be extremely cost effective: When tradable air pollution permits were introduced to control sulfur emissions (precursors of acid rain) in the United States, emission reductions were achieved at about half the cost that analysts had predicted before the system was implemented.

The Kyoto Protocol, an international treaty aimed at reducing global warming, seeks restrictions on carbon-dioxide emissions. It also calls for trade in emissions. A company that is more efficient than the standard will be able to sell its excess credits to less efficient companies. Thus, an incentive is provided to all companies to install means to reduce their emissions.

In the case of electric power plants, with a credit program, energy companies with "dirty" power plants can buy the right to exceed pollution standards or install new equipment to cut emissions. Pollution has declined because the total allowances available add up to substantially lower emissions than before the program started, while each company gets to map its own strategy for meeting its limits.

8.4 Innovation and Environmental Sustainability

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Since the industrial revolution, economic development has been based on two rather convenient assumptions: (1) that the resources of the earth are available in unlimited supply as inputs to production and (2) that the environmental damage caused by firms, industries, and nations in their pursuit of wealth has no economic significance. Clearly, in these enlightened times the falsity of such assumptions can no longer be ignored. In this section I propose that the self-serving assumptions of the past can be supplanted by pro-growth/pro-environment strategies enabled by the power of human creativity and innovation.

The World Commission on Environment and Development has defined **sustainable development** as economic growth that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (Esty, 1994). From a less human-centered perspective, sustainable development implies that the rates at which we consume resources and create pollutants must be controlled in such a way that economic growth can continue indefinitely without causing irreversible environmental damage. (For further discussion, see OECD, 1997b.) Fortunately, such a balance is achievable: The natural environment has a powerful capacity to cleanse itself. Although the ecosystem of Prince William Sound, for example, has been irrevocably altered by the *Exxon Valdez* disaster, life has returned, and its former beauty has largely been restored.

Economically speaking, environmental damage from industrial activity is a negative externality that, in cases such as global warming, can create unde-

sirable spillovers to every corner of the planet. These negative spillovers are perpetuated by the fact that environmental costs are not accounted for in business transactions. This market failure causes producers to have no financial incentive to reduce waste or eliminate emissions. In the absence of either effective government regulation or countervailing market forces, shared resources such as lakes and rivers, the atmosphere, rain forests, and fossil fuels will be subjected to unrestrained use by profit-seeking individuals. If left unchecked, the inevitable result will be environmental tragedy. Fortunately, however, the environmental debate progressed during the 1990s from the anti-industry, antiprofit, and antigrowth rhetoric of radical environmentalism to the realization that business must play a central role in achieving the goal of sustainable development (Elkington, 1994, p. 91).

There are two general approaches to engaging industry in the battle to save our environment: either through government regulation or market-driven technological innovation. Unfortunately, the costs of government-mandated protection measures such as the "polluter pays" principle can be high, and it is hard to find a politician who would willingly impose such a steep bill on domestic industries. Yet without some reasonable safeguards, there is no guarantee that increased wealth will make people better off in the future. Unrestrained development can make society richer, but at what point does the degradation of our surroundings and the risks to our health render growth in per-capita income sadly irrelevant?

In an ideal world, one might imagine that altruism alone would drive companies to innovate new ways to conserve resources and reduce harmful emissions. Given the competitive realities of global commerce, however, it seems unlikely that solutions will be put forward without a suitable economic incentive being provided by government. In fact, I suggest that the most optimistic scenarios for sustainable development involve synergistic innovations in both regulatory policy *and* environmentally friendly technologies. Governments can provide creative economic incentives that will induce industries to innovate, while the actual methods and technologies used to capture these incentives would be left to the discretion of industry. Such a partnership between the public and private sectors would reduce the potential economic hardship that could result from targeted environmental policy, while catalyzing industrial innovation through the allure of profit maximization.

From a policy perspective, the most problematic environmental concerns are those that impact common resources, with global warming being the most prominent among these issues. (For a broad overview of the issue of global warming, see Read, 1994.) Both the atmosphere and the greenhouse gases being emitted into it are common to everyone on the planet, yet it is in no country's best interest to take unilateral action. Indeed, such action would be fruitless: Even if the United States reduced its substantial greenhouse gas emissions to near zero, the rate of atmospheric degradation over the long term would hardly be affected. It is only through multilateral

action by both advanced and developing nations that further destabilization of the earth's climate can be avoided (Schelling, 1997).

From the viewpoint of industry, the range of attitudes toward environmental protection is striking, with energy-intensive sectors typically giving the cold shoulder to the implementation of multilateral environmental agreements. This position has been taken to an extreme by some self-interested industry leaders, whose antiregulation rhetoric sounds disconcertingly similar to the "scientific" propaganda of major cigarette manufacturers during the 1970s and 1980s. Capitalizing on the indeterminate results of scientific investigations into global warming, influential leaders such as Exxon Corporation's chairman Lee Raymond have campaigned both domestically and in developing nations for a 20-year moratorium on greenhouse gas controls, ostensibly to give science sufficient time to "thoroughly understand the problem." A sensible counterpoint to this cynical perspective has been offered by John Browne, the chief executive of British Petroleum: "The time to consider policy dimensions of climate change is not when the link between greenhouse gases and climate change is conclusively proven, but when the possibility cannot be discounted and is taken seriously by the society of which we are a part" ("Exxon Urges . . . ," 1997).

In December 1997, a global-warming treaty was forged in Kyoto, Japan, by negotiators representing 159 nations. According to the so-called Kyoto Protocol, the United States is required to reduce its emissions of greenhouse gases by the year 2010 to a level that is 7% below domestic emissions in 1990. European nations are assigned a target of 8% below their emissions in that same year, while Japan somewhat reluctantly agreed to a target reduction of 6%. To meet the goals of the Kyoto Protocol, the United States will have to reduce emissions of carbon dioxide, carbon monoxide, methane, and other carbon-based gases by roughly one-third of the current projections for U.S. output of these gases in 2010. (For additional discussion of the Kyoto Protocol, see Coppock, 1998.)

One of the most promising policy innovations resulting from the Kyoto meeting was a recommendation that an international market be established in **emissions credits**. The concept is simple: Nations whose firms reduce their emissions below a specified level can sell their excess reductions to firms in nations that are over their limits. In this way, market forces can be engaged in the battle to control global warming. In a speech to Congress, Senator Robert Byrd stated that "reducing projected emissions by a national figure of one-third does not seem plausible without a robust emissions-trading and joint-implementation framework" (Swift, 1998, p. 75).

The international trading of emissions credits allows firms and nations alike to reduce their output of carbon-based gases in the most economically efficient way. Under such a regime, firms would have the flexibility to select the most efficient methods for achieving their emissions targets, either through immediate action or by purchasing credits from other firms or nations until an optimal improvement plan could be implemented. Command-and-

control policy measures that force firms to adopt "quick-fix" solutions can be suboptimal in terms of the cost to firms and, more important, in terms of overall effectiveness. If firms are given time to implement the most efficient and cost-effective innovations, the economic impact of emissions reductions can be dramatically reduced ("Global Warming . . . ," 1998).

The trading of emissions credits between nations can result in far greater economic efficiency, since the cost of reducing the emissions of advanced manufacturing processes in the North can be as much as 10 times higher than the cost of the same improvement in the South. In a credit-trading system, firms in the United States that buy emissions credits from China, for example, would essentially be subsidizing the modernization of China's energy-related industries. Since all emissions are equivalent from a global perspective, this could be a far more cost-effective solution than attempting to make incremental improvements at home. An international "commodity market" in emissions credits would allow the market price for these credits to approach the marginal cost of emissions reductions worldwide. Assuming that the transaction costs are kept low, credit trading would provide an efficient economic incentive for firms to innovate environmental solutions.

There is an excellent recent example of the synergy between the incentive provided by credit trading and the power of technology to reduce environmental damage. In 1990, the U.S. Acid Rain Program was created with the goal of halving the emissions of sulfur dioxide by domestic utilities. According to a study by the Government Accounting Office, this credit-trading system has decreased the cost of pollution reduction to half of what was expected under the previous rate-based measures, and well below industry and government estimates. Moreover, by 1995, one-third of all utilities that complied with this measure did so at a net profit, due to innovations that yielded unforeseen savings upon changeover to low-sulfur coal (Swift, 1998, p. 77).[1]

Fortunately, government policy is not the only source of economic incentives; the marketplace offers a price premium for many environmentally safe products, potentially offsetting much of the recurring costs associated with these socially responsible strategies. There has been a surprising shift in the preferences of consumers in recent years toward environmentally friendly products, a movement that is often referred to as the "greening of the marketplace." Ultimately, such ethical consumers may have the final word in global environmental protection, by insisting on high standards of corporate citizenship. Programs such as eco-labeling provide an opportunity for firms to advertise their social responsibility, while imparting a "green tinge" to their corporate brands. The development of so-called **green products** is an

[1]The U.S. Acid Rain Program is a notable model of a broader multilateral credit-trading scheme for another reason. The use of high-quality monitoring, the implementation of a public allowance tracking system, and the imposition of steep penalties have led to 100% compliance among U.S. utilities. Similar tough enforcement regimes will be needed to avoid rampant cheating on any multilateral global warming agreement.

example of how a pull from the marketplace can spur environmentally friendly innovations. The two complementary goals of green design are (1) to prevent waste, by reducing the weight, toxicity, and energy consumption of products, and by extending their service life; and (2) to improve the management of energy and materials, through techniques such as remanufacturing, recycling, composting, and energy recovery (OTA, 1992).

Many companies have already adopted corporate-level environmental strategies. Techniques such as voluntary environmental audits and product life-cycle impact analyses are the first steps toward integrating environmental costs into the core strategies of firms. Guidance for enterprise-wide management of environmental issues is provided by global standards such as the International Standards Organization's ISO-14000 series. Those firms requiring outside expertise will find that there is no shortage of consultants available, spanning all aspects of environmental protection.

Restoration of the earth's environment will offer tremendous innovation opportunities well into the 21st century. The market for environmental products and services is expected to reach $300 billion by 2000 (Elkington, 1994, p. 67). According to one estimate, 40% of global economic output in the first half of the 21st century will be derived from environmental or energy-linked products and technologies (OECD, 1997a). U.S. firms currently hold an edge in important nonpolluting energy technologies, including reliable solar power, gasoline alternatives based on agriculture, zero-emissions fuel cells, and so on. (For more information on environmentally critical technologies, see *World Resources Institute Annual Yearbook,* 1992.)

Once market forces begin to act on problems such as global warming, the profit incentive will fuel the creative fires of entrepreneurs and innovators, potentially yielding faster-than-expected emission reductions. A decade ago, an international negotiating team met in Montreal to establish a protocol for eliminating the use of chlorofluorocarbons (CFCs), the compounds linked to depletion of the earth's ozone layer. At that time, both government and industry predicted an economic catastrophe. Instead, CFC emissions have declined so rapidly that replenishment of the ozone layer now is expected to occur early in the 21st century. Much of this tremendous progress was the result of a skillful realignment by the manufacturers of air conditioners and refrigerators to non-ozone-depleting refrigerants, a transition that went virtually unnoticed by consumers ("Hot Air Treaty," 1997).

The ethical use of technology, coupled with responsible action on the part of industries and governments, can simultaneously raise both the quality of life *and* the quality of the environment throughout the world. If we can all learn to cooperate toward such a goal, the effects could be significant within our lifetimes. Thus, the human capacity to invent, adapt, and solve intractable problems represents our greatest hope in the battle to save the natural world.