorance of critical ecological and social costs has arguably long biased modern society toward endless growth even as the ecosphere slowly implodes. It is entirely possible that if we could subject the global economy to a valid BCA, we would find that the ecological and social costs of growth at the margin now exceed the benefits. We may have entered an era of what Herman Daly calls "uneconomic growth"—growth that makes the world poorer, not richer. True cost economics may well mean no-growth economics. The fact that the world's rich and powerful reap most of the benefits of growth, while the poor and the global commons bear most of the unaccounted costs, undoubtedly contributes to present policy paralysis.

Such conclusions are not cause for despair but rather should liberate society from the dictates of oppressively wrong-headed economic models. Governments, the private sector, and nongovernmental organizations must learn to eschew "crackpot rigor." We all share this single planet and cannot afford to be blinded by faulty theory and vacuous analysis. By all means, use BCA for those tangible things to which we can legitimately ascribe a dollar value. This may bring us closer to the efficient market economy to which we aspire. But both business and ordinary citizens must recognize that the results are not in themselves a sufficient basis for decision making.

In the end, sustainability is mainly a political, not an analytic, goal. Society must recognize that even as we strive for true cost economics, the most critical ecological and social choices must be made "without prices, without apologies" (Vatn and Bromley 1994). Given the scale of the problem, multiple conflicting values, gross distributive inequity, and a deepening well of uncertainty, there is no substitute for informed, cautiously practical political judgment, all for the common good.

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See also Accounting; Cap-and-Trade Legislation; Consumer Behavior; Development, Sustainable; Ecolabeling; Ecosystem Services; Energy Efficiency; Green GDP; Human Rights; Investment, Socially Responsible (SRI); Natural Capitalism; Performance Metrics; Triple Bottom Line

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United Nations Global Compact

The largest corporate citizenship initiative in the world, the United Nations Global Compact serves as a framework to help companies align strategies and operating practices with a core set of ten principles that address the areas of human rights, labor standards, the environment, and anti-corruption. Formally launched in 2001, it had approximately 6,000 international businesses as signatories by 2009.

In 1999, then United Nations secretary-general Kofi Annan spoke at the World Economic Forum in Davos, Switzerland. In that speech, Annan made the following call for greater corporate citizenship on the part of business:

> I want to challenge you to join me in taking our relationship to a still higher level. I propose that you, the business leaders…and we, the United Nations, initiate a global compact of shared values and principles, which will give a human face to the global market.
>
> Globalization is a fact of life. But I believe we have underestimated its fragility. The problem is this. The spread of markets outpaces the ability of societies and their political systems to adjust to them, let alone to guide the course they take. History teaches us that such an imbalance between the economic, social and political realms can never be sustained for very long.…
>
> We have to choose between a global market driven only by calculations of short-term profit, and one which has a human face. Between a world which condemns a quarter of the human race to starvation and squalor, and one which offers everyone at least a chance of prosperity, in a healthy environment. Between a selfish free-for-all in which we ignore the fate of the losers, and a culture in which the strong and successful accept their responsibilities, showing global vision and leadership.

Annan had recognized a changing reality for corporations: corporate citizenship, also called corporate responsibility, was becoming increasingly important both to companies themselves, particularly large companies in the public eye, and to the stakeholders (and, not incidentally, the natural environment) with whom companies interacted as they went about their businesses. In challenging corporations to take action, Annan laid the basis for what has become the largest corporate citizenship initiative in the world, the United Nations Global Compact.

Defining Corporate Citizenship

Corporate citizenship can be defined as a manifestation of a company's vision and values as expressed through the strategies and operating practices by which the company develops relationships with societies, stakeholders, and the natural environment as core elements of its business model. In addition, fundamentals of corporate citizenship are found in the responsibility, accountability, transparency, and sustainability practices (processes, programs, and policies) of the firm. Corporate citizenship includes but goes beyond the company's corporate social responsibilities, which are manifested in their practices that directly benefit society, stakeholders, and the natural environment.

This definition explicitly distinguishes corporate citizenship (or responsibility) from corporate social responsibility by recognizing the inherent and frequently discretionary (Carroll 1979) social-betterment aspects of corporate social responsibility, and the intrinsic relationship of corporate citizenship to the company's business model and practices. It also recognizes that the major impacts of a corporation derive not from its social-betterment activities but from the ways in which it implements its business model, hence its treatment of primary stakeholders (such as investors, employees, customers, and suppliers) as well as secondary stakeholders (including communities, governments, and others affected by the firm's business model).

The Global Compact's Ten Principles

The United Nations Global Compact (UNGC), which was formally launched as an entity under the banner of the U.N. in 2001—two years after Kofi Annan's speech at the World Economic Forum—is now, by its own estimation, the world's largest corporate citizenship initiative. The UNGC bills itself as a framework that helps companies align their strategies and operating practices with ten principles drawn from globally accepted U.N. documents.

The Global Compact asks companies to embrace, support, and enact, within their sphere of influence, a set of core values in the areas of human rights, labor standards, the environment, and anti-corruption. The following ten principles appear on the UNGC website (The Ten Principles n.d.).

Human Rights

- **Principle 1**: Businesses should support and respect the protection of internationally proclaimed human rights; and
- **Principle 2**: make sure that they are not complicit in human rights abuses.

Labor Standards

- **Principle 3**: Businesses should uphold the freedom of association and the effective recognition of the right to collective bargaining;
- **Principle 4**: the elimination of all forms of forced and compulsory labor;
- **Principle 5**: the effective abolition of child labor; and
- **Principle 6**: the elimination of discrimination in respect of employment and occupation.

Environment

- **Principle 7**: Businesses should support a precautionary approach to environmental challenges;
- **Principle 8**: undertake initiatives to promote greater environmental responsibility; and
- **Principle 9**: encourage the development and diffusion of environmentally friendly technologies.

Anti-Corruption

- **Principle 10**: Businesses should work against corruption in all its forms, including extortion and bribery.

Developing Corporate Citizenship

The Global Compact is a network organization at its core, consisting of its signatories and supported by the U.N. Global Compact Office in New York and six U.N. agencies: The Office of the High Commissioner for Human Rights, the United Nations Environment Program (UNEP), the International Labor Organization (ILO), the United Nations Development Program (UNDP), the United Nations Industrial Development Organization (UNIDO), and the United Nations Office on Drugs and Crime.

By 2009, UNGC had nearly 6,000 corporate signatories, of which about 5,200 were companies, both large and small, from around the planet, each of which had agreed to uphold the UNGC's ten principles and report on an annual basis. The UNGC, which is entirely voluntary, moves the corporate citizenship agenda forward through two main objectives: mainstream the ten principles into business activities globally, and catalyze actions in support of broader U.N. goals, such as the Millennium Development Goals (which are attempting to vastly reduce the number of people living in extreme poverty by 2015).

The UNGC works to achieve its objectives through a variety of means, including policy dialogues, learning, local networks, and partnership projects. Policy dialogues are multistakeholder meetings around specific issues related to corporate citizenship. Learning involves sharing best practices on the UNGC's website, including in-depth case studies, which are sometimes presented at conferences. More than seventy local networks have been developed globally as a way of supporting signatories as they attempt to live up to the ten principles. The UNGC organizes workshops and training for participants, as well as regular conferences, to share learning and best practices, and it encourages companies to participate in partnership projects with their stakeholders, especially when they are related to other U.N. objectives, like the Millennium Development Goals, human rights, labor rights, sustainability, or anti-corruption initiatives.

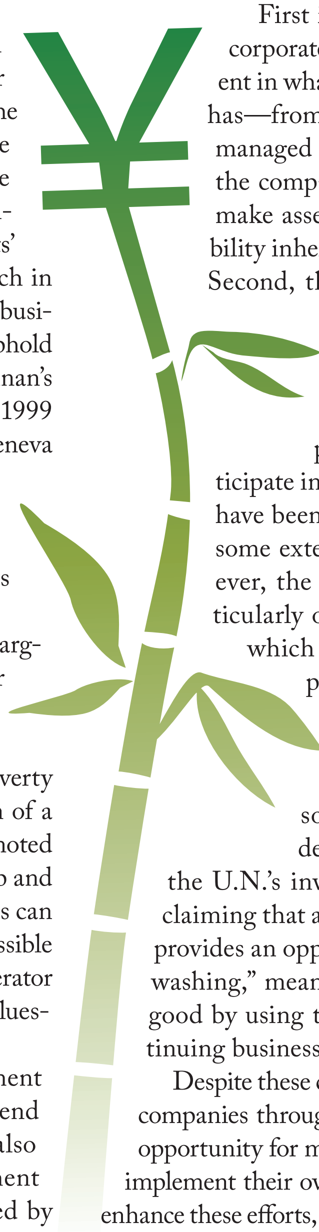
Because the UNGC is a voluntary initiative, it has no authority to sanction signatories that are noncompliant with the principles. In that sense, the ten principles are aspirational in that they set a standard that companies agree voluntarily to meet. To deal with criticisms that it lacked sanctioning capacity, the UNGC has implemented integrity measures, which include limiting the use of the U.N. and UNGC logo and name only to authorized users and delisting signers who fail to "communicate on progress" on a regular basis, which is a simple requirement for signatories.

The UNGC has identified several benefits for companies that join, including association with the U.N. with its global reach and convening power. The Global Compact believes that signing on demonstrates leadership and advances responsible corporate citizenship, and that the learning shared among signatories can help develop practical solutions to problems related to globalization, sustainable development, and responsibility, especially when multiple stakeholders are interested in issues. Further, joining the UNGC suggests that the signatory is taking a proactive stance on important issues, thereby managing risks and potentially enhancing reputation, which is a key resource for many companies when they think about corporate citizenship.

The Global Compact has established a foundation to support its work and also has helped to launch other initiatives, including in 2007 Geneva Declaration at the tri-annual International Leaders Summit, held at the U.N. in Geneva, Switzerland. Endorsed by the one thousand CEOs and executives attending the summit, the Geneva Declaration affirmed the participants' commitment to following a principles-based approach in their business models, including encouraging other business partners (such as suppliers and distributors) to uphold the Global Compact's principles. In line with Kofi Annan's original "call to action" to the business community in 1999 to engage in positive ways with society, the 2007 Geneva Declaration states that "globalization, if rooted in universal principles, has the power to improve our world fundamentally—delivering economic and social benefits to people, communities and markets everywhere."

The Geneva Declaration, which was signed by the largest gathering of business leaders ever brought together by the United Nations, was endorsed in a global context of widening gaps between rich and poor, with more than a billion people living in extreme poverty on less than one dollar per day, and the expectation of a serious lack of jobs for youths. The declaration also noted that "Through a commitment to corporate citizenship and the principles of the UN Global Compact, companies can continue to create and deliver value in the widest possible terms. In this way, globalization can act as an accelerator for the diffusion of universal principles, creating a values-oriented competition for a 'race to the top.'"

Recognizing the important role that management education plays in shaping leaders who can contend with issues of corporate citizenship, the UNGC also launched Principles for Responsible Management Education in 2007. These principles were endorsed by two accrediting agencies—the U.S.-based Association to Advance Collegiate Schools of Business (AACSB) and the European Foundation for Management Development (EFMD)—and numerous management education programs.



Corporate Citizenship and the UNGC

By focusing directly on the business model, good corporate citizenship asks companies, as did Kofi Annan, to take care in implementing their business models and also to participate actively—as individual citizens do—in ensuring that their roles in society are beneficial rather than harmful. Taking this perspective, there are two additional key aspects of corporate citizenship that need attention.

First is the recognition that some level of corporate citizenship or responsibility is present in whatever actions and impacts a company has—from good to poor, whether effectively managed or not. Outside observers looking at the company's impacts can and frequently do make assessments about the level of responsibility inherent to given activities.

Second, there is some concern and criticism about corporate involvement in political activities, a notion that is implicit in the use of the term *citizenship*. Unlike individuals, corporations are not people who can participate in democratic processes. Corporations have been granted the rights of individuals to some extent by various judicial rulings; however, the reality of the size and power, particularly of large multinational corporations, which frequently become involved in the political process through donations to campaigns, lobbying, and other means, has caused critics to question whether this corporate personhood is helpful or harmful to democracy. In addition, some criticize the U.N.'s involvement with corporations at all, claiming that an initiative like the Global Compact provides an opportunity for what critics label "bluewashing," meaning that companies attempt to look good by using the U.N.'s blue-flag logo while continuing business as usual.

Despite these criticisms, the U.N.'s involvement with companies through the Global Compact has provided opportunity for many companies to learn how to better implement their own corporate citizenship practices. To enhance these efforts, the UNGC provides numerous opportunities for engagement among and between companies and with other stakeholders, for dealing with issues that companies are facing for which relatively little has been known in the past (for example, how to cope in situations of conflict), and for moving forward a broad agenda of corporate responsibilities that encompass the most universal and aspirational qualities embedded in globally accepted U.N. documents, which are the basis of UNGC's ten principles.

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See also Corporate Citizenship; CSR and CSR 2.0; Development, Sustainable; Equator Principles; Fair Trade; Human Rights; Stakeholder Theory; Social Enterprise; Transparency

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Water Use and Rights

United Nations treaties guarantee the human right to water. Although states must fulfill this human right and businesses must respect the state's obligation, approximately 900 million people around the world do not have access to safe drinking water. Despite growing awareness of the need for sustainable water use by companies, increasing global population and inequitable access to water will create controversy and lead to conflict.

All human beings are born with equal and inalienable rights and duties. The right to water is an implicit part of the right to an adequate standard of living and the right to the highest attainable standard of physical and mental health, both of which are protected by the International Covenant on Economic, Social and Cultural Rights, adopted by the United Nations in 1966. The human right to water is explicit in two United Nations human rights treaties: the Convention on the Elimination of All Forms of Discrimination against Women (1979) and the Convention on the Rights of the Child (1989). The Geneva Conventions (1949, 1977) guarantee the protection of this right during armed conflict.

The United Nations Committee on Economic, Social and Cultural Rights (CESCR) monitors the implementation of the International Covenant on Economic, Social and Cultural Rights, and in its General Comment 15 on the right to water in 2002, CESCR stated that "the water supply for each person must be sufficient and continuous for personal and domestic uses."

About thirty governments (including South Africa, Uruguay, and Ecuador) have explicitly recognized the right to water in their constitutions or national laws. These states have three types of obligations (World Water Council 2005):

- Respect: Government must refrain from unfairly interfering with people's access to water (for example, disconnecting their water supply).
- Protect: Government must protect people's access to water from interference by others and provide an effective remedy for those who are denied this right (for example, when third parties set unaffordable prices for access to water).
- Fulfill: Government must take all possible steps with available resources to realize people's right to water (for example, passing legislation and implementing programs to increase access to water and monitor progress toward achieving this right).

As such, this explicit recognition aims to ensure water for all and gives the poorest and most excluded consumers a voice to hold governments accountable for their obligations. In 2006, 93 percent of the population in South Africa had access to safe drinking water, according to the World Health Organization (WHO) and United Nations Children's Fund (UNICEF) Joint Monitoring Programme (JMP) for Water Supply and Sanitation (2008). Nevertheless, around the world approximately 900 million people currently do not have access to this right to water for drinking, personal sanitation, washing of clothes, food preparation, or personal and household hygiene (WHO and UNICEF JMP 2008).

The Role of Business

Those states that have recognized the right to water have a duty to ensure that everyone enjoys access without discrimination. While states have overall responsibility for ensuring that the right to water is realized, each individual state determines the manner in which services are provided, managed, or regulated to meet its obligations. The right does not prescribe the particular model for service delivery, the role of public and private sectors, or the role of civil society.

An emerging area of debate relates to whether water as a right is at odds with the view of water as profit: who guarantees the right when government confers water provision to a private company? When rights are in place and prioritized, are governments equipped to adequately regulate them? The Dublin Principles recognize that water has an economic value in all its competing uses and should be recognized as an economic good (International Conference on Water and the Environment 1992). A WHO and UNICEF cost-benefit analysis showed that every dollar invested in improved drinking water and sanitation services could yield economic benefits of four to thirty-four dollars (2005, 4). Managing water as an economic good is claimed to be an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources.

CESCR's General Comment 15 makes clear that having a right to water does not mean having a right to free water, but the water must be:

- safe (of adequate quality)
- accessible (within safe physical reach and affordable)
- sufficient (adequate, continuous, water supply for personal/domestic uses)

Some private water providers, including Suez Environment, have explicitly recognized the right to water: "We see progress towards universal access to water and sanitation as one of the raisons d'être of a private water operator" (Suez Environment 2007, 1). In addition, PepsiCo adopted a human-right-to-water policy for its domestic and overseas operations in 2009. The announcement committed PepsiCo to respecting the right to sufficient clean water, as well as individuals' rights to be involved in the development of processes that extract water from their communities (PepsiCo Inc. 2009). Such recognition is not just altruistic; it is also driven by the enlightened self-interest of a company that intends to operate over the long term. Consideration of water uses and water rights can decrease the costs of operations in water-scarce areas, increase profit margins, mitigate risks to operations (including social, economic, regulatory, and reputational risks), and ensure that communities give companies the social license to operate (Morikawa, Morrison, and Gleick 2007).

Thus, companies have legal and moral obligations to operate in ways that do not undermine the state's obligation to respect, protect, and fulfill human rights. John Ruggie, the United Nations special representative on the issue of human rights and transnational corporations and other business enterprises, has developed a framework that outlines the state's general duty to protect human rights and the responsibility of business to respect human rights (Ruggie 2008; Morikawa, Morrison, and Gleick 2007).

Raising Awareness of Unsustainable Practices

Concepts such as *virtual water*, *water footprints,* and *water offsetting* have been developed to discuss how domestic, industrial, environmental, and agricultural uses of water contribute to water stress or environmental impacts.

Virtual water (or embodied water) is a measure of the total water used in production of a good or service. For instance, one cup of coffee requires 140 liters of water to grow, produce, package, and ship the beans. That is roughly the same amount of water that an average person in England uses daily for drinking and household needs. Proponents of this concept believe that consumption will be cut, and sustainability will improve, if consumers are aware of how much water is used to produce everyday items.

Companies are using the *water footprint*—an indicator of the total volume of fresh water that is used to produce the goods and services consumed by an individual or community or produced by the business—to better understand water sustainability issues in their operations and supply chain. For instance, the water footprint of SABMiller's beers in South Africa and the Czech Republic has been measured as equivalent to 155 liters of water for every liter of beer (SABMiller and WWF 2009).

The *water-neutral* or *water-offset* concept (similar to that of carbon-neutral or carbon-offset) requires that individuals and corporations undertaking water-consuming activities make their activity "water neutral" by investing in water-saving technology, water-conservation or environmental-protection measures, wastewater treatment, and clean water supply to the poor. Such enlightened self-interest will contribute to the company operating over the long term. For instance, PepsiCo India is working to achieve a positive water balance by reducing water use in manufacturing plants, saving water through reuse and recycling initiatives, constructing rainwater-harvesting structures on manufacturing facilities, and implementing projects like the direct seeding of paddy fields in Punjab, Rajasthan, Tamilnadu, and Karnataka.

Concepts like virtual water, water footprints, and water neutrality or water offsetting might be useful for raising awareness—informing consumers of how much water is used in products and services—but conclusions drawn from such measurements often need clarification. It is necessary to assess products both for how much water they use and the impact on the country where they are produced. For example, a high-water-content item imported from a dry country should be rated worse than one from a place where water is abundantly available. If labeling products to inform consumers of the amount of water used in their production leads to boycotting, negative consequences for economic growth and poverty reduction could result. It remains to be seen whether these tools are attempts at corporate "bluewashing" (equivalent of greenwashing for the water and sanitation sector)—or whether concern for sustainable water use will remain a long-term business concern.

One potential mechanism to assist companies—both directly and through supply chains—in the development, implementation, and disclosure of water sustainability and sanitation policies and practices is the CEO Water Mandate. This public-private initiative was launched in July 2007 by the United Nations Global Compact, the government of Sweden, and a group of companies. As of 11 November 2009, it had fifty-eight signatories. The CEO Water Mandate expects industrial water users to make a commitment to water stewardship and to ensure that their activities have a favorable impact on the right of access to water (for example, undertaking a human rights impact assessment before setting up a facility; ensuring access to information and community participation; abiding by relevant laws, regulations, and policies; ensuring that wastewater and industrial byproducts are treated to minimize their impact on communities, aquatic systems, and water sources).

Controversies

Globally, roughly 10 percent of all water is used for domestic purposes, 20 percent is used for industrial uses, and 70 percent is used for agriculture. Changing certainty of water resource availability affects all water-using sectors—agriculture, hydropower, water supply and sanitation, and the environment.

Water Scarcity

While the global population is expected to rise significantly, accessible freshwater supplies are not. Inequitable access to water (both supply services and the natural resource) results in unmet water needs and causes economic, social, and environmental problems. In addition, it is expected to trigger conflict in and between countries. For example, as water scarcity becomes more apparent, instances of violence and conflict over water availability will increase at the global level and down—for example, in the Middle East region (Zeitoun 2008), in the country of Darfur (Tearfund 2007), and at the local level in the Sanjay Nagar slum in Bhopal, where family members who drilled a hole in a water pipe to collect water during a drought were murdered by angry neighbors who accused them of stealing water (Chamberlain 2009).

Sub-Saharan Africa is more at risk from water scarcity and water stress than other regions. In 2006, only 58 percent of the population of sub-Saharan Africa had clean drinking water (JMP 2008). And the United Nations Environment Programme (UNEP) estimates that by 2025, up to twenty-five African nations—roughly half the continent's countries—will suffer from a greater combination of increased water scarcity and water stress. Experts recommend that countries at the greatest risk of climate variability require significant investment in rainwater harvesting and water storage: yet Ethiopia has only 43 cubic meters of storage capacity per capita (World Bank 2009), less than 1 percent of the 5,000 cubic meters of storage capacity per capita of the United States and Australia (World Bank 2009). In Kenya, flooding in 1997 and 1998 cost the country 11 percent of its gross domestic product (GDP), while the drought in 1999 and 2000 cost the country 16 percent of its GDP. Better water storage could have prevented that drought from significantly affecting Kenya's economy (Malkiewicz 2008).

Industrial and Agricultural Uses

Without sufficient water, agriculture and industry are impossible. Agricultural development has the potential to increase economic growth, yet just 3.7 percent of arable land in sub-Saharan Africa is irrigated (compared with 26 percent in Asia) (UNECA 2003, 2). The Commission for Africa recommends a doubling of this area by 2015 to help poor farmers cope with rainfall variability and increase their productivity (2005).

In relation to soil, water, and agriculture, commentators refer to *blue water*, the water in rivers and streams, and *green water*—which accounts for two-thirds of water supply—the water that is in the soil and available to plants. Thus water access and water rights are often linked to land distribution. Yet this is a source of great inequity in many societies. Nine out of ten poor people in rural areas are smallholder farmers who depend on plots of less than two hectares for their food. And while women perform the majority of the world's agricultural work, they often do not have secure land tenure since customary laws often prevent women from inheriting land. The right to property, land reform, and small-scale agricultural improvements (such as drip irrigation) offer a solution to water stress and could play an important role in ensuring access to a dependable food supply.

Along with concern about developed countries using the water resources of some of the world's driest countries (manifest in measurement tools such as water footprints), more recently alarm has been raised about agri-colonialism—the acquisition of arable land and water by water-and-resource-scarce countries (for instance, those in the Middle East) in other more water-abundant countries (for example, Madagascar or Sudan) to ensure their own food security.

Similarly, beverage companies have been criticized for exacerbating water shortages in regions that suffer from water scarcity (Girard 2005). Extraction of groundwater for soft-drink and bottled-water production can compete with smallholder farmers' dependence on water for their livelihoods, in some cases leaving them unable to irrigate their lands and exposing poor households to the risk of losing their livelihoods. Complaints have also been made that these companies have contaminated groundwater, which further depletes the quantity of available usable water.

Traditional or Customary Users of Water

Customary law and customary water rights, particularly in rural areas and those countries where customary law constitutes a legitimate source of law, can also have a significant role in water resource management. Where water is scarce, the impact of inequitable distribution of water use and rights can be a cause of stress in communities. For instance, conflict may arise where official mechanisms for regulating the extraction and use of water resources through government permits or licenses conflict with customary practices. Moreover, conflict may result where access to safe drinking water for personal and domestic uses is prioritized over agricultural uses or where there are tensions between sedentary and nomadic pastoralists competing for water and grazing land.

Water is central to the well-being and survival of livestock, a key asset and often a source of income in many communities for providing traction power, manure for crop growing, and milk and meat for nutrition. In the case of a drought, nomadic and sedentary herders lose their livestock and their livelihoods, leaving them with no financial resources to acquire food.

Water, Food, and Energy Nexus

Almost 70 per cent of all available freshwater is used for agriculture. According to the United Nations Environmental Programme (UNEP), approximately 20 percent of worldwide water use is industrial (UNEP 2002). Increasing population will need more food and more electricity, meaning that two of the largest water users (water for agriculture and storage for hydropower generation—19 percent of the total electricity product, according to Walter Hauenstein [2005]) are in potential competition for a predictable supply. Investment in hydropower and irrigation has a clear role to play in fostering economic development. Yet economic development, industrialization, population growth, and rapid urbanization can, in turn, increase pressure on the quantity of available water and create tensions about how water is assigned to new urban and industrial development.

Sociocultural Activities

Water plays a role in many religious and cultural ceremonies or beliefs (for instance, the ceremony of baptism for Christians, the cleansing ritual of *abhisheka* for Hindus, and ablutions like *ghusl* and *wudu* for Muslims). Some cultures believe in water animism—that river water, lakes, and springs are living and possess souls. But there is still very limited understanding of how the use of water for cultural and religious activities fits within a rights-based approach (Zenani and Mistri 2005).

Transboundary Water

Conflicts over water in regions where water resources are shared between countries, such as those in the Nile Basin, have economic and political implications for food and water security in those river basins. Increasing cooperation and investment in the fair allocation of water resources will help reduce water scarcity and conflict and promote economic development. Yet questions remain about how to regulate, govern, and implement treaties aimed at managing cross-boundary resources.

Outlook for the Next Decade

The realization and implementation of the human right to water has yet to be evaluated for the improvements it has made to drinking-water supply in developing countries. Research is required to establish what the right means, the difference it makes to access, and the impact of context on the realization and implementation of the right. For instance, Article 25 of the U.N.'s Universal Declaration of Human Rights (adopted in 1948) acknowledged the following: "Everyone has the right to a standard of living adequate for the health and well-being of himself and his family, including food." Yet the 2008 Global Hunger Index stated that thirty-three countries, mostly in Africa, face a "grave" threat of hunger. Altogether the number of people chronically hungry worldwide rose from 848 million in 2007 to 923 million people in 2008—about one-sixth of the world's population (von Grebmer et al. 2008).

Right to Sanitation

One of the targets of the United Nations Millennium Development Goals (MDGs) is to halve the proportion of people without access to basic sanitation by 2015—that is, sanitation that prevents human contact with human waste. Yet in 2006, 2.5 billion people around the world did not have access to a basic toilet (WHO and UNICEF JMP 2008, 2). At the current rate of progress in sub-Saharan Africa, this target will not be met for another century. Lack of sanitation has implications for health, dignity, education, and economic growth.

Access to sanitation benefits the economy: studies have shown that for every dollar invested in sanitation, the economic return is nine dollars (WHO and UNICEF 2005). Lack of sanitation also has direct consequences for individual businesses: companies that do not provide accessible, sufficient, suitable, and separate sanitation facilities for men and women prevent employees from performing their jobs effectively and interfere with the employees' right to work in healthy and safe working conditions. Women are particularly affected by a lack of sanitation, especially during menstruation and pregnancy.

Water Use and Climate Change

The impacts of climate change for water use and water rights must also be considered. The Stern Review on the Economics of Climate Change (HM Treasury 2006) and the fourth Intergovernmental Panel on Climate Change (IPCC 2009) Assessment Report, published in 2007, both noted that the majority of the impacts resulting from climate change would be experienced through the impact on water. By 2025, it is estimated that 3 billion people will live in water-stressed countries—75 to 250 million in Africa alone (UNDP 2006). The Intergovernmental Panel on Climate Change estimates that by 2080 an extra 1.8 billion people—a quarter of the world's current population—could be living and dying without enough water. In just twenty-five years the glaciers in the Himalayas, which provide water for three-quarters of a billion people, could disappear entirely. And although not clearly attributable to climate change, El Niño events have become more common in recent decades, bringing droughts and heavy rain that result in flooding. Such water shortages, droughts, and floods result in damage to crops, livestock, infrastructure, and homes; increased drylands; lost biodiversity; declining water quality; changing patterns of pests and disease; and reduced economic growth.

Lower and more erratic rainfall together with water shortages will increase the difficulty of accessing safe drinking water and basic sanitation, especially for the poorest and most vulnerable people. This has serious implications for MDG targets to halve the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015. And its consequences for water use and water rights require further investigation.

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See also Agriculture; Climate Change Disclosure; Ecolabeling; Ecosystem Services; Energy Industries—Hydroelectric; Energy Industries—Wave and Tidal; Health, Public and Environmental; Human Rights; Public–Private Partnerships; United Nations Global Compact

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Z

Zero Waste

The term zero waste *dates from the 1970s, when chemists at the California company Zero Waste Systems Inc. collected, cleaned, and resold used chemicals from microchip and electronics manufacturers. In 1996, Canberra, Australia, became the first city in the world to enact a zero waste law requiring the government to produce "no waste by 2010." The zero waste movement hopes to live up to its name with a combination of community actions and market-based approaches and legislation.*

The zero waste principle, which has proponents worldwide, assumes that waste is not intrinsic to human activities and that many forms of waste—solid waste, hazardous waste, administrative waste, waste of efficiency, waste of energy, waste of human resources—can be removed from the processes of human society. Most often, the term *zero waste* applies to material waste—for example, the 254 million tons of garbage generated in the United States in 2007, of which only 85 million tons were recycled (US EPA 2008). A zero waste strategy seeks to move from an industrial system that requires a solution to the problem of waste disposal to a system that focuses on efficient resource management from the beginning to the end of a process. A strategy for eliminating material waste might involve better industrial design, the use of recycled or reused raw materials, reduced packaging, conscientious consumption, reusing materials, and composting or recycling any materials that cannot be reused. The success of such an approach requires the participation of suppliers, manufacturers, distributors, consumers, municipalities, waste management companies, and recyclers; for this reason, many zero waste advocacy groups call for immediate action by lawmakers.

The Fourth R: Responsibility

Most people are familiar with the three Rs—reduce, reuse, recycle—but zero waste strategies call for a fourth R—responsibility. In the system that exists throughout most of the United States, for example, the responsibility of the manufacturer ends when a product reaches the retailer; individual responsibility ends with separating recyclables from trash; community responsibility ends with meeting regulations for landfilling or incineration. In a zero waste model, a producer's responsibility begins with product design and continues through the end of the product lifecycle. The responsibilities of individuals and communities are likewise extended.

Industrial Responsibility

A zero waste strategy requires industry to pursue three important developments: design for sustainability, clean production, and extended producer responsibility.

According to Eco-Cycle CEO Eric Lombardi (2001), "recycling is only an end-of-pipe solution to a problem that has its beginning at the front end of the pipe . . . on the designer's desk." Reducing constituent materials in a product or its packaging keeps those materials out of the product lifecycle stream; it also saves the energy that would have been used to produce, process, and recycle the eliminated materials. Products can be designed using materials that are easily reused or recycled (and use materials that have already been used or recycled), and they can be designed to last longer. Some manufacturers have found that by recovering and reusing parts and materials in their products that they can save money on disposal and production costs. Xerox Corporation in Europe, for example, used the same trucks that took their machines to sixteen different countries to collect old machines. These were taken to warehouses in Venray, the Netherlands, where the machines were stripped down. In 2006, the company recovered 96 percent of the equipment material as either reusable parts or recyclable materials; in total, Xerox's reuse, recycling, and remanufacturing initiatives have diverted more than 2 billion pounds of waste from landfills and saved the company $2 billion between 1991 and 2007 (Environmental Leader 2007).

Manufacturing processes in a zero waste model would also be redesigned to eliminate the waste of unused raw materials or materials used in the processes (such as chemicals, cleaning fluids, and water). In the 1970s, for example, chemists at the California company Zero Waste Systems Inc. (the first public use of the term *zero waste*) collected solvents and other "used" chemicals from microchip and electronics manufacturers, removed contaminants, and resold the chemicals. In 2008, forty-three General Motors plants were "landfill-free," recycling or reusing 96 percent of scrap materials and converting 3 percent to energy; the sale of scrap metal generated close to $1 billion in revenue for the auto manufacturer (Sustainable Life Media 2008). Subaru's Lafayette, Indiana, plant was the first auto assembly plant to achieve landfill-free status by reusing or recycling 99.3 percent of its excess materials (Subaru of America 2009).

Hazardous Substance Reduction

A zero waste plan would also require manufacturers to eliminate hazardous substances from products and processes. This includes toxic metals such as lead, cadmium, and mercury (which have no known biological use); compounds containing the problematic elements chlorine, bromine, and fluorine (also known as halogens); and air pollutants, such as carbon dioxide, carbon monoxide, sulfur dioxide, and nitrogen dioxide (as by-products of production activities, and through the use of electricity generated from fossil fuels). Many electronics manufacturers, for instance, have been using brominated flame retardants (BFRs) and plastics made from polyvinyl chloride (PVCs) in their products, which are precursors to carcinogenic dioxins and furans. The formation of these toxic compounds is even more likely when electronics are incinerated. In 2006, Apple Inc. issued a specification to its supply chain, restricting concentrations of bromine and chlorine to less that 15 parts per million (ppm) (with the exception of external power supplies) and eliminated mercury from many of its LCD displays; Sony Ericsson produces phones that are 99.9 percent halogen free and requires its suppliers to declare all compounds used in their products (Nimpuno, McPherson, and Sadique 2009).

Extended Producer Responsibility

Extended producer responsibility (EPR) or product stewardship means that manufacturers take responsibility for a product through its entire lifecycle—including packaging materials and any materials leftover after the product is used. EPR might come in the form of a product take-back program, in which the manufacturer collects excess materials and used products from consumer and recycles, remanufactures, or reuses them. Many toner producers, for instance, provide a label for mailing back a used toner cartridge in the same packaging with a new cartridge. Such programs, whether voluntary or enforced by law, encourage producers to design products and packaging with the end of the lifecycle in mind.

Another form of EPR policy requires the manufacturer of a product to pay for its disposal. Such policies create incentive for the producer to reduce waste and design products for ease of reuse or recycling. The state of California's bottle bill, for example, requires beverage manufacturers to pay a fee equal to the difference between the cost of recycling a container and the value of the scrap material recovered from the container; hence manufacturers can cut costs by making bottles and cans that are easier to recycle. While such policies associate a cost with waste, they do not require manufacturers to develop an infrastructure for handling postconsumer materials.

Community Responsibility

Community responsibility begins with source separation and door-to-door collection systems. This varies from the once-a-week collection of three containers in San Francisco, to the four containers used in some cities in Italy, where the collection of specific containers takes place on different days of the week.

In these systems one container is used for kitchen waste, one or more for recyclables, and a third for the remainder, or residuals. The container for the organics, especially kitchen waste, is the most important division. On the street, organic materials cause odors; in landfills they generate methane and leachate, or noxious liquid leached from the landfill.

Perhaps the most important reason to collect clean organic waste—compost—is that it is needed by farmers to replenish their soils of depleted nutrients. Composting also has a distinct advantage over incineration. Composting reduces the global warming involved in the production of synthetic fertilizers and sequesters (i.e., isolates and stores) the carbon in wood and other cellulosic fibers, thereby delaying the release of carbon dioxide. With incineration the conversion of cellulose and other organic material to carbon dioxide is immediate.

Individual Responsibility

Product take-back programs and community recycling/composting initiatives work best when consumers willingly participate. Unfortunately many consumers have become used to the ease of tossing used products in the trash; to ensure widespread participation, zero waste programs must either require very little additional effort on the part of the consumer, offer incentives for those that participate, or penalize those who do not. Laws that offer an incentive for participation, such as the return of a deposit on beverage containers, have worked particularly well. Seven of the eleven U.S. states that passed bottle-bill laws have found at least a 30 percent reduction in the total amount of litter (Container Recycling Institute 2009), which presumably indicates that more bottles and cans were being recycled. Some communities have begun charging a fee for collecting more than a specified amount of trash from a household.

Incineration Versus Zero Waste

Incineration converts three to four tons of trash into one ton of ash that nobody wants. The zero waste strategy, when implemented, converts three tons of trash into one ton of compostables and one ton of recyclables. A combination of composting and recycling saves three to four times more energy than the amount of electricity generated by an incinerator (incinerators generate steam that is then used to drive a turbine to produce electricity). One report from Europe indicates that a combination of composting and recycling produces forty-six times less global warming gases per ton of waste processed than that generated by an incinerator producing electricity; figures vary along with materials. For example, recycling PET plastic (commonly used in disposable water bottles) saves twenty-six times more energy than burning it (David Suzuki Foundation et al. 2005, 1).

For local economics, the zero waste strategy is cheaper and produces more jobs than incineration does. Moreover, the money spent on the program stays largely in the local community, whereas a lot of the money spent on the incinerator leaves the community.

Recyclables

Under the zero waste strategy, recyclable materials go to material recovery facilities, of which there are hundreds of successful examples around the world. Their function is to separate paper, cardboard, glass, metals, and plastic and to prepare them to meet the specifications of the industries that will use these secondary materials to manufacture new products. Some of these plants are built to handle a single stream of mixed recyclables; others deal with two streams, for example, paper products in one stream and bottles in the other.

Because of their high employment demands and economy of scale, these plants are best located in large cities, which are usually more conveniently located to industries that can use the secondary materials. This sets up an ideal partnership between urban and rural areas: cities export their organics to the rural areas, and the rural areas transfer their recyclables to the cities.

Reuse, Repair, and Retraining Centers

Another important reduction strategy is the establishment of reuse, repair, and retraining facilities. There are many successful examples of such operations running as either for-profit or nonprofit entities. An example of the former is Urban Ore in Berkeley, California, which has been running for more than twenty-five years. It grosses nearly $3 million and employs more than thirty full-time employees. The company accepts anything reusable and lays out the goods like in a department store. The company pays donors for valuable items, but usually people are happy to see their secondhand appliances and furniture used again and not simply crushed and sent to a landfill or burned in an incinerator.

This type of operation works because reusable items are valuable. Recyclables are high volume and low value; reusables are low volume but high value. Reuse and repair centers will thrive financially as long as there are people who enjoy searching for a bargain. A very profitable part of this operation is the section set aside for building materials (timber, bricks, bathroom fittings, doors, and windows) that come from deconstruction or renovation of old buildings. Increasingly, builders drop off their recovered materials and pick up reusable items for new projects.

Deconstruction

Going hand in hand with reuse and repair operations is the deconstruction—as opposed to demolition—of old buildings. Deconstruction takes longer but yields more employment opportunities and valuable materials. In some cases recovered materials, such as doors and windows, can be reused as they are. In other cases materials, such as lumber, can be used to make new items, such as furniture. This stimulates the development of other businesses. An example is Renovators Resource in Halifax, Nova Scotia, which sells beautiful furniture made from materials ranging from old window frames to church pews.

Another niche industry created from the notion of fighting waste comprises businesses that offer to reuse and recycle the items and materials yielded by the renovation of hotels and office buildings. Often such renovations produce a pile of rubbish in containers outside the building. These niche companies remove the items in a careful way to minimize damage and contamination and thereby relieve the building manager of finding a home for these objects and materials.

After removing the recyclables and compostables, maximizing waste reduction initiatives, and stimulating the reuse and repair of objects and deconstruction, the residual fraction remains. Currently the residuals in most communities are sent either to a landfill or an incinerator, but in the future the zero waste strategy envisages that they will be sent to a "residual separation and research center" (see below). But first, more effort must be made to reduce this residual fraction.

Reducing the Residuals

The separation of clean organics and marketable recyclables can help lead to a sustainable future, but residuals do not. Residuals are the many unnecessary, unrecyclable items—especially packaging—of the modern world. As these pile up in landfills, more governments and private enterprises are taking steps to reduce their use and production.

In Ireland, for example, the government in 2002 introduced a fifteen-cent tax on each plastic shopping bag used in shopping malls. Within one year, this measure reduced the use of these bags by 92 percent, and the other 8 percent put more than 12 million euros into funds for other recycling initiatives (Rosenthal 2008). In Australia some eighty towns have banned the use of plastic shopping bags (Lowy 2004). In some supermarkets in Italy, dispensing systems allow customers to reuse their own containers for various liquid items (water, milk, wine, shampoo, and detergents) as well as solid items such as grains and cereals. In addition, at one such market, Effecorta in Capannori (which opened in 2009), 95 percent of the merchandise is produced within 70 kilometers of the store.

Pay-by-Bag Systems

The pay-by-bag system encourages citizens to maximize the diversion possibilities by penalizing the production of residuals. Typically, recyclables and compostables are picked up free or at a flat rate (sometimes absorbed in local taxes), but an extra charge is applied to residuals. In some communities the residuals are weighed; in others, stickers are purchased to place on each bag placed on the curb, or special plastic bags have to be purchased. This simple fiscal step has led to significant reductions in many areas.

Residual Separation and Research Facilities

In the zero waste strategy, residuals are sent to a residual separation and research facility, not directly to a landfill. In a separation facility, the contents of garbage bags are dumped onto a conveyer belt, where more organics, recyclables, and toxics are separated from the residuals. The remaining materials are shredded to reduce the volume entering the landfill (and biologically stabilized to prevent the generation of methane).

In a zero waste system, researchers would collect information about the common residuals to drive further changes in product design. A research facility inserted into a residual screening facility would have several advantages. First, it would provide vital information regarding waste to industrial designers, linking the front end—design—to the back end—waste disposal—of the product lifecycle. By focusing on reducing waste and making products easier to reuse or recycle, such research would reduce reliance on incineration and other less-than-ideal waste management strategies. Combining research with residuals separation also integrates higher education into the process, framing zero waste as an important and achievable step toward sustainability. In February 2010, a residual separation and research facility opened in Trapani, Sicily, and on 23 January 2010, Capanorri (in Tuscany) announced the opening of Zero Waste Research Center.

Traditionally the approach to resolving the problems posed by landfills has been to apply more sophisticated engineering in an effort to contain both gaseous and liquid effluents (leachate). This has involved daily cover, methane capture, and lining and leachate collection systems. The goal has been to control what comes out of landfills regardless of what is put into them; the zero waste approach sets out to control what goes in. With this screening approach, new landfills will be smaller than raw waste landfills and safer than incinerator ash landfills.

Hurdles to Zero Waste

In 1996, Canberra, Australia, became the first city in the world to enact a zero waste law. The law required the government to produce "no waste by 2010." By 2003 it was achieving almost 70 percent diversion (Australian Government 2006), but this figure was largely influenced by the huge diversion of both yard waste and heavy building and construction debris. The program established a "resource recovery park" in an effort to colocate all the industries that make products of separated materials as well as those marketing resusable items.

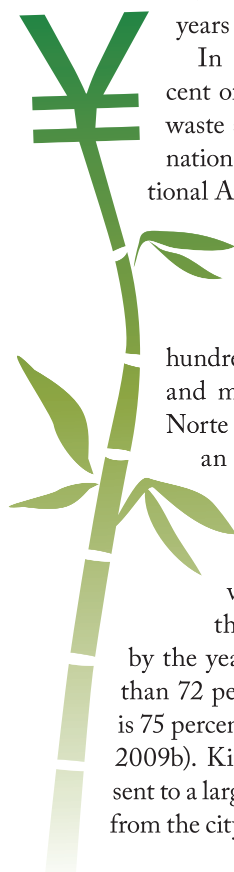
Of late the program unfortunately has run into some setbacks. In 2008, the diversion rate fell to 73 percent, from 76 percent the previous year (Violante 2009). This prompted Canberra's chief minister Jon Stanhope to announce in January 2009 that the 2010 goal would "never, ever, be achieved" (Violante 2009); an increase in the quantity of landfill waste per capita might explain the failure. But Gerry Gillespie of the New South Wales Department of Environment and Conservation argues that the problem may have emanated from the waste management industry—by sending 200,000 tons to landfills instead of 100,000 tons, the waste management contractor earns upwards of $300,000 a year (Gillespie 2009).

Zero waste initiatives also can be hindered by a slow economy. From late 2008 to early 2009, the U.S. prices of raw materials dropped dramatically—the price paid for a ton of paper, for instance, dropped from $105 to $25 in a six-month span (Szczepanski 2009). This was a tough blow to companies and municipalities that relied on revenues from the sale of recyclable materials. Los Angeles County's Sanitation District was forced to cut hours, which led to thousands of pounds of recyclables being diverted to landfills (Szczepanski 2009). Eureka Recycling, a nonprofit firm contracted by St. Paul, Minnesota, requested a $500,000 increase to its contract with the city, which company officials said was necessary for the firm to stay in business (Smetanka 2009). But these may be isolated cases; strict contracts with municipalities and a premium on landfill space should deter most contractors from dumping recyclables into landfills (Szczepanski 2009).

Successful Zero Waste Initiatives

In Nova Scotia in the late 1990s, a citizens' initiative adopted a plan prepared by a consulting firm from Seattle that involved source separation and door-to-door collection of recyclables, organics, and residuals. The citizens made two changes to the original plan. First, everywhere the written plan used the word *waste* they changed it to *resources*. In addition, because of bad experiences with landfills, the citizens required that no organic waste go into the landfill without processing. This drove the construction of residual screening facilities. After five years the province had achieved a 50 percent diversion rate and became the first province in Canada to do so (Webb 2001). In the process, 1,000 jobs were created collecting and treating the discarded materials (Greene 2001). Nearly all the separated materials are reused in Nova Scotia's own industries. The program has been the subject of a genuine progress index analysis, which, unlike other indices such as the gross national product, includes estimated social benefits. The result of this analysis is hugely positive, largely driven by the social consequences of generating so many new jobs.

Other Canadian communities have followed Nova Scotia's example. Prince Edward Island has door-to-door collection of recyclables and compostables for every household on the island. The city of Markham (north of Toronto) has diverted 70 percent from its landfill in two years (Flaherty 2009).



In New Zealand, more than 66 percent of communities have declared a zero waste strategy, a program endorsed by the national government (Zero Waste International Alliance 2008).

In California, since the passing of a state law requiring communities to divert 50 percent of their trash from landfills by the year 2000, hundreds of towns and cities have achieved and many have exceeded this goal. Del Norte and Almeida counties have declared an active zero waste strategy (Zero Waste International Alliance 2008).

San Francisco, with an estimated population of around 850,000 and very little space, is among the cities that have adopted a zero waste goal by the year 2020. The city now diverts more than 72 percent of its trash; its target for 2010 is 75 percent (City and County of San Francisco 2009b). Kitchen and other organic wastes are sent to a large composting plant about sixty miles from the city. The site is surrounded by farmland,

and local farmers use the compost to produce fruit, vegetables, and wine, which are sent back to San Francisco. A large fraction of the kitchen waste in San Francisco comes from restaurants and hotels, and the city has a team of workers educating kitchen staff to optimize their collection of clean material. The restaurants and hotels have an incentive to do this: as of 21 October 2009, the city passed the Universal Recycling and Composting Ordinance, which can result in a fine of up to $1,000 for property owners who fail to separate compostables, recyclables, and trash (City and County of San Francisco 2009a).

Italy has pioneered some of most cost-effective and rapidly applied door-to-door collection systems in the world. The program began when farmers approached the Agricultural School in the Parco Monza, near Milan, and asked where they could get more organic material for their soil. They found out that there was plenty of organic material in the domestic waste stream, but it could yield compost good enough to use in agriculture only if it were collected separately at the source. This would necessitate door-to-door collection. Thus begun the very popular *porta-a-porta* collection system in Italy.

In February 2007, Capannori, near Lucca, became the first community in Italy to formally declare a zero waste strategy. In 2009, the town reported a recycling rate of 82 percent, saved over 2 million euros in disposal costs, and earned 340,000 euros from paper recycling (Zero Waste in Caponnori 2009). The Val di Fiemme region, a collection of eleven villages in the Italian Alps, averaged an 82 percent diversion rate in 2008 (Yepsen 2009, 39). The municipality conducted audits on the remaining 18 percent and found that disposable diapers made up the largest portion of the remaining material. The community began sending out compostable wipes and reusable diapers to parents of newborns. In Piedmont's Villafranco d'Asti, a community of 30,000 has reached a diversion rate of 85 percent.

Outlook for the Twenty-First Century

A zero waste society is an ambitious goal, but not impossible; it would require radical changes in the actions and attitudes of individuals, communities, states, nations, and corporations. Zero waste initiatives have been successful in some communities and some corporations, and those examples may encourage more to follow. Even though Canberra did not meet its goal, the city's diversion rate went from 22 percent in 1996 to 73 percent in 2008 (Violante 2009), and its difficulties may steer other municipalities away from the same mistake. Whether or not zero waste is ultimately achievable, setting the bar at zero encourages a philosophy of continual improvement, in which no amount of waste is considered acceptable.

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The EDITORS

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See also Chemistry, Green; Consumer Behavior; Design, Industrial; Energy Efficiency; Facilities Management; Lifecycle Assessments (LCAs); Municipalities; Packaging; Remanufacturing

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