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CHAPTER 6

The Economy and the Environment

ECONOMIC PROSPERITY and environmental quality are widely regarded as two of this Nation's most important goals. Some view these as competing goals and argue that economic growth begets environmental degradation. Increasingly, however, this conventional wisdom is being questioned, and a new consensus is emerging that economic growth and environmental quality need not be incompatible. Indeed, economic growth and environmental quality are in many respects complementary. For example, economic growth provides the opportunity for firms to invest in new facilities that are cleaner and more efficient. It is no coincidence that the wealthy societies are the ones that are both willing and able to devote substantial resources to environmental protection.

Compatibility between economic growth and environmental improvement is far from automatic, however; it depends on selection of appropriate goals and careful design of regulatory programs. Environmental goals must balance the associated benefits and costs. The public interest is best served when government provides a framework that creates incentives for the private sector to seek out the most cost-effective way to meet its regulatory goals. Government should *not* be in the business of picking environmental protection technologies and imposing them on firms, their workers, and their customers.

This chapter presents the Administration's principles for environmental regulation and illustrates how they can be put into action to address local, national, and global environmental concerns. The consistent application of these principles will ensure that this Nation's considerable investment in environmental protection—$81 billion in 1987, about the same as all American households' electricity and natural gas utility bills—will be made in ways that help to achieve *both* a strong economy *and* a healthy environment.

PRINCIPLES FOR ENVIRONMENTAL REGULATION

Market-based economies do not automatically provide the level of environmental quality that consumers desire. Understanding why environmental protection may require government action leads to an understanding of policies that best serve both the economy and the environment.

MARKET FAILURE

Environmental problems arise in market economies when private individuals and businesses lack incentives to take full account of the environmental consequences of their actions. These market failures, which provide a rationale for government action, can be traced to three sources.

First, individual producers or consumers who pollute the environment generally do not pay for their pollution, even though it may harm others or cause others to incur additional costs. Excess pollution results, just as free electricity would lead firms and households to use electricity without regard to the resources used to produce it.

Second, no single individual can produce tangible evidence of an overall improvement in environmental quality by his or her own actions to reduce or control pollution. When there are some costs and no apparent payoff for individual cleanup effort, rational individuals may be unwilling to act, even in cases where a coordinated effort would yield environmental benefits that exceed the costs of collective action. This problem is analogous to that faced by a stadium full of standing football fans who would all be happier to see the game sitting down if only their actions could be coordinated.

Finally, the private market does not always produce the information needed to solve public problems. Private firms typically do not realize profits from research and development aimed at understanding environmental processes or the relationship between pollution and human health. Government action is often necessary to produce such information to further public policy objectives.

Regulations can also be motivated by factors other than the market failures outlined above. Paternalism, the belief of legislators and regulators that they can improve citizens' overall welfare by taking certain choices out of their hands, can play a significant role. Because the diversity of individual choice generally reflects differences in tastes, needs, and situations among individuals, paternalistic regulation is much more likely to reduce overall well-being than to increase it. Another motive for regulation is the pursuit of private advantage, which can be reflected in the specific design features of regulations that may be broadly grounded in public interest consideration. For example, firms routinely seek to keep their existing products and facilities under the current regulatory regime when more stringent regulations are implemented for new products and facilities.

ENVIRONMENTAL REGULATION

The Federal Government's involvement in environmental protection is relatively recent. The Congress first enacted major legislation between 1970 and 1980. Many environmental programs enacted in this era rely heavily on an approach referred to as command-and-control regulation. Alternative regulatory schemes that use market incentives to further environmental goals, such as emissions charges or tradable emissions allowances, can serve both the environment and the economy by reducing the costs of environmental protection (Box 6–1).

Box 6–1.—A Glossary of Environmental Regulation Terms

Command-and-Control Regulation—a system of administrative or statutory rules that requires the use of specific control devices on classes of selected pollution sources or applies emissions standards to narrowly defined pollution sources.

Emission Standard—a limit, usually expressed as a maximum allowable emission rate, applied to an individual pollution source.

Emission Charge—a fee levied by the government on each unit of pollutant emitted.

Tradable Emission Allowances System—a regulatory regime in which all sources of pollution are required to hold allowances for all emissions of covered pollutants. The government distributes a number of allowances equal to the target emissions level, which can then be freely bought and sold within the private sector.

In the final decade of this century, new environmental issues that include stratospheric ozone depletion and possible global climate change are receiving increased attention. Advances in science are also leading to deeper understanding of problems such as acid rain and pesticide contamination. As the list of environmental concerns grows, policymakers must carefully design programs to make progress on several fronts while minimizing adverse impacts on the economy.

Regulatory goals should be set so that the potential benefits to society from regulation outweigh the potential costs. Specific objectives should be chosen to maximize net benefits to the extent possible. It is impossible to remove all pollution or environmental risks, just as it is impossible to remove all risk of accident or illness. As any given pollutant or risk is reduced, the costs of further reductions rise and the incremental benefits fall. Because these additional benefits often become minuscule and the additional costs become astronomical as the limit of zero pollution or zero environmental risk is approached, the pursuit of such extreme goals is likely to reduce the overall quality of life. Cost-benefit analysis can be useful both in setting appropriate goals within a particular area of concern and in setting priorities across areas.

Where regulation is necessary, it should wherever possible employ economic incentives to achieve its goals rather than attempt to legislate behavior without changing the underlying structure of private incentives. Where incentive-based approaches such as emissions fees or tradable allowances cannot be used, it is preferable to let each firm decide how best to meet flexible performance standards rather than to impose inflexible design standards that specify how pollution must be controlled. Regulation should also define pollution sources broadly rather than narrowly, to give plants that emit emissions at more than one point flexibility in meeting an overall emissions objective. Regulation of any type should pass a test for cost-effectiveness—reaching its goals at the lowest possible cost. To forsake cost-effectiveness simply wastes resources that could be used for many purposes, including further environmental improvement.

The command-and-control approach generally fails to create incentives consistent with regulatory goals. Indeed, the hallmark of the command-and-control approach is the uniform treatment of pollution sources without regard for the differences in damages they cause or the costs of control. Because command-and-control regulation relies on administrative or statutory rules, flexibility is limited and incentives to firms are distorted. The likelihood that innovation to reduce the costs of pollution control will be met by tighter regulatory requirements presents a particularly large disincentive to innovation (Box 6–2).

Finally, often an insufficient private incentive exists to undertake research that is necessary to understand and rationally address environmental issues. Government support may be required to spur inquiry into environmental problems, benefits and costs of action, and methods of pollution reduction.

In short, the following principles should guide environmental regulation:

- Goals for pollution abatement and risk reduction should be based on a comparison of the costs and benefits involved. Elimination of all risk is almost never a sensible goal.
- Where possible, market-based approaches that provide flexibility, encourage innovation, and support economic growth should be used to achieve environmental goals in a cost-effective manner.
- Government policy should encourage the development and sharing of scientific and technical information relevant to environmental quality issues.

Box 6-2.—Problems with Command-and-Control Regulation

Regulators generally lack the detailed knowledge of individual production facilities and processes and of alternative production and abatement methods that would be necessary to implement an efficient regulatory program by command-and-control.

Firms sensibly expect that any demonstration of potential for environmental improvement or the exploration of new approaches to emission control will increase their risk of being targeted for tougher emission standards. Therefore, there is a disincentive to innovate that magnifies the inefficiency of command-and-control regulation over time. Regulators may try to overcome the incentive problem by incorporating their own forecast of future technology into regulatory requirements. This inflexible approach is a poor substitute for a decentralized innovation process in which many possibilities are pursued at the same time, with winners emerging naturally only as additional information is developed.

Command-and-control regulation also fails to account for private responses that tend to neutralize its impact. For example, a common regulatory practice is to impose new product standards that are tougher than those for existing products and facilities. This practice locks in the continued use of old products or facilities that may actually be more environmentally damaging. Aside from being costly, such standards can actually increase pollution from levels that might have been obtained without a bias against new investment.

Finally, command-and-control regulation sometimes involves issuing threats that are not credible. In 1976, when it became clear that car manufacturers could not meet the automobile emissions standards for the 1977 model year, the Congress quickly revised the standards. The implicit threat to shut down the U.S. auto industry was simply too draconian to be believed.

The rest of this chapter considers the application of these principles in the Administration's proposals to update the Clean Air Act and food safety legislation, in Federal soil conservation programs, and in the Administration's approach to global environmental issues.

THE CLEAN AIR ACT

Prior to 1970, State and local governments held the primary responsibility for determining air quality targets and emission control strategies. Some States and cities, such as California and Pittsburgh, did address pollution problems. Others, however, were reluctant to impose and enforce strict pollution controls that might drive industry elsewhere.

The Clean Air Act amendments enacted in 1970 expanded the Federal role in clean air issues beyond its previous focus on support for scientific research on air pollution problems. Under its provisions, the Environmental Protection Agency (EPA), which was also established in 1970, sets national air quality standards for major pollutants. These standards, defined as permissible concentration levels of pollutants in the air over a specific time period, are designed to protect the health of the most sensitive members of the population with an adequate margin of safety and without regard to cost. National emission standards for new industrial, utility, and commercial facilities that are significant sources of pollution and new car emission standards are also set and administered at the Federal level. State and local governments retain responsibility, however, for developing plans to reduce emissions from existing utility and industrial pollution sources so that air quality standards are met or exceeded at all locations.

EXPERIENCE UNDER THE CURRENT LAW

Meeting the objectives of the Clean Air Act has been complicated by several factors. One is the sheer number of pollution sources. There are an estimated 27,000 major industrial and utility sources of air pollution in the Nation. Mobile sources of pollution (automobiles, trucks, aircraft, and locomotives) number well over 150 million, and vehicle miles traveled have been steadily increasing. Moreover, because pollutants are transformed and transported in the atmosphere, the selection of control strategies is complicated.

Despite rising levels of economic activity and automobile use, emissions of the most common air pollutants have declined substantially since 1970. For example, emissions of carbon monoxide, particulate matter, and lead fell by 39, 62, and 96 percent, respectively, between 1970 and 1987. Yet, in 1987, 12 years past the original target date for meeting air quality standards, more than 100 million people lived in areas where air quality standards had not all been achieved. Failures to meet the ground-level ozone standard accounted for 90 percent of these exposures. Some have argued, however, that this official measure of air quality status gives little indication of normal air quality in affected areas. For example, air quality monitoring data show that the air quality standards are met more than 99 percent of the time in all areas other than Los Angeles, and 97 percent of the time there, even though it is the city with the most polluted air in the United States.

A major feature in the regulatory approach of the Clean Air Act is the requirement that new facilities meet EPA emission rate standards. This approach can effectively offer grandfather protection to old facilities and slow the rate at which firms replace older, inefficient plant and equipment with newer plant and equipment that meet EPA standards.

This peculiar consequence of regulation is apparent in the utility sector. Concern over the impact of emission standards on mining employment in high-sulfur coal regions led the Congress in 1977 to mandate a design standard for new coal-fired power plants. Sulfur dioxide removal from exhaust gases (via scrubbing technology) was required even when the same emission rate could be reached at lower cost by burning low-sulfur coal. Because such scrubbing may add 20 percent to the capital cost of a new plant, and old generating units can be kept running for 65 years or more, replacement of old generating capacity inevitably slowed. Moreover, because new generating units with scrubbers often have higher operating costs than old unscrubbed units, utilities naturally chose to run the old units as much as possible. Having new, clean plants sit idle while old, dirty ones operated at full capacity was an unintended consequence that vividly illustrates the perverse effects that command-and-control regulation can have.

THE CLEAN AIR INITIATIVE

The Administration has proposed a comprehensive plan for revising and strengthening the Clean Air Act. The Administration's proposal includes initiatives to achieve complete attainment of air quality standards, control toxic air pollutants, address the problem of acid rain, and reduce automobile emissions. The acid rain and automobile emissions programs provide particularly clear applications of the Administration's regulatory principles. The former proposes the use of tradable emissions allowances to reduce sulfur dioxide emissions from utility plants that are a primary cause of acid rain (Box 6–3). The latter uses flexibly applied and carefully targeted standards to limit automobile emissions that are the major source of ground-level ozone pollution.

TRADABLE ALLOWANCES FOR SULFUR DIOXIDE EMISSIONS

The Administration proposes to achieve a permanent 10-million-ton reduction in annual sulfur dioxide emissions in a cost-effective manner, using a system of tradable emissions allowances. The use of tradable emissions allowances is an approach that has been repeatedly advocated in this *Report* for more than a decade. Emission allowances reflecting the required reduction in current emissions

Box 6-3.—Acid Rain and Sulfur Dioxide

Acid rain results from the formation of sulfuric and nitric acids in atmospheric reactions involving sulfur dioxide and nitrogen dioxide. These acids fall to the Earth's surface as dry particles or mixed with rainfall over an area that may extend for hundreds of miles from the location where emissions occur. Thus, emissions from the Midwest can cause acid rain in the Northeast. Rainfall in the most heavily affected areas is eight to nine times more acidic than it would be under pristine conditions.

Sulfur dioxide is regulated as a pollutant under the Clean Air Act. Federal air quality standards for sulfur dioxide are currently met at virtually all locations throughout the country. In some areas, compliance was attained by switching to fuels with lower sulfur content. In others, scrubbing technology was applied to remove sulfur from smokestack gases. Another approach was to build taller smokestacks that spread emissions over a much wider area and allowed standards to be met at all measuring sites near the emission point. Building taller smokestacks was very cost-effective within a local area. But over a larger region, it exacerbated the contribution of sulfur dioxide emissions to the formation of acid rain. The 1977 Clean Air Act amendments limited allowable stack height.

While measured urban sulfur dioxide air quality has improved steadily, aggregate sulfur dioxide emissions, which heavily influence acid rain levels, have declined by only 28 percent since 1970. Almost two-thirds of sulfur dioxide emissions come from electric utility plants, with industrial sources accounting for the bulk of the remaining emissions. Most utility emissions occur at coal-burning power plants—particularly from older plants burning high-sulfur coal without emission controls.

are allocated to existing utility plants. Plant owners, who are required to hold allowances equal to their actual emissions, are then free to trade these allowances among themselves. Thus, the emission rates of individual plants can vary considerably, while overall emissions are automatically held at the target level. An additional requirement that operators of new utility plants hold allowances equal to their emissions after the system is fully in place guarantees against any rise in utility emissions over time.

The allowances trading system has several major advantages over the command-and-control approach. The tradable-allowances approach is estimated to result in cost savings of at least 20 percent annually—totaling billions of dollars over the next two decades—compared with command-and-control regulations. These savings arise from the ability to trade allowances in order to take account of differences in plant access to low- and high-sulfur coal supplies, in expected plant life, and in site constraints that may rule out the installation of scrubbers at some plants. With tradable permits, a plant with low control costs has an incentive to control more and sell its excess allowances to a plant that could only reduce emissions to its original allocation at very high cost. The scope for trading is widened by allowing industrial sources with low control costs to participate in the system and by a provision for the conversion of nitrogen dioxide emissions reductions in excess of required levels into allowances.

Incentives for Conservation and Innovation

Because reductions in electricity generation levels translate directly into a reduced need to hold allowances, the allowances system puts utility energy conservation programs on an equal footing with other emissions reduction strategies. Firms can also economize on allowances by using cleaner plants more intensively. By requiring utilities to buy or hold a costly allowance for each ton of pollution they emit, the allowances system uses the private objectives of cost minimization and profit maximization to promote environmentally sound practices. By ensuring that each pound of actual emissions carries a cost, which will be reflected in the price of electricity, additional conservation is promoted as demand falls in response to higher prices. In sum, a market-based approach sends the proper signals to both consumers and producers, resulting in cost-effective reductions in pollution.

Immediate cost savings are only part of the benefits of the trading program. The possibility of future trading creates strong incentives for further cost reduction and innovation by both utilities and nonutility firms, which could save additional billions of dollars. Utilities can take advantage of the opportunity to carry forward unused allowances for future sale or use. Such banking of allowances would shift emissions reductions from the future toward the present, allowing for more rapid environmental improvement while lowering compliance costs. Firms always stand to gain if they can achieve additional emissions reductions at a cost below the market value of the allowances that would be freed up for external sale. Thus, these firms have a continuing incentive to explore new abatement and combustion technologies, nonconventional energy sources, conservation programs, and other options that emerging technologies and local circumstances may suggest. Because allowances are transferable and continue in force after the retirement of the plant to which they were initially allocated, the investment disincentive implicit in standard regulatory schemes is avoided.

The inherent flexibility of the allowances system, which lets the market choose among competing approaches, is particularly valuable given the impossibility of knowing which technology will prove to be best over the long haul. Several different technologies for burning high-sulfur coal cleanly without scrubbing, as well as improved scrubbers, are currently under development. New concepts will undoubtedly arise over the next decade. The government is no more capable of picking winners in emissions-control technology than in other industrial arenas. By encouraging decentralized innovation and avoiding the pitfalls of centralized technological planning, the allowances system maximizes the potential for the invention and application of new ways to achieve environmental protection.

The Workability of the System

There are several precedents for successful emissions trading and marketable allowances systems. Nationally marketable allowances were used during the phasedown of the lead content of gasoline, with substantial savings. EPA's longstanding bubble policy allows owners of an industrial facility with multiple pollution sources to balance more control at some sources for less control at others to meet emissions targets on a cost-effective facility-wide basis. Since their inception in the 1970s, bubbles have saved billions of dollars compared with a policy of requiring each source to meet its own emissions standard. Trading is also used in EPA's offset policy, which allows construction of new facilities in areas that do not meet air quality standards to be offset by reductions in emissions from existing facilities. Trading in these programs has occurred despite the high air quality modeling costs incurred to verify that proposed trades will not worsen the air quality at any location. Transaction costs for sulfur dioxide emissions trading will be much lower, because local air quality modeling will not be required and continuous emissions monitoring data will be available to verify compliance.

The incentive-based approach to environmental protection offers clear advantages over command-and-control regulation, yet it generates several philosophical and practical criticisms. A common objection is that a marketable allowances system gives industry a right to pollute that it would not otherwise have. This view fails to recognize that command-and-control regulation confers exactly the same sort of pollution right, only in a nontransferable form.

Some observers have raised the concern that trade in allowances will be inhibited by State regulatory actions or manipulated to prevent the entry of new producers into the electric power market. However, facts about market structure and behavioral incentives suggest that the market for allowances will work. The initial distribution of allowances among a large number of utilities means no one firm or State could exercise market control. Antitrust laws provide an additional safeguard against the possibility of anticompetitive behavior. Existing incentives for cost and rate minimization should lead regulators and utilities with low-cost emissions reduction opportunities to sell sufficient allowances to meet the demand from new plants and new entrants. Of course, there is no guarantee that *every* utility or regulator will seek to minimize costs and electric rates and maximize shareholder returns. But in a competitive situation, cost-minimizing behavior by every participant is not required for the market to work effectively.

AUTOMOBILE EMISSIONS CONTROL

The goals selected in the President's clean air package reflect the careful comparison of benefits and costs that is a fundamental consideration in the Administration's approach to regulatory policymaking. For example, the President's package includes tighter tailpipe emissions standards for new cars and light trucks and other measures to reduce automobile emissions significantly. However, it explicitly rejects a proposal for unreasonably stringent tailpipe standards that has been advocated in some quarters.

EPA estimates that the exotic technologies required to attain such an unreasonably stringent standard would add about $500 to the cost of each new vehicle. At a projected sales rate of approximately 14 million covered vehicles per year, the additional costs would be more than $7 billion annually, almost doubling the projected costs of all actions proposed by the Administration to reduce urban ozone pollution. This standard would result in slightly lower emissions from each new car. However, because consumers would undoubtedly respond to higher new car prices by buying fewer new cars, emissions of pollutants that contribute to ozone formation could actually *increase* in the period immediately following adoption of these extreme standards, as consumers would be led to make greater use of old vehicles with significantly higher per mile emission rates. Even after a complete phase-in of vehicles meeting the extreme standard, total reductions in emissions of pollutants that contribute to ozone formation would be only slightly larger than emissions reductions under the President's proposal. Spending $7 billion or more per year to achieve, at most, very small environmental improvements is simply not sensible.

Flexibility and Targeting

The President's clean air initiative also incorporates flexibility in its provisions for automobile emission standards. Automakers can average across their product line to reach applicable standards, opening the possibility of substantial cost savings while achieving exactly the same environmental benefits as a standard applied on a car-by-car basis. Because an automaker who elects to use averaging must necessarily produce some vehicles that are cleaner than the standard, averaging implicitly encourages advances in emission-control technology.

Cost-effectiveness is also enhanced by tailoring program requirements to local needs rather than using a one-size-fits-all approach. Some areas currently meet air quality standards for ground-level ozone, while others do not. Because air quality standards are set at levels that protect the public health with an adequate margin of safety, areas that already meet standards have little to gain from further reductions in emissions. Cost-effectiveness requires focusing reductions where they are needed. For this reason, the Administration's plan for extra-clean, alternative-fueled vehicles is carefully targeted on the areas with the most severe nonattainment problems. Even within these areas, local authorities are free to opt out of the program if they can achieve equivalent air quality benefits in other ways.

The targeted approach is also evident in the President's proposal for recovery of refueling emissions. Refueling vapors can be recovered using either on-board canisters or gasoline pump recovery systems. The latter approach is preferable because it can be applied selectively in areas with ozone problems without imposing unnecessary costs on new car buyers in clean areas. It also provides more immediate environmental benefits in problem areas, because all pumps can be modified long before all cars on the road are replaced. In this matter, as in many others, environmental and economic interests are convergent.

RISK AND THE REGULATION OF AGRICULTURE

Today the regulation of agriculture involves a complex array of Federal programs—from traditional price support and acreage reduction programs to conservation, environmental, and food safety regulations—administered by the Department of Agriculture, the Environmental Protection Agency, and the Food and Drug Administration. Some programs, such as the acreage reduction programs, affect a farmer's land-use and crop-choice decisions. Others, such as pesticide regulations, affect choice of production methods. Still others, such as conservation regulations, may affect both land-use and management decisions. The combination of farm production decisions and the physical characteristics of farmers' fields—such as soil type, depth of groundwater, and proximity to surface water—are key factors that determine the impacts agriculture has on the environment.

Two questions arise regarding environmental issues that relate to agriculture. What are the circumstances in agriculture that may justify government intervention? When government action is justified, how can policies be designed to reduce environmental risks to appropriate levels at least cost?

SOIL CONSERVATION RECONSIDERED

The dust bowl of the 1930s, dramatized by John Steinbeck's *The Grapes of Wrath*, left a public perception that the effects of soil erosion can have dire economic consequences. Because of the dust bowl experience, a principal objective of soil conservation programs since the 1930s has been to prevent the loss of agricultural productivity. Yet, analyses of data on soil erosion indicate that the principal benefits from soil conservation are the prevention of offsite damages such as water pollution, not the prevention of agricultural productivity effects. There is accordingly a need to reconsider the design of soil conservation programs.

Soil Erosion and Productivity

Alarming stories in the press periodically warn that erosive practices are again ruining American farmland and will lead to a food crisis. Such alarmist claims are not supported by the facts. The Department of Agriculture estimates that some 2 billion to 3 billion tons of soil are lost from farmers' fields to erosion each year in the United States. Topsoil is a renewable resource, however, and is replaced as organic matter from crop residues is incorporated into the soil. Because of this replenishment, the rate of net loss of topsoil in the United States as a whole is low.

The gains and losses of soil are not distributed evenly, however. Some areas are net losers and may experience lower productivity as topsoil becomes shallow. These productivity losses are largely offset by gains elsewhere. The Department of Agriculture recently estimated that continuing current rates of soil erosion for 100 years would reduce productivity only about 2 percent (Table 6–1). Because *annual* productivity gains in U.S. agriculture have averaged more than 2 percent for the past 20 years, one year's normal productivity growth will offset the likely effects of erosion on productivity over the next century.

TABLE 6–1.— *Estimated Percent Loss of Productivity From 100 Years of Erosion*

Farming region	Water erosion	Wind erosion
Northeast	7.1	(1)
Lake States	.9	.7
Corn Belt	3.5	(1)
Appalachia	4.7	(1)
Southeast	1.3	(1)
Delta States	1.6	(1)
Northern Plains	.6	.3
Southern Plains	.2	2.1
Mountain States	.4	1.4
Pacific States	2.3	.2
United States	1.8	.5

[1] Less than 0.01 percent.

Source: Department of Agriculture, *The Second RCA Appraisal*, June 1989.

Alarmist claims about soil erosion's effects on agriculture also appear to run counter to basic economics. The farmer who uses erosive practices that cause a decline in current or future expected productivity of the land reduces the value of that land. This loss takes the form of lower farm output and a lower value of the land as an asset. Landowners thus have an economic incentive to limit erosion to the degree that it is profitable to do so. Department of Agriculture research shows that erodibility and topsoil depth do help explain differences in land values. These findings mean that buyers and sellers of farmland are in fact aware of these factors and generally take them into consideration in their decisionmaking. Even if some buyers and sellers of farmland are unable to know the impacts of erosion on productivity precisely, there is no reason to believe the government would be able to do so significantly better.

In short, private gains from soil conservation provide farmers and landowners with adequate incentives to protect soil productivity without government intervention. It is in environmental and other offsite effects of soil erosion that the market fails to account adequately for the effects of erosion, and it is there that government conservation programs are needed.

Pollution Effects of Soil Erosion

There are a host of offsite effects of wind and water erosion. Wind erosion contributes to particulate air pollution in the Western United States that is estimated to cause $4 billion or more in annual damages in the form of increased cleaning costs, reduced recreational opportunities, and impaired health. Erosion caused by water runoff is a major cause of water pollution that damages reservoirs and navigational channels, harms aquatic and plant life and wildlife, has adverse effects on human health, and reduces the recreational value of lakes and rivers. These damages are estimated to range from $5 billion to $18 billion annually.

These damages reflect a classic market failure: farmers typically bear little if any of the cost of the offsite effects of erosion from their fields. Agricultural pollution usually originates on many farms and it is difficult to attribute any specific amount of damage to any one source. Consequently, policies to control agricultural pollution usually must be designed to change farmers' production decisions—such as tillage practices or chemical use—that are related to pollution. The design of efficient environmental policies is complicated by the effects that Federal agricultural subsidies have on farmers' management decisions.

The Conservation Reserve Program

This program was introduced in the 1985 farm bill to accomplish environmental objectives, such as improved water quality, by removing highly erodible land from production. This program was also intended to help curb the production of subsidized commodities and to provide income support to farmers. About 34 million acres are now enrolled, roughly 8 percent of U.S. cropland. In exchange for government payments, farmers must plant grass or trees on the enrolled acres. All farmers can participate in the program, provided their land meets technical criteria for erodibility.

The Conservation Reserve Program illustrates the potential benefits of conservation programs and the problems in designing programs to meet environmental, income-support, and broader policy objectives. In order to attract widespread participation, the program originally allowed farmers to enroll any land in the program that met erodibility criteria, whether or not erosion was likely to cause damages such as water pollution. The program thus provided an incentive for farmers to place low-valued land into the program. Consequently, a disproportionately large share of the acres enrolled—more than 40 percent—is nonirrigated land in the Plains and Mountain States, where most wind erosion occurs but damages are relatively small. Relatively few acres in the program are higher valued land in the Midwest and South, where most water erosion occurs and a large part of the nationwide damages also occur. Because it is estimated that only 30 percent of the most highly erodible land is now enrolled in the program, it can be concluded that an even smaller share of the damage caused by erosion is being prevented.

Federal agricultural policy also strives to maintain and enhance the U.S. position as the major agricultural exporter in the world. Conservation programs that attempt to achieve environmental goals by removing millions of acres of cropland from production are not consistent with this broader policy objective. The inconsistency in U.S. policy is highlighted by the 1985 Food Security Act. The act established the Conservation Reserve Program to remove 40 million to 45 million acres of U.S. cropland from production and simultaneously instituted an export subsidy program—the Export Enhancement Program—to increase U.S. agricultural exports. These conflicts between environmental and trade objectives may increase if current international negotiations, discussed in Chapter 7 of this *Report,* lead to agricultural policy liberalization.

IMPROVING CONSERVATION PROGRAM DESIGN

The targeting problems encountered with the Conservation Reserve Program and its inconsistency with broader U.S. policy objectives both suggest that the Federal Government should reconsider its approach to conservation programs. How can conservation programs be made more effective at meeting conservation objectives and also be consistent with broader policy and trade objectives?

The answer is to target environmental impacts while keeping as much viable land in production as possible. Land retirement could still be used in those special circumstances, such as protection of wetlands, in which there are no viable alternative methods to meet environmental objectives.

Conservation programs are not an efficient means of transferring income to farmers because they do not target those farmers who might be thought to be deserving of income subsidies. Hence, they should not be used as a means to support farm income. Instead, conservation programs should be designed to achieve environmental objectives by targeting land that causes offsite damages and land that needs to be protected for other environmental reasons such as protection of wildlife. The recent changes in the Conservation Reserve Program's eligibility criteria, to include environmentally sensitive lands such as wetlands and areas bordering rivers and lakes, represent a move toward better targeting of environmentally sensitive land. These criteria could be further improved by explicitly linking them to potential damages. If the program enrollment is increased from the current 34 million acres to 40 million as proposed by the Administration, participation should be extended to land meeting criteria that target environmental damages.

Conservation programs could also be made compatible with both environmental and trade objectives by using economic incentives to encourage farmers to invest in conservation improvements that reduce wind and water erosion damages while keeping land in production. Investments such as terracing and windbreaks can be used to reduce wind erosion, and filter strips and grassed waterways can reduce water pollution. Federal conservation programs have long shared the costs of these investments, but not in a way that targets the investments to mitigate offsite damages. Such targeting could be accomplished by linking these investment incentives to the potential for erosion to cause environmental damage.

PESTICIDES: BENEFITS, RISKS, AND REGULATION

Pesticides are believed to have been a major contributor to the growth in the productivity of U.S. agriculture since the 1950s. This growth in productivity—almost 220 percent since the early 1950s—has benefited consumers by making more food available at lower prices. Pesticides are poisons, however, and their widespread use in agriculture has led to growing public concern about detrimental effects on human health and the environment.

Many pesticides have immediate health effects that pose a risk to pesticide users and others from accidental poisonings. Some scientists also believe that low-level exposure to many pesticides may cause delayed health effects. These delayed effects—cancers, birth defects, and neurological disorders—are much more difficult to demonstrate than immediate effects. Because experimentation on humans is not possible, researchers must infer delayed effects from animal studies or from statistical data on human exposure. Because neither method provides definitive data, regulatory decisions regarding delayed effects are inevitably based on imperfect scientific evidence.

The effects of pesticides on nature may be even more difficult to measure and evaluate than the effects on human health. Countless plant and animal species inhabit the natural world. Plants themselves contain many natural pesticides necessary for survival. The scientific challenge to understand the effects of pesticides is great, even if attention is focused only on those organisms that have immediate economic value. Researchers have only recently begun to construct a framework for systematic quantitative assessment of pesticide impacts.

The Regulatory Process

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) directs EPA to evaluate the effects of pesticides on human health and the environment and to regulate pesticide use as necessary to balance benefits and risks. Pesticides that pass the benefit-risk analysis under FIFRA must also meet a health-risk tolerance for residues in processed foods established by the Federal Food, Drug, and Cosmetic Act (FFDCA). The risk tolerance is to be set in light of the need for "an adequate, wholesome, and economical food supply." EPA uses available data—including laboratory studies of effects on animals, pesticide use data, and food consumption data—to estimate the risk of an adverse health effect (e.g., the probability of a person developing a cancerous tumor during a lifetime). This risk estimate is then used with other relevant information to make regulatory decisions.

This regulatory scheme is straightforward in principle, but its information requirements are burdensome in practice. Within the next decade, EPA must evaluate hundreds of active ingredients contained in thousands of pesticides. Because many studies and analyses are required on each active ingredient, EPA faces a formidable regulatory task. The current regulatory process takes years to complete. In deciding whether to remove a dangerous pesticide from use, current procedures can take 4 to 8 years. Some of the delays in the regulatory process can be attributed to the way it is organized, and the Administration has proposed reforms to expedite the process. But a major constraint is still the time and cost involved in producing reliable scientific information needed to make responsible decisions.

Negligible Risk and the Delaney Clause

Both risks and benefits of a pesticide are considered in setting most tolerances under FFDCA and in all regulatory decisions under FIFRA. For most decisions, EPA uses the concept of negligible risk. A negligible risk is one below which it is deemed that the public health is not threatened, and is often interpreted to be a lifetime cancer risk in the range of 1 in 1,000,000. When a chemical's risk is estimated to be less than 1 in 1,000,000, its use is not regulated. When a chemical's risk exceeds 1 in 1,000,000, benefits from use are weighed against risks in making a regulatory decision.

A different risk standard is applied in the case of pesticide residues in processed foods, however, because of the Delaney Clause in Section 409 of FFDCA. The Delaney Clause states that a pesticide that has been found to cause cancer cannot be registered for use if *any* residues are found in processed foods. This zero-residue standard implies a zero-risk tolerance for carcinogenic pesticides in processed foods, no matter how small the risk or how large the economic benefit from their use. Thus, benefits are balanced against risks if a carcinogenic pesticide residue is present on fresh produce, but not if it is found in processed food.

The Congress adopted the Delaney Clause's zero-risk standard in the 1950s when laboratory techniques were able to detect residues only in parts per million. With modern techniques, such as gas chromatography, it is possible to detect residues in parts per billion, effectively increasing the stringency of the Delaney Clause's risk standard by a factor of one thousand.

The current negligible-risk standard for pesticides is very stringent—some would say excessively so—and represents a high degree of safety. More stringent pesticide regulations could have little effect on the total number of cancers. To put pesticide health risks into perspective, consider that the risk of cancer in the U.S. population is 300,000 in 1,000,000. Pesticides account for only a small fraction of the 2 percent of cancers attributed to all sources of pollution, whereas tobacco use and diet are believed to contribute to about 65 percent of all cancers. The National Cancer Institute has announced its goal to reduce cancer mortality in the year 2000 by 50 percent through changes in tobacco use, diet, and health care. The Institute's focus on reductions of large risks, rather than ones that are already negligible, is clearly sensible.

THE ADMINISTRATION'S PROPOSALS FOR PESTICIDE POLICY REFORM

The National Academy of Sciences recently studied pesticide regulation extensively and recommended that the inconsistencies between FIFRA and FFDCA be eliminated by abandoning the distinctions now made between residues in processed and nonprocessed foods and by replacing the Delaney Clause with a negligible-risk standard for all pesticides. The National Academy concluded that the consistent application of a negligible-risk standard for carcinogens in food would allow regulatory efforts to be focused on the most dangerous substances and would thereby dramatically *reduce* total dietary exposure to cancer-causing pesticides with modest reduction of pesticide benefits.

The Administration proposes to adopt the National Academy's recommendation that a negligible-risk standard replace the Delaney Clause in FFDCA. Where risk is greater than negligible, the Administration proposes to extend to processed foods the existing regulatory procedures for nonprocessed foods. These procedures allow economic and health benefits of a pesticide to be balanced against risks in all cases. By allowing better targeting of regulatory efforts, this change should *reduce* cancer risks.

The Administration's food safety proposal also would amend FIFRA to strengthen and simplify the pesticide regulation process. The President's plan would establish a periodic review of all pesticides, simplify and make more effective the process of canceling the use of a pesticide found to be harmful to public health, and improve enforcement of pesticide regulations.

Other Regulatory Reforms

Pesticide regulation, like air pollution regulation, is based largely on command-and-control techniques (Box 6–2). Uniform regulatory standards are notoriously inefficient because they fail to take into account the diversity of local conditions. Because pest problems are often location-specific, large production inefficiencies can be caused by uniform pesticide regulations. There is a need for alternative, cost-effective methods of pesticide regulation that allow farmers to adapt production methods to the particular pest problems they face. For example, it may be possible to employ a system of marketable pesticide-use allowances to reduce pesticide contamination of surface and groundwater efficiently. A marketable allowances system (Box 6–1—tradable allowances) would restrict the total use of pesticides in environmentally sensitive areas and would allow those farmers who benefit most from pesticides to use them.

Both Federal and State governments have already financed research into production practices that impose fewer health and environmental risks. For example, many States have developed research programs under the rubric of integrated pest management. Also on the horizon are promising developments in biogenetic research that could enhance pest resistance and reduce the need for chemical pest control. In 1990, the Administration will begin a 5-year interagency research initiative to improve understanding of the process of groundwater contamination, develop safer production practices, and disseminate the new practices through the Extension and Soil Conservation Services.

Better data on actual pesticide use, occupational exposure, and environmental contamination are needed to enable regulators to make informed decisions. The Department of Agriculture is currently improving data on pesticide use. The EPA is now conducting the first national assessment of pesticide contamination of well water. Further funding of pesticide data collection and analysis is under consideration.

ENVIRONMENTAL EFFECTS OF FEDERAL FARM PROGRAMS

Federal farm programs may encourage farming practices that increase health and environmental problems. Farm programs may have adverse environmental impacts through several channels. Crop-specific subsidies can encourage farmers to use more fertilizers and pesticides. To limit the costs of programs, farmers can receive subsidies only on those acres that are part of the farmer's program crop base. This criterion for program participation creates a disincentive to rotate crops, even though crop rotation is an important nonchemical technique for pest control. Thus, the programs may further aggravate pesticide pollution by encouraging farmers to substitute chemical pest control for nonchemical control.

When farm subsidies are based on how much land a farmer devotes to particular crops such as wheat and corn, land suitable for those crops becomes more valuable. Higher agricultural land values in turn encourage farmers to bring more land into production. Land that is not already being farmed is generally less productive or more costly to convert to agricultural uses. Such land may be steeply sloped and thus erodible, or it may be wetlands that provide important wildlife habitat. Agricultural subsidies based on land use thus create incentives for farmers to use land in ways that may increase adverse environmental impacts.

Unfortunately, only limited research has addressed the linkages between agricultural policy and environmental quality. Some evidence supporting these linkages is contained in case studies conducted by the National Academy of Sciences in its report, *Alternative Agriculture*. Other research casts doubt on the generality of that evidence, however. Research shows that pollution caused by agricultural chemical use, for example, depends on the physical characteristics of the farmer's field and its proximity to groundwater and surface water. The diversity of conditions under which agricultural production takes place makes it very difficult to draw broad generalizations from limited data.

The potential adverse environmental impacts of Federal agricultural programs could be reduced by breaking the links between agricultural subsidies and farmers' production and land-use decisions. These links could be broken, for instance, by making three changes: continuing the reductions of price-support levels that were begun by the 1985 farm bill; relaxing restrictions on the use of land enrolled in subsidy programs; and changing the criterion for receipt of subsidies from one that is based on crop acreage to one that is not related to production of a specific crop. For example, an income-based safety net could replace the current system of crop-related deficiency payments. These same policy changes would also bring U.S. agricultural policy in line with the broader trade policy goals of this Administration that are discussed in the next chapter of this *Report*.

GLOBAL ENVIRONMENTAL ISSUES

Like environmental problems at the local or national level, global environmental problems arise because actions taken by one individual have unintended adverse effects on another. Global environmental problems are complicated by the fact that the individuals involved live in many nations. Because one nation cannot impose its wishes on another, international cooperation is required to solve such problems. Differences across countries—in income, natural resource endowments, population, sensitivity to particular environmental changes, and the political strength of environmental movements—mean that countries inevitably have different views on these issues. At the Paris Summit in July 1989, the President joined other heads of state in recognizing the need for cooperation in addressing global environmental concerns. The President has also encouraged international organizations to facilitate international cooperation to solve global environmental problems.

Stratospheric ozone depletion and possible climate change are two global issues that may affect the economy and the environment far into the next century. To evaluate the impact of a policy course chosen today, the impact it will have on the economic well-being of *both* current and future generations and its environmental impact must be assessed.

Scientific evidence of possible stratospheric ozone depletion is stronger than scientific evidence of possible global warming, although significant uncertainties surround both. These uncertainties extend to environmental and economic as well as scientific aspects of these two issues. Because policymakers must understandably make decisions before information on such issues is complete, the government has an important role to play in supporting basic scientific and economic research that can reduce critical uncertainties in the meantime.

Even when uncertainty cannot be eliminated, identifying a probable range of effects can inform policy choice. For example, a consensus that changes in global climate will lead to at most a small rise in sea level over the next 60 years would make a policy response to protect high-value coastal areas more feasible than if a large rise were expected. Finally, because the regulatory agenda is often influenced by public perceptions that may not accurately reflect available knowledge, the government also has a responsibility to educate the public.

STRATOSPHERIC OZONE DEPLETION

Ozone in the upper layer of the Earth's atmosphere (the stratosphere) provides an essential screen from the Sun's ultraviolet rays. In recent years, evidence has mounted that the stratospheric ozone layer is being depleted. Several chemical compounds, most notably chlorofluorocarbons (CFCs) and bromofluorocarbons (halons) have been identified as sources of the increased atmospheric concentrations of chlorine and bromine that cause ozone depletion. These chemical compounds have long atmospheric lifetimes, so that even if their production were halted immediately, elevated concentrations of chlorine and bromine would persist for decades before subsiding. If production is phased out by 2000, current chlorine concentrations would be likely to increase by 50 percent and then decline slowly to one-half of current levels by 2080. Without any production curtailment, these concentrations would rise indefinitely.

The appearance of a major hole in the stratospheric ozone layer over Antarctica, where no emissions originate, illustrates the global scope of the ozone-depletion problem. Long before the hole was observed, the United States acted in 1978 to ban the use of CFCs as aerosol propellants, a use in which substitutes were readily available. Canada and Sweden followed suit. CFCs and halons are also used in applications such as automotive and residential air-conditioning systems, refrigerators, and fire extinguishers; as blowing agents in the production of insulating board and other foam products; and as industrial solvents. These uses of CFCs and halons have continued to grow.

Protecting the Ozone Layer: Benefits and Strategies

The potential benefits from protecting the ozone layer—improvements in human health and favorable impacts on crops, fish, and materials—arise from lower exposure to solar ultraviolet radiation. Both skin cancer and cataracts are related to cumulative exposure to ultraviolet radiation. A phaseout of CFCs and halons is estimated to reduce the incidence of these health problems in the current population by 50 to 75 percent from levels that would prevail if there were no curtailment of production. (This estimate is likely to be high, because it assumes that individuals take no offsetting actions to reduce their exposure to increased ultraviolet radiation.) For future generations, which would suffer a greater cumulative exposure to ultraviolet radiation if ozone depletion continued, the health benefits would be even larger.

The geographic distribution of ozone-depleting emissions and their expected growth unless action is taken is such that no single country can act alone and have a significant impact on stratospheric ozone depletion. Individual countries have little reason to act alone. The benefits of national policies to reduce ozone-depleting emissions spill over national boundaries, but costs are concentrated where reductions occur. Thus, the application of cost-benefit criteria on a national level would cause any one country, working in isolation, to reject control measures that may be desirable from a global perspective.

Two international agreements regarding ozone depletion are currently in effect. The 1985 Vienna Convention established a framework for international scientific and technical cooperation. The 1987 Montreal Protocol commits signatories who are major CFC users to freeze production levels by 1989, and then to cut their production in half by 1998. In addition, beginning in 1992 the production of several halons is frozen at 1986 levels. The United States and other major industrialized countries have announced further intentions to phase out production of CFCs and halons completely by the turn of the century if safe substitutes are available. Amendments and revisions to the Montreal Protocol, including extending coverage to other compounds with ozone-depleting potential, are currently under consideration.

Hydrochlorofluorocarbons (HCFCs), the most promising substitutes for CFCs in a wide range of applications, themselves have one-fiftieth to one-tenth the ozone-depleting potential of CFCs. By allowing HCFCs to substitute for CFCs in the near term, the Montreal Protocol rejects the uneconomic approach of barring all new ozone-depleting compounds regardless of their advantage relative to current products and their usefulness during the transition to substitutes with no effect on the ozone layer.

Atmospheric lifetime is one important factor in decisions regarding the coverage of the protocol. Decisions to reduce or eliminate the use of short-lived ozone-depleting compounds, such as methyl chloroform, involve weighing the short-term impact of delay against the opportunity to develop improved substitutes to lower the economic costs of action. Under these conditions, it may be sensible to eliminate their use as good substitutes become available.

Costs of Protecting the Ozone Layer

Preliminary estimates place the U.S. costs of a phaseout of CFCs and halons by 2000 at $2.7 billion over the next decade if the schedule of intermediate reductions currently incorporated in the Montreal Protocol is maintained. Acceleration of this schedule would drive compliance costs upward significantly. These cost estimates reflect a substitution strategy involving conservation, process changes, and the use of more expensive substitute compounds. The availability of substitutes is critical to avoid economic disruption.

The United States is using transferable allowances to implement the reductions required under the protocol in a cost-effective manner. Manufacturers and importers of CFCs and halons will receive permits in proportion to their base period market shares. As supply is restricted, rising prices will encourage users with available low-cost substitutes to switch, leaving remaining supplies for high-value uses. This approach avoids unnecessary direct regulation of end-use applications, while ensuring compliance with U.S. obligations to reduce production and consumption. Moreover, because there are significant economies of scale in the production of CFCs and halons, the use of permit transfers to concentrate production in a small number of facilities during the phasedown has the potential to increase efficiency on the supply side. Allowing for this kind of flexibility on the international level would yield further cost savings.

GLOBAL CLIMATE CHANGE

Greenhouse gases (carbon dioxide, methane, CFCs, and nitrous oxide, among others) absorb heat that radiates from the Earth's surface and send some of the heat downward, warming the climate. Many scientists believe that fossil fuel burning, certain agricultural practices, deforestation, and other human activities that increase the atmospheric concentration of greenhouse gases will alter the global climate. Scientists are much less confident of the magnitude, timing, location, and character of the greenhouse-induced warming. Many argue that no warming has yet occurred despite a substantial increase in greenhouse emissions; some contend that appreciable future warming is unlikely. Others strongly dispute these views.

Computer models of the Earth's climate system are a principal tool of global climate research. Economic models of energy supply and demand provide the future emissions projections used as input by the climate models. Economic models can also be used to assess the cost and growth impacts of policy actions to change the future emissions profile.

Economic and Scientific Uncertainties

Projections of future emissions of greenhouse gases, a critical input to climate models, are highly sensitive to future rates of population growth, economic growth, and development of new technologies for energy production and use. The inability to place narrow bounds on any of these factors necessarily places very wide bounds on any forecast of future emissions. One recent study could conclude only that actual global carbon emissions from fossil fuel combustion in the year 2050 are likely to be between 50 and 1,100 percent of current annual emissions. This result is typical of the high degree of uncertainty in this area.

Even if estimates of future emission levels are correct, the magnitude of actual climate change will depend on numerous interrelated and, as yet, poorly understood geophysical processes that have both positive and negative feedbacks on warming. For example, an increase in evaporation from a warmer climate will almost certainly increase average cloud cover. Depending on their altitude and configuration, additional clouds can either intensify or counteract warming. Current climate models are incapable of providing reliable estimates of the effect that clouds will actually have if warming occurs.

If the atmosphere begins to warm, a transfer of heat from the air to the oceans is expected to slow the rate at which air temperature actually rises. This effect, which would decrease as ocean temperatures increased, could delay the full effect of any increase in the concentration of greenhouse gases on air temperature for a period ranging from decades to centuries, with wide variations by region. Regional variation in other critical effects such as seasonality, rainfall distribution, and soil moisture is also likely, but current climate models lack sufficient resolution to identify regional differences clearly. This deficiency makes it difficult to specify, among other things, the sea level rise resulting from any degree of average warming.

Considerable resources and effort are being devoted to resolving uncertainties in climate modeling, and in gaining a better understanding of processes that are poorly understood and are not explicitly treated in current climate models. The President's 1991 budget proposal includes $1.03 billion in funding for global climate change research. This figure reflects an increase of 57 percent over the current funding levels and a 100-percent increase over 1989 expenditures. The United States has also taken a leadership role in the Intergovernmental Panel on Climate Change, the primary international forum for consideration of the scientific, socioeconomic, and policy issues concerning global climate change.

At the Malta meeting with the Soviet President in December, the President of the United States announced his intention to host a

White House Conference on Scientific and Economic Research on the Environment in the spring of 1990. The general purpose of this high-level international meeting will be to advance the quality and understanding of the scientific and economic analytical tools and data necessary to confront international environmental problems, including global climate change. Sound scientific and economic analyses must be the foundation for any policy action in this area. The President of the United States also offered to host the first negotiating session for an International Framework Convention on Global Climate Change in the fall of 1990.

The compounded uncertainties of the projections of future emissions and the climate models present a formidable barrier to accurate forecasting. At present, there is an extremely high level of uncertainty regarding possible future climate change. Some reputable scientists believe that there will be no significant greenhouse warming over the next century. But other reputable scientists believe that a warming of between 1.5 °C and 4.5 °C (with most recent estimates falling into the lower half of this range) could occur by the middle of the next century if emissions grow rapidly. A warming of this magnitude could result in a rise in sea level estimated to range from a little under one foot to about a foot and a half by the end of this period. Both the more optimistic and the more pessimistic judgments are subject to revision as scientific and economic inquiry progresses and additional data are gathered.

If the current understanding of greenhouse processes is correct, some warming could occur by virtue of past emissions. Therefore, some adaptation would be required even if future greenhouse emissions were sharply curtailed. Even though scientists may yet learn that no significant warming is likely, it is nonetheless worthwhile to address two distinct policy questions. First, what actions could be taken now to limit emissions of greenhouse gases and what are the likely costs of those actions? Second, what are the possible economic and other effects of warming that, if these scientists are correct, will occur in any event?

Sources of Greenhouse Gas Emissions

Some steps have already been taken that will reduce greenhouse gas emissions. In addition to their role in stratospheric ozone depletion, CFCs account for 14 percent of total greenhouse emissions from human activities on an impact-weighted basis; the planned phaseout of CFCs is clearly important. In the recently negotiated agreement to replenish the financial resources of the International Development Association, the United States called for preparation of environmental action plans in borrowing countries, expansion of programs for end-use energy conservation and renewable energy sources, and other environmental reforms.

On the domestic front, the Administration's clean air initiative promotes the development of technologies that will improve the efficiency of converting energy stored in coal and other fossil fuels into electricity. The allowances system and the proposed cap on sulfur dioxide emissions may also focus renewed attention on improving efficiency in end-uses of electricity as an alternative to new fossil-fueled generating capacity. Although the measures cited above should reduce net greenhouse emissions, the justification for taking these actions does not depend on resolving the high uncertainties about possible climate change.

Carbon dioxide accounts for about one-half of the current greenhouse gas emissions caused by human activity. The shares of methane, CFCs, nitrous oxide, and other gases are 18, 14, 6, and 13 percent, respectively. Clearly, possible climate change is not a one-gas problem: gases other than carbon dioxide play a significant role. Nonetheless, international attention and current analysis of greenhouse gas limitation policies focus almost exclusively on carbon dioxide.

THE COSTS OF REDUCING CARBON DIOXIDE EMISSIONS

Fossil fuel combustion is the primary source of carbon dioxide emissions. Deforestation accounts for an additional 10 to 30 percent. Other activities such as agriculture and cement manufacturing contribute smaller shares. Although all fossil fuels contain carbon, coal contains about 1.75 times as much carbon per unit of heat energy as natural gas and about 1.25 times that of oil.

In contrast to the situation for CFCs, low-cost substitutes for fossil fuels used in electricity generation, transportation, heating and cooling, and process heat applications are not currently available or on the immediate horizon. Unlike sulfur dioxide, no commercially feasible technology for scrubbing carbon dioxide from combustion waste gases is available. Thus, for the foreseeable future, only lower energy consumption or fuel switching could reduce carbon dioxide that results from fossil fuel combustion. A substantial increase in the price of fossil fuels would likely be required to reduce consumption substantially.

Experience following the 1973 and 1979 oil shocks shows that large increases in the price of energy can reduce the energy intensity of economic activity. The period between 1973 and the sharp decline in oil prices in 1986 saw a significant increase in the relative price of energy. Between 1973 and 1985, the price of energy rose by 47 percent relative to nonenergy products at the consumer level and by more than 80 percent at the industrial level. The ratio of energy use to real gross national product fell by 2.3 percent annually in the United States over this period as consumers and producers responded to higher energy prices by substituting away from energy and energy-intensive products. With no growth in energy consumption over the period 1973 to 1985, carbon dioxide emissions remained level. The impact on carbon dioxide emissions of the increase in the share of primary fossil energy derived from coal over this period was offset by growth in the use of nuclear power, which produces no greenhouse emissions, and of natural gas. However, the growth rates of output and productivity over this period, 2.3 percent and 1.0 percent, respectively, were far below the corresponding rates of 3.7 percent and 2.9 percent for the 1948–73 pre-shock period.

The relationship between energy prices, energy consumption, and economic growth is also reflected in more recent data covering a period of significant decrease in relative energy prices at the consumer and industrial levels. Between 1985 and 1988, annual growth rates in output and energy use snapped back to 3.6 percent and 2.7 percent, respectively.

Although the slowdown in productivity and output growth between 1973 and 1985 can be attributed to many factors, higher energy prices clearly played an important role. Energy price increases of comparable or larger size would likely be needed to induce the large energy efficiency improvements and demand reductions that must occur to achieve the ambitious targets for carbon dioxide emissions reductions that some have advocated. Although much has changed since 1973—it may be harder now to expand reliance on nuclear power, for instance, even though the regulatory policy errors of that period are less likely to be made—the oil-shock period provides a useful benchmark for consideration of the likely impact of emission reduction policies on output and productivity growth. On balance, there is no reason to believe that an attempt to reduce energy use significantly would be substantially less economically disruptive today.

Modeling the economic effects of policies to curtail carbon dioxide emissions is still in its infancy, and results of modeling efforts remain tentative and controversial. (Even less has been done with regard to other greenhouse gases.) *Recent studies suggest, however, that the costs of policies to stabilize or reduce carbon dioxide emissions from fossil fuel combustion would be high.*

One recent study placed the cost of gradually reducing U.S. carbon dioxide emissions by 20 percent between now and 2100 to range from $800 billion, under optimistic scenarios of available fuel substitutes and increasing energy efficiency, to $3.6 trillion under pessimistic scenarios. These present-value estimates, which reflect the discounting of real future costs at a 5-percent annual rate (Box 6–4), are between 35 and 150 times larger than EPA's similarly discounted estimate of the costs that would be incurred over the next century by consumers and industries forced to use more expensive or less effective substitutes if a complete phaseout of CFCs and halons were implemented by the year 2000.

Box 6-4.—Discounting Over Long Horizons

The costs of reducing greenhouse gas emissions must be borne both now and well into the next century; the benefits of slowing climate change may not be perceptible for many decades. Discounting is required to compare costs and benefits—both market and nonmarket—that occur at different dates.

Suppose, for instance, that a 5-percent real rate of interest is appropriate for these calculations. (If an investment yields a 9-percent rate of interest in dollar terms, but prices rise by 4 percent per year, the real purchasing power of invested funds grows by 5 percent annually.) One dollar invested at 5 percent per year in 1990 will return $18.68 in purchasing power in 2050 if the interest income between 1990 and 2050 is reinvested. Therefore, it makes no sense to spend $1 today to obtain benefits worth $10 in 2050: future generations must receive at least $18.68 in 2050 benefits to be better off than they would be if the dollar were invested instead.

It is always possible to compare values in either current or future terms. To compare in 1990 terms, one must divide the 2050 value by 18.68. Thus, $100 billion in 2050 is worth only $5.35 billion in 1990. To compare in 2050 terms, $100 billion in 1990 is worth $100 billion x 18.68 = $1,868 billion, or $1.868 trillion. Either approach will give comparable results; what matters is that all values are placed on a consistent basis.

The costs of carbon dioxide stabilization policies can also be looked at from a future perspective. The present-value estimates cited above reflect reductions in real U.S. output ranging from 1 to 5 percent over the 2010 to 2100 period. Other preliminary estimates place the cost of stabilizing 2050 emissions at 1990 levels in the range of 1 to 2 percent of 2050 gross national product (GNP). To put these estimates in perspective, a 2-percent reduction in GNP in the year 2050 is worth about $340 billion 1990 dollars, assuming a 2-percent average annual rate of economic growth between now and 2050.

The impact of carbon dioxide stabilization policies can also be considered in terms of growth-rate impacts. A recent estimate based on energy-output balance relationships suggests that global carbon dioxide stabilization could cut world economic growth in half, even after accounting for substitution toward cleaner energy. Other studies and U.S. experience following the oil shocks suggest substantial if less dramatic impacts. As shown in Chapter 4, even small changes in growth rates can have a large effect on future output levels.

Clearly, economic models as well as climate models are subject to considerable uncertainty. The early estimates of potential costs described above are far from definitive. The critical uncertainty regarding forecasts of the date and cost at which alternative technologies will become available is unlikely to be resolved soon. Meanwhile, the refinement of current estimates and the development and application of new, more detailed economic models would help to provide a stronger foundation for decisions regarding possible actions to limit carbon dioxide emissions.

Other Issues in Reducing Carbon Dioxide Emissions

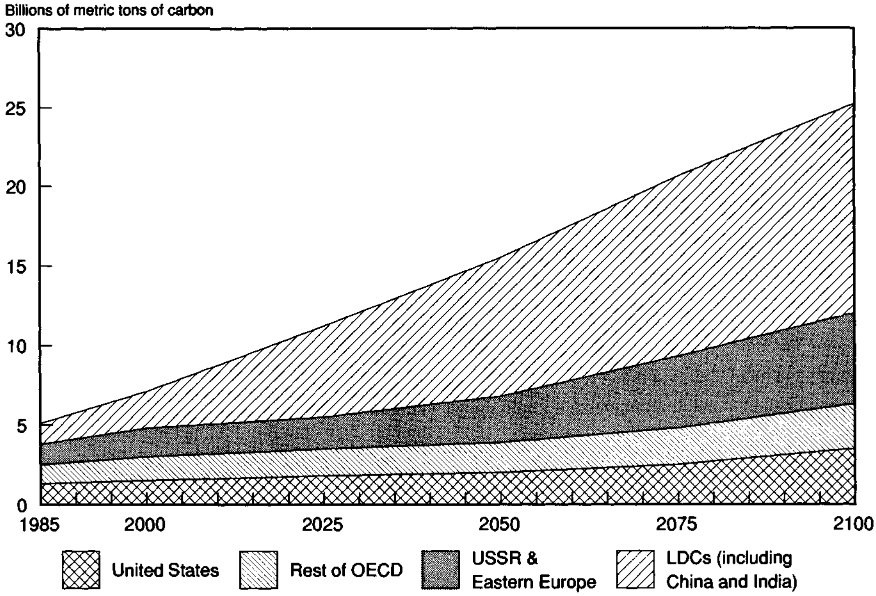
Reductions in U.S. carbon dioxide emissions on a unilateral basis or in cooperation with other Organization for Economic Cooperation and Development (OECD) countries alone would not significantly alter the projected growth in world carbon dioxide emissions (the OECD is an international organization of industrialized countries that promotes economic growth and trade). Chart 6–1 shows current and projected shares of total carbon dioxide emissions. The emissions share of the United States and other industrialized countries is projected to decline sharply as non-OECD economies experience growth and increasing energy intensity. Developing countries are expected to account for the majority of future emissions increases. Clearly, any significant reduction in emissions growth would require the cooperation of the Soviet Union, Eastern Europe, and the developing countries.

The ratio of carbon dioxide emissions to energy consumption depends on the mix of energy sources employed and thus varies substantially among industrialized nations. This ratio is high for the United States, which depends more heavily on coal than most of its major competitors (Table 6–2), as is energy use per dollar of GNP. *All else equal, uniform international standards or user charges for carbon dioxide emissions are thus likely to have a larger adverse impact on the United States than on its major competitors.* In particular, a fee on carbon dioxide emissions (discussed below) would increase electricity rates in the United States relative to rates in countries that rely more heavily on nuclear and hydroelectric energy, which produce no greenhouse emissions, or in countries relying on fossil fuels with less carbon per unit of energy content. This situation presents a marked contrast to the 1973 and 1979 oil shocks, where greater U.S. self-sufficiency in energy provided an advantage relative to most other industrialized countries.

Other than hydroelectric or geothermal power, which have very limited potential to supply increased electricity within the United States, nuclear power is the only large-scale technology for electric-

Chart 6-1

CARBON DIOXIDE EMISSIONS BY REGION. The LDC share of carbon dioxide emissions is projected to grow rapidly. The U.S. share is projected to decline.



Source: Environmental Protection Agency, *Policy Options for Stabilizing Global Climate* (Rapidly Changing World Scenario).

TABLE 6-2.—*Fuel Share in Electricity Generation, 1986*

[Percent]

Country	Coal	Oil	Gas	Nuclear, Hydroelectric, and Geothermal
Canada	15.7	1.3	1.5	81.5
France	9.7	1.5	.8	88.1
West Germany	56.9	3.1	6.2	33.8
Japan	14.7	28.2	19.3	37.8
Netherlands	26.8	5.1	61.8	6.3
Sweden	3.0	2.0	.1	94.9
United States	56.2	5.5	10.1	28.1

Source: Organization for Economic Cooperation and Development, "Energy Policies and Programmes of IEA Countries—1987 Review," Paris, 1988.

ity production that is both benign from a greenhouse emissions perspective and commercially available now. Policies regarding the future role of nuclear power, including the timetable for the development and commercialization of modularized, inherently safe reactor designs, will need to be closely coordinated with policies that affect the future role of fossil-fuel generation.

POLICY TOOLS TO IMPLEMENT A REDUCTION IN GREENHOUSE GAS EMISSIONS

A variety of policy tools, including user charges, correction of market failures, regulatory standards, expanded funding for research on and development of substitutes for fossil fuels and other sources of greenhouse emissions, and efforts to reduce and reverse deforestation, could be used to slow the buildup of greenhouse gases in the atmosphere. These approaches are relevant for nearly all greenhouse gases, not just carbon dioxide. While international attention has naturally focused on carbon dioxide as the single largest contributor to the greenhouse effect, control costs must also be considered in the design of any strategy to reduce net emissions of greenhouse gases. A cost-effective strategy may involve a focus on other gases or on sinks that absorb greenhouse emissions. Different approaches may be suitable for different countries.

A fee, charge, or tradable allowances system for greenhouse gas emissions based on an index of the global climate impacts of each greenhouse gas would provide a least-cost reduction in such emissions. A fee or a tradable allowances scheme would lead firms and individuals to consider the social cost of greenhouse emissions in their private decisions. An emission charge or the need to consider the value of allowances would affect decisions ranging from the choice among alternative technologies for generating electricity, to the energy efficiency of cars, buildings, and industrial equipment, to the demand for automobile travel. Because market-based approaches are flexible and provide incentives that affect decisions at all points along the production-consumption chain and across all industries, they automatically focus on those activities where emissions reductions can be achieved at least cost.

The economic impact estimates for carbon dioxide stabilization discussed above reflect the high costs of reaching very ambitious goals even when efficient market-oriented tools are used. Market-based approaches could also be implemented at a less draconian level to nudge the economy gently and gradually in the direction of greater energy efficiency. Such an approach would test the flexibility of the economy without betting the current way of life on the outcome.

Publicly supported research and development of nonfossil energy sources, including biomass, solar, and next-generation nuclear fission, may contribute to a reduction in greenhouse emissions. It is often noted that the fruits of innovation cannot always be fully captured by the innovator, leading to underinvestment in the development of new technology. This problem is particularly acute for innovations that address a global problem, such as greenhouse emissions. Breakthroughs in environmentally benign technologies hold the promise of lowering the future emissions trajectory while advancing economic progress. Opportunities also exist outside the energy area. For example, emissions of methane from agriculture might be cut through the development of improved techniques for farming and livestock management.

Reforestation can contribute to reductions in net emissions of carbon dioxide into the atmosphere. Just as tropical deforestation increases carbon dioxide emissions by releasing carbon that is fixed in trees through photosynthesis, reforestation can increase the uptake of carbon dioxide from the atmosphere by increasing photosynthesis. Reforestation potential varies significantly across countries according to their climate and land use patterns. The United States has an abundant supply of urban and rural land suitable for reforestation. Large-scale reforestation efforts could have significant impacts on agricultural and timber production, however, which would in turn affect consumers and producers in those markets.

Correcting Market Failures

In some cases, market failures may serve to increase emissions of greenhouse gases. *Interventions that address market failures directly are generally preferable to direct regulation via standards.* Approaches that merit consideration include public information programs, promotion of efficient appliances by utilities, and changes in mortgage qualification rules to reflect appliance operating costs.

One promising concept to reduce the growth in electricity use is demand-side management. A utility faced with capacity constraints would consider proposals for demand reduction through efficiency improvements and proposals to increase supply on an equal footing, and choose the lowest cost alternative. One barrier to implementing programs of this type is that utility profits under traditional State rate-setting regulation are often linked directly to the level of electricity sales. Regulatory changes at the State level, possibly to permit nonutility companies to bid for demand reduction that can be compared with the costs of increasing supply, are needed to implement demand-side management. Although estimates of the emissions reductions available through widespread application of this approach vary widely, the removal of regulatory barriers and biases in the market for electric power makes economic sense.

The Limitations of Efficiency Standards

Energy efficiency standards can also be used to overcome information barriers and institutional rigidities. However, this command-and-control approach has several significant disadvantages compared with incentive-based systems or alternative approaches that address perceived market failures directly. First, the burden of meeting standards cannot be reallocated across industries or across the different greenhouse gases in private cost-saving transactions. Second, in the absence of price increases for fossil fuels, standards can increase the demand for energy-using services. Finally, standards reduce the range of products available to meet diverse consumer needs.

The costs of efficiency standards are often hidden. For example, a higher average fuel economy standard might force consumers to buy only the more fuel-efficient and generally cheaper vehicles in the existing product line, thereby actually reducing their purchase and gasoline costs. However, out-of-pocket costs do not reflect costs imposed by denying consumers the option to purchase other valued attributes such as safety, performance, and comfort. Higher fuel efficiency without higher fuel prices also lowers the per mile cost of driving, which encourages more trips, more fuel consumption, and more emissions. Because fuel economy labels already inform consumers about energy consumption, and few apparent institutional rigidities exist, the economic rationale for stringent auto efficiency standards is doubtful at best.

Assertions that efficiency improvements are cost-saving or nearly costless beg the question why these improvements are not automatically taking place. Such assertions must be examined to see if the claimed efficiency gains involve the sacrifice of other product attributes that were excluded from the analysis or market imperfections that could be addressed directly. One must ask whether the analysis considers the entire range of consumer usage rates and energy prices, or is based only on national average values.

In the latter case, efficiency standards may appear to be cost-effective on the national level, while actually restricting the choices of only those consumers who face low energy prices or have low usage rates (and thus energy consumption) for the product. Those with high usage rates or those who face high energy prices would purchase high-efficiency products even in the absence of mandatory standards. Taking this diversity into consideration, an efficiency standard that appears to save money on the national level may actually impose costs.

IMPACTS OF CLIMATE CHANGE

Available assessments of the costs of substantially slowing the rate of greenhouse gas emissions may reach the trillions of dollars. What benefits might be obtained with those costs? This question is difficult to answer, but it is possible to identify several nonmarket impacts of possible future climate change, and to arrive at preliminary estimates of some market effects.

There may be both positive and negative effects of climate change on human health, although these effects are controversial. Temperature extremes—both hot and cold—are associated with higher mortality rates for populations, such as the elderly, that are susceptible to physical stress. These relationships suggest that higher temperatures in winter could reduce weather-related illness and death, whereas higher summer temperatures could increase them. These adverse health effects are not well understood, however, as illustrated by the fact that the average temperature differential between New York City and Atlanta is as large as the most extreme predictions of warming, yet there is no evidence that Atlanta's warmer climate creates a greater health risk than New York's. There could also be changes in the regional distribution of vector-borne diseases, such as those carried by ticks, fleas, and mosquitoes, associated with climate change.

Substantial reductions in economic growth in low-income countries caused by attempts to reduce greenhouse gas emissions could have far greater adverse health consequences than any direct health effects associated with climate change. When one considers the very close relationship around the world between income levels and important health indicators such as infant mortality and life expectancy, it is clear that one of the most important factors affecting health is the ability to afford adequate nutrition and health care.

If global warming occurs, its impact on plants and animals, including humans, is likely to depend on how rapidly it occurs. Both the human and other species' ability to adapt to warming appear to increase if the rate of change is slow. In agriculture, plant breeding and biogenetic techniques can be used to adapt crop varieties to changes in solar radiation, temperature, and moisture. These techniques are more likely to succeed when the incremental changes are small and there is adequate time to undertake adaptive research. In the wild, species can adapt to climate change by moving to suitable environments or adapting to new ones through natural selection. Scientists believe that some wild species of plants and animals may not adapt to rapid climate change and might be lost, thus threatening the biological diversity that has evolved over millions of years. The fact that many medicines contain active ingredients obtained from substances in plants and animals, especially those in the tropics, suggests that a reduction in diversity could represent a significant economic loss.

There is also some reason to believe that extreme weather events may be more important than the increase in average temperature for adaptation to and survival of climate change. A change in the frequency and intensity of hurricanes and tornadoes, for example, could substantially affect their costs, measured in both human life and property.

Sea-level rise is another possible effect of global warming. The U.S. coastline, like the coastlines of other industrial maritime nations, has been extensively developed, with buildings often within

100 feet of the sea. The cost of protecting the entire U.S. shoreline against substantial sea-level rise would be prohibitive, as it would be for many countries with densely populated low-lying areas. The cumulative costs of protecting densely developed shoreline areas from a 20-inch rise is estimated to be between $37 billion and $50 billion, or between $7 billion and $10 billion in present value under the assumption that all costs were incurred in 2025. If the costs of protecting against sea-level rise were spread over the more distant future, as seems likely, their present value would be lower. If the sea level rises gradually and predictably, a reasonable response strategy might include steps to encourage some population and economic activity to relocate inland to higher ground when existing structures come due for routine replacement.

Most sectors of industrial economies are not climate-sensitive, or could adapt to climate changes. The costs of adaptation depend on how rapidly warming occurs. Useful lives of plant and equipment tend to be shorter than 50 years, so that a slow warming trend would permit change in the location and composition of economic activity without major or unanticipated disruptions. More rapid changes could result in loss of some immobile private assets, abandonment of certain public infrastructure, and reinvestment at new locations.

The most significant impacts on industry are likely to be in activities that involve biological processes that are sensitive to temperature and rainfall such as agriculture, forestry, and fishing—which account for about 2 percent of U.S. GNP. Global climate change could have both positive and negative impacts on productivity. Up to a point, higher carbon dioxide concentrations improve the efficiency of photosynthesis and thus increase agricultural productivity. Warming could change the amount and distribution of precipitation and shift cropping patterns regionally, but regional predictions are now considered highly unreliable.

Preliminary analyses show that global climate change could result in a net loss in agricultural productivity, but no evidence shows that it would threaten the world's food supply even under the most pessimistic scenarios. The Department of Agriculture has made preliminary estimates of the regional and global economic impacts of changes in agricultural production that might be associated with warming. Under one scenario, the net global costs of a doubling of atmospheric carbon dioxide were estimated to range from $35 billion to $170 billion annually, with the United States losing $1 billion annually. Equally plausible but less pessimistic assumptions about yield effects implied small net gains to the global and U.S. economies. Underlying these small net effects would be some redistribution of income from consumers to producers through higher agricultural prices.

These estimated impacts on global and U.S. agriculture can be put into perspective by comparing them with the impacts of agricultural policies discussed in Chapter 7. Using the same economic model, Department of Agriculture researchers estimated that the trade-distorting policies now in place around the world impose a net cost on the world of $35 billion annually and $10 billion annually for the United States. Thus, the annual costs of current agricultural policies are estimated to be the same order of magnitude as the estimated agricultural impacts of global warming. However, the agricultural losses from a doubling of carbon dioxide are not likely to occur until well into the next century. For example, using a 5-percent real interest rate, a global loss of $170 billion in 2050 amounts to about $9 billion in 1990 dollars (Box 6–4). Thus, the costs of today's agricultural policies are estimated to be more important in economic terms than even pessimistic estimates of the effects of global warming, largely because the former must be borne in the present and the latter may occur, if at all, in the relatively distant future.

SUMMARY

The United States is taking a leadership role in international efforts to reduce scientific and economic uncertainties about global climate change and to build a common understanding about all aspects of the climate change issue from the basic Earth science, to impacts on human activities, to potential response strategies. The data now available on the economic costs of reducing greenhouse gas emissions suggest that it may be as important to improve understanding of the economics of global warming as it is to improve current ability to predict warming itself.

Policies such as the phaseout of CFCs, the President's clean air proposal, and reforestation can significantly reduce global net emissions of greenhouse gases. At the same time, they can be justified on their own merits. Increased research and development funding and modest changes in fuel prices can reflect the broader social interest in promoting energy conservation. Currently available analyses indicate that near-term stabilization or immediate reduction of carbon dioxide emissions from fossil fuel combustion is likely to impose large economic costs on current and future generations. Such measures must be carefully scrutinized, given the current limited understanding of the impacts and likelihood of global warming. The highest priority in the near term should be to improve understanding in order to build a foundation for sound policy decisions.

Until such a foundation is in place, there is no justification for imposing major costs on the economy in order to slow the growth of greenhouse gas emissions. Policies that may result in slower growth in greenhouse emissions, but can also be fully justified on other grounds, are the best short-run way to address this potential problem while the uncertainties that exist today are reduced. Being justified on other grounds means that a program yields non-greenhouse benefits commensurate with its costs; it cannot mean simply having some non-greenhouse benefits. The adoption of many small programs, each of which would fail a standard cost-benefit test, could significantly slow economic growth and eliminate jobs.

Because the intense research currently underway may reveal that it is desirable to slow the growth of greenhouse gas emissions, it is useful to consider the elements of what would be an economically rational strategy to do so. Any strategy to limit aggregate emissions without worldwide participation would be likely to fail. A cost-effective policy must provide for comprehensive coverage of both sources and sinks of all major greenhouse gases. It must also provide appropriate incentives for emissions reductions and deal directly with market failures. Carbon dioxide emissions, in particular, could be reduced at much lower cost through the use of emissions fees than through government-imposed standards for energy efficiency.

CONCLUSION

There is widespread agreement that both economic growth and environmental quality are desirable policy goals. They need not be incompatible, and are in many respects complementary. Three principles should guide regulation. First, realistic environmental and risk-reduction goals that balance benefits and costs must be set. Second, strategies that work with rather than against market incentives should wherever possible be used instead of less effective command-and-control regulation. Market-oriented approaches, such as marketable air pollution allowances, create incentives for firms to achieve environmental goals in a cost-effective manner. Third, government should support the development and dissemination of scientific and technical information about environmental and health risks.

The Administration's clean air initiative, its proposals to improve pesticide regulation and food safety, and its efforts to improve the understanding of global environmental issues each illustrate how these principles for environmental regulation can be put into action. Other pressing environmental issues will face the Nation in the 1990s and beyond. The application of these principles to all environmental problems will help to achieve both a strong economy and a healthy environment.