Annu. Rev. Energy Environ. 17:187–210

POLLUTION CHARGES FOR ENVIRONMENTAL PROTECTION: A Policy Link Between Energy and Environment

*Robert N. Stavins**
John F. Kennedy School of Government, Harvard University, Cambridge, Massachusetts 02138 and Resources for the Future, Washington, D.C. 20036

*Bradley W. Whitehead**
McKinsey & Company, Inc., Cleveland, Ohio 44114-1873

KEY WORDS: market-based environmental policies, economic incentives, pollution taxes, green taxes, incentive-based environmental policies

CONTENTS

*Stavins is an Associate Professor of Public Policy and a Senior Research Associate, Center for Science and International Affairs, at the John F. Kennedy School of Government, Harvard University, and a University Fellow of Resources for the Future; Whitehead is a Management Consultant for McKinsey & Company, Inc.

MARKET-BASED INCENTIVES FOR ENVIRONMENTAL PROTECTION

Environmental awareness is at an all-time high among the public in the United States (1). In the 1970s, such awareness led to landmark legislation to improve the quality of our air, land, and water. In the 1990s, much of this legislation is before the Congress for reauthorization and the nation is poised to address old and new environmental problems. The lessons learned and the limitations imposed by increasingly scarce resources, however, have altered the perspectives from which citizens and policy makers are seeking solutions that are less costly, require less government intervention, and push technological development further than conventional policies.

This article examines pollution charges, a set of environmental policy instruments that are receiving increased consideration in discussions of many environmental issues. Our purpose here is not to survey—comprehensively or otherwise—the extensive economic literature on pollution charges, which dates back at least to the early 1970s.[1] Rather, our purpose is to provide a brief introduction and overview for researchers and practitioners working in other disciplines of some current thinking on pollution charges and related market-based environmental policy mechanisms in the highly political context of contemporary policy deliberations.

New Environmental Challenges

Historically, US environmental policy has been characterized by a belief that government must compel the market to "behave" environmentally, no matter what the cost, by regulating market forces. Although this approach has produced environmental progress over the past two decades, it has not been without significant side-effects. In particular, this approach has placed unnecessary cost burdens on the economy, has stifled the development of new, more effective environmental technologies, and has engendered excessive litigation and other forms of conflict among regulators, environmentalists, and private industry. As a result, today's policy makers face the challenge of finding ways to "do more with less" while harnessing, rather than obstructing, market forces.

DOING MORE WITH LESS: THE NEED FOR COST-EFFECTIVENESS Environmental protection can no longer be considered in isolation from its costs. This stems in large part from the sheer magnitude of environmental protection expenditures as well as heightened concern over international competitiveness and excessive government intervention. The US Environmental Protection Agency

[1] A. C. Pigou is generally credited with developing the idea of a corrective tax to discourage activities that generate what economists call "externalities," such as environmental pollution. See Pigou (1a). A review of practical design and implementation was provided by Russell (1b).

(EPA) estimates that more than $100 billion is now spent annually by the US economy to comply with federal environmental laws and regulations.[2] In terms of government outlays, federal, state, and local budget deficits make it less likely that environmental protection can be increased simply by spending more money on programs and policies already in place. Citizens are also recognizing the limits of financial resources, as witnessed by the failure of several environmental initiatives in recent elections.

The increased caution about the degree and type of regulatory burdens placed upon businesses, entrepreneurs, and citizens does not imply that citizens and policy makers have stopped worrying about the benefits of environmental protection. To the contrary, environmental concerns continue to surface as major public preoccupations. Instead, the concern is reflected as a desire for cost-effective mechanisms. To some, this means getting more environmental protection for the same level of expenditures. To others, it means getting the same level of protection for less cost. To both, it means making the most of scarce resources and maximizing returns on environmental investments.

HARNESSING, NOT OBSTRUCTING, MARKET FORCES The market has historically been viewed as the principal villain in the pollution "tragedy"; its forces have been blamed for driving firms to ignore the environmental consequences of their activities. According to this viewpoint, market forces must be checked; the government should make decisions that the market cannot or will not make for itself. As a result, the government's proper role has been defined as both setting the goals of policy and intervening in the production process itself by specifying technologies and procedures.

Political leaders are coming to recognize, however, that market forces are not only part of the problem, but also a potential part of the solution. Stopping market forces would not only be virtually impossible, but most likely counterproductive. Policies are needed that mobilize and harness the power of market forces on behalf of the environment, making economic and environmental interests compatible and mutually supportive (3, 4).

Traditional Mechanisms Versus Market-Based Incentives

The policy maker's task separates into two parts; the choice of the overall goal and the selection of a means or "instrument" to achieve that goal (5).[3]

[2]This estimate excludes environmental activities not directly associated with pollution control or cleanup, such as wildlife conservation and land management. The $100 billion estimate covers spending by private business (63.0%), local governments (22.5%), the federal government (11.0%), and state governments (3.5%). For further discussion, see (1c). Jorgensen & Wilcoxen (2) provide a recent analysis of the impact of environmental regulation on productivity.

[3]In practice, of course, the two tasks are linked within the political process because both the choice of the goal and the mechanism for activating it have important political ramifications.

This paper focuses on the latter task—meeting a given goal or standard at minimum cost—although issues of efficiency—selecting that goal that maximizes the difference between benefits and costs—are also considered. Before investigating market incentives, in general, and pollution charges, in particular, it is useful to review the regulatory approach most frequently used—command-and-control.

CONVENTIONAL COMMAND-AND-CONTROL REGULATORY APPROACHES Command-and-control regulations tend to force all firms to behave in the same way when it comes to pollution, shouldering identical shares of the pollution-control burden regardless of their relative costs. Government regulations typically set uniform standards for all firms; the most prevalent standards are technology- and performance-based standards. As the name suggests, technology-based standards specify the method, and sometimes the equipment, that firms must use to comply with a regulation.[4] In one case, all firms in an industry might be required to use the "best available technology" to control water pollution; in a more extreme example, electric utilities may be required to utilize a specific technology, such as electrostatic precipitators, to remove particulates. Performance standards, on the other hand, set a uniform control target for all firms while allowing them some latitude in how they meet it. Such a standard might set the maximum allowable units of pollutant per time period, but be neutral with respect to the means by which each firm reaches this goal.[5]

Holding all firms to the same target can be both expensive and counterproductive. Although uniform standards can sometimes be effective in limiting emissions of pollutants, these standards typically do so at relatively high costs to society. Specifically, such standards can force some firms to use unduly expensive means of controlling pollution.[6] The reasons are simple: the costs of controlling emissions can vary greatly between and even within firms, and the right technology in one situation may be wrong in another. Indeed, the cost of controlling a given pollutant may vary by a factor of 100 or more

[4]Usually, regulations do not explicitly specify the technology, but establish standards on the basis of a particular technology. In situations where monitoring problems are particularly severe, however, technologies are specified.

[5]The text provides only a brief and very general description of the nature of conventional policy approaches. For a detailed description—on a case-by-case basis—of existing command-and-control instruments, see Portney (6).

[6]In a survey of eight empirical studies of air-pollution control, Tietenberg found that the ratio of actual, aggregate costs of the conventional, command-and-control approach to the aggregate costs of least-cost benchmarks ranged from 1.07 for sulfate emissions in the Los Angeles area to 22.0 for hydrocarbon emissions in all domestic DuPont plants. See Tietenberg (7).

among sources, depending upon the age and location of plants and the available technologies.[7]

This regulatory approach also tends to freeze the development of technologies that could provide greater levels of control. Little or no financial incentive exists for firms to exceed their control targets; the system may also discourage experimentation with new technologies. In fact, a firm's reward for developing a new technology may be that it will subsequently be held to a higher standard of performance. As a result, financial resources that could be invested in technology development are diverted to legal battles over what are or are not acceptable technologies and standards of performance.

MARKET-BASED INCENTIVES Market-based incentives equalize the level of marginal costs of compliance among firms, rather than each firm's level of control.[8] They do so by transferring more of the pollution control burden to firms with low costs of control. The result is that for a given level of aggregate control, fewer total economic resources are used (or more pollution control can be achieved for the same level of resources).

While the precise mechanics of market incentives vary by type, they share a basic underlying principle. Simply stated, the government imposes financial incentives (or disincentives) on pollution-related activities that make it in the self-interest of firms and individuals to behave in socially desirable ways. In effect, these systems ensure that environmental costs imposed on society are factored into decision making, i.e.—in the language of economists—they "internalize externalities." Thus, the more costly the government makes it to pollute, the more likely firms are to prevent pollution before it happens. The extent to which they will do so depends on their internal costs of control relative to the disincentive (or incentive). A firm with low marginal costs of controlling pollution could therefore be expected to control more than a firm with high costs. Furthermore, firms will choose the pollution reduction path most appropriate to their situation, whether that be the implementation of control devices, new production processes, a changed product mix, or the development of new technologies. The central role of the government is to establish incentives so that costs incurred by firms are sufficient to achieve

[7]Numerical examples of the variance of incremental costs of air-pollution control are provided by Crandall (7a).

[8]The marginal costs of pollution control are the additional or incremental costs of achieving an additional unit of pollution reduction. If these marginal costs of control are not equal across sources, then the same aggregate level of pollution control could be achieved at lower overall cost simply by reallocating the pollution control burden among sources, so that the low-cost controllers controlled proportionately more and the high-cost controllers controlled proportionately less. Additional savings could theoretically be achieved through such reallocations until marginal costs were identical at all sources.

the desired level of aggregate pollution control, and—as with any regulatory system—to monitor compliance and enforce the law.

A common misperception of incentive systems is that they represent a laissez-faire, free-market approach. This is not the case. They recognize that market failures are typically at the core of pollution problems, but they reject the notion that such failures justify "scrapping" the market system and dictating firm or consumer behavior. Instead, they ensure that environmental consequences are reflected in decision making, but provide a degree of freedom of choice to both businesses and consumers when selecting the best way to reduce pollution. Incentive-based regulations thus harness rather than impede market forces and channel those forces to achieve environmental goals at the lowest possible cost to society at large. Furthermore, they make the environmental debate more understandable to the general public by allowing political attention to be focused on what our environmental goals should be, rather than on difficult technical questions about different means for reaching these goals.[9]

Economic-incentive systems can be thought of at the broadest level as falling into four categories:

1. *Pollution Charges*. Producers of pollution are charged a fee on the amount of pollution they generate. A subset of this category are deposit-refund systems, within which an initial charge (or some portion thereof) is rebated if certain actions are undertaken.
2. *Tradeable Permit Systems*. The government establishes an overall level of allowable pollution and then allots this in the form of permits among firms. Firms that keep their emissions below the allotted level may sell or lease their surplus permits to other firms or use them to offset excess emissions in other parts of their own facilities (8).
3. *Removal of Market Barriers*. In some cases, substantial gains can be made in environmental protection simply by removing existing government-mandated barriers to market activity. For example, measures that facilitate the voluntary exchange of water rights can promote more efficient allocation and use of scarce water supplies, while curbing the need for expensive and environmentally disruptive new water-supply projects (9).
4. *Eliminating Government Subsidies*. Many existing subsidies promote economically inefficient and environmentally unsound development. A major example is provided by the US Forest Service's "below-cost timber sales," which recover less than the cost of making timber available (10).[10]

[9]For an analysis of the problems of EPA's historical focus on technical questions, see Landy, Roberts, and Thomas (7b).

[10]Other examples of economically inefficient and environmentally disruptive subsidies include those associated with US Army Corps of Engineers flood control projects, US Bureau of Reclamation projects, and Bureau of Land Management and Forest Service public lands grazing programs. On these, see (5).

These subsidies encourage excessive timber cutting, which leads to substantial loss of habitat and damage to watersheds.

CHOOSING BETWEEN TRADITIONAL MECHANISMS AND MARKET-BASED INCENTIVES Both command-and-control and incentive-based mechanisms serve a purpose in environmental protection. Command-and-control approaches tend to be more applicable in situations that involve highly localized effects and threshold damages and where concern thus focuses on the level of pollution emitted by individual sources. Incentive-based systems, on the other hand, are most appropriate for problems of aggregate pollution over relatively large areas (e.g. acid rain and global climate change), since less control is exercised over the emissions of any specific site.

The primary advantage of market-based incentives is their cost-effectiveness; however, cost-effectiveness is not the sole criterion policy makers should use to evaluate existing or proposed policies. The notion of fairness or equity is prominent among the other major criteria, which include information requirements, monitoring and enforcement capability and costs, political feasibility, and clarity to the general public (11, 11a). Most environmental policies require some trade-off between economic efficiency or cost-effectiveness and equity. Even when the aggregate benefits of a policy greatly exceed its aggregate costs, there are usually some individuals or firms who are made worse off.

Whether such groups should be compensated as part of policy design is, to a large degree, a political question. Its answer will depend upon alternative notions of fairness. What is important is that mechanisms do exist for providing compensation to those affected by incentive-based policies, if this is deemed appropriate. In general, when some form of adjustment is merited, it may be desirable to link it to the nature of the harm done (12). For instance, if a policy raises energy prices, these may impose a particular burden on low-income households. The response in such a case may be to implement "lifeline" rates for initial increments of energy use. If employees are displaced, job-search and job-training programs can soften the impact. When the Clean Air Act was reauthorized in 1990, a program was established to provide job-training and other forms of compensation for workers displaced by the new law, at an estimated cost of $250 million over five years (13).

POLLUTION CHARGES: WHAT THEY ARE AND HOW THEY WORK

This section describes the mechanics of pollution charge systems, reviews our experience with them, discusses ways to use the revenues collected, and compares charges with tradeable permits.

The Mechanics of Pollution Charge Systems

Charge systems reduce polluting behavior by imposing a fee or tax on polluters. Ideally, the fee should be based upon the amount of pollution they generate, rather than on their pollution-generating activities.[11] In some cases, however, it may be based upon the expected or potential quantity of pollution.

The Organization for Economic Cooperation and Development (OECD) distinguishes five types of pollution charges: *effluent charges,* based upon the quantity of discharges; *user charges,* such as payments for public treatment facilities; *product charges,* which are based upon the potential pollution of a product; *administrative charges,* which are payments for government services such as registration of chemicals; and *tax differentiation,* which provides more favorable prices for "green" products (14).

A true pollution charge provides incentives to firms (or consumers)[12] to reduce "emissions" by modifying their decision making. In the presence of a pollution charge, firms will reduce pollution when that is the less expensive option, and they will pay the pollution charge when that is less costly. Firms will reduce pollution up to the point at which their marginal costs of control are equal to their pollution-tax rates. As a result, firms will control to different degrees; firms with high marginal costs will control less, and those with low costs will control more.

Charge systems force firms to internalize the externalities they create in the course of production. Pollution poses real costs to society (for example, health consequences, property damages, and aesthetic impacts), but firms typically do not have to pay for these damages and hence face little or no incentive to take them into account in production decisions. Pollution charges place an explicit value on these "external" consequences and force firms to recognize and pay for them or the cost of avoiding them.

Pollution charges also provide strong incentives for firms to develop and adopt new, improved control technologies (15). Under command-and-control, firms face little financial incentive to perform better than the standard. Pollution charges, however, do not specify a technology or a fixed standard. Charges are incurred for each increment of pollution (rather than only for pollution above a standard), motivating firms to improve their financial

[11]For example, a pollution charge might take the form of a charge per unit of sulfur dioxide emission, not a charge per unit of electricity generated. The choice of whether to tax pollution quantities, activities preceding discharge, inputs to those activities, or actual damages depends on trade-offs between costs of abatement, mitigation, damages, and program administration, including monitoring and enforcement.

[12]Pollution charges can be applied either to producers or consumers. In the rest of the chapter, we refer only to firms (and production), although the same concepts apply to consumers.

performance by developing technologies that allow them to increase their pollution control.

Identifying the desirable charge level is critical. If the charge is set too high, production will be curtailed excessively; if the charge is set too low, insufficient environmental protection will result. Finding the right level presents policy makers with both theoretical and practical challenges. As with any regulatory system, policy makers must seek an overall target that balances control costs, benefits, and equity. Theoretical and political questions of economic efficiency and distributional "fairness" generally arise. At a more practical level, however, the linkage between charges and control must be determined. Estimating this relationship can be difficult, especially given our limited experience with charge systems; and while experimentation with various charges to find the right level might arguably be desirable, political realities and the creation of uncertain economic expectations is likely to prevent such tinkering with the tax system.

Adoption of Charge Systems

True pollution charge systems have not been adopted in the United States. Although a few policies have embraced some "green tax" characteristics, these mechanisms are aimed primarily at generating revenue rather than discouraging pollution. The US approach to chlorofluorocarbons (CFCs) is a good example. In 1989, Congress enacted an excise tax on CFCs (16), which deplete stratospheric ozone. As part of the Montreal Protocol and the subsequent London Revisions of 1990, the United States agreed with other nations to phase out all CFCs by the year 2000 (17, 18). The primary mechanism for the United States to achieve its targets is a tradeable permit system, however, and the excise tax does not materially affect either the level or rate of the CFC phase down. Instead, it is simply a charge on the sale of permits whose purpose is to ensure that any windfall profits associated with constrained supply accrue to the government rather than to private industry (19).

Although many European nations[13] have implemented air- or water-pollution charge mechanisms, these systems also function primarily to generate revenues rather than to discourage pollution. Even when mechanisms are intended to create pollution-reduction incentives, the fee levels are often set too low to change producer behavior (20). One partial exception is the Effluent Charge Law adopted by the Federal Republic of Germany in 1976 (21). However, even this charge is not a fully functioning market incentive;

[13]Included are the United Kingdom, France, the Netherlands, Sweden, Norway, Denmark, Finland, Italy, and Germany.

because the fee is linked to uniform performance standards, marginal costs of control are not equalized and full cost-savings potentials are not realized (22).

Collected Revenue Utilization

One major by-product of charge systems is a flow of financial resources from polluters to the government. This financial transfer can be substantial; the Congressional Budget Office estimates that a $100 per ton charge on carbon dioxide (CO_2) emissions (to address global climate change) could result in more than $120 billion in annual revenues to the government (23). This raises the obvious question of how such revenue should be used.

At least three possible courses of action are readily identifiable: investments in pollution control; deficit reduction; and reductions in other taxes (24). The first option is to use the tax revenue to finance other environmental programs (such as mitigation and cleanup) without increases in other taxes. The second option—reducing the federal budget deficit—has obvious appeal; Paul O'Neill, of the Aluminum Company of America (Alcoa), suggested in the summer of 1990 that energy taxes could most effectively accomplish the dual goals of reducing pollution and reducing the budget deficit (25). The most attractive option, however, may be the third—using pollution-charge revenue to offset reductions in other taxes.

Pollution charges are "corrective" taxes that actually reduce market inefficiencies (by discouraging undesirable activities, such as pollution, which cause externalities). This effect contrasts sharply with that of most other taxes, including corporate profit, Social Security and other payroll, and personal income taxes, which tend to distort market functioning and generate inefficiencies by discouraging fundamentally desirable activities such as labor and the generation of capital (26).

The corrective nature of pollution charges provides a "double dividend" (27): a revenue-neutral tax policy change, combining the introduction of pollution charges with the reduction or elimination of other taxes, would both protect the environment by reducing harmful emissions and offset market distortions associated with other taxes (for example, US personal and corporate income taxes generate distortions or pure losses of 20 to 50 cents for every new dollar of revenue collected) (28). This double dividend may be particularly relevant in today's political climate where policy makers are reluctant to consider any new taxes.

Comparing Charges with Tradeable Permits

Pollution charges are frequently seen as an alternative to tradeable permits, another incentive-based mechanism. While both possess advantages, their applicability depends upon both the specific environmental problem being addressed and the particular objectives of the public policy. This section offers a quick comparison of the two systems to highlight the circumstances under which each is likely to be most appropriate.

1. Permits fix the level of pollution control while charges fix the marginal costs of pollution control. Under a permit system, policy makers determine how much total pollution can occur (through the issuance of permits), but they cannot set bounds on expenditures for pollution control. This strategy could be particularly appropriate for environmental problems with tight margins of error or with marginal costs of control that do not rise dramatically with increasing regulatory stringency. Charge systems, on the other hand, control the maximum amount that a firm may pay for each increment of emissions, but do not dictate with certainty how much control will actually occur. Such a tactic may be more suitable where the margin of error on damages is not tight but the potential industrial impacts of "over-control" are especially great (28a). This could occur, for example, where small increases in control costs lead to very large swings in production and employment.

2. In the presence of technological change and without additional government intervention, permits freeze the level of pollution control while charges increase it. Under a permit system, technological improvement will lower pollution-control costs and permit prices, rather than emissions levels, unless the government intervenes. Such technological change under a charge system, however, will both lower total pollution-control costs and increase levels of control. Although firms will choose to control more emissions and pay less taxes, this can be offset by the expanded production that results from lower operating costs.

3. With permits, resource transfers are private-to-private while they are private-to-public with pollution charges.[14] Under permit trading, firms choosing to emit pollution beyond their initial permitted level must make payments to other firms who agree to control more than their initial share. With charges, payments for uncontrolled emissions flow to government. For those who believe that the private sector can utilize these resources more effectively, permits offer an advantage over charges. Alternately, the government can earmark the revenue from charges for environmental investments, deficit reduction, or reductions in distortionary taxes.

4. While both charges and permits impose costs on industry and consumers, charge systems make the costs more explicit to both groups. Both charges and permits force firms to internalize the costs of their pollution, either through expenditures on pollution controls or through cash payments (buying permits

[14]This assumes that permits are distributed free of charge to firms, not auctioned by the government. In the latter case, permits and charges are quite similar in terms of these financial transfers. In actual applications, tradeable permit systems have always involved free distribution of permits to firms.

or paying charges). Charge systems, however, make these costs very visible both to industry and the public. While this may be problematic for short-term political reasons, it may ultimately be advantageous in that it can educate the public about the costs and trade-offs associated with various levels of environmental control.

5. *Permits adjust automatically for inflation, while charges do not.* Because a permit system's "currency" is emission rights, price movements in the overall economy will not affect levels of emissions control. Under a charge system, however, inflation would reduce the taxes (which are expressed in dollars per ton, for example) in real terms. Firms would therefore control less. An obvious way to resolve this problem would be to link the charge rate to some price index.

6. *High transaction costs can drive up the total costs of compliance, having a negative effect under either system.* Transaction costs (e.g. costs associated with identifying willing buyers and sellers of permits or costs of tax collection) can decrease the amount of trading that will occur in a marketable-permit system (29) and the amount of pollution control that will be achieved with a charge system.

7. *Permit systems may be more susceptible to "strategic" behavior.* If any one firm controls a significant share of the total number of permits, its activities may influence permit prices. Although no magic cut-off point exists, it is unlikely that firms could engage in price-setting behavior if they controlled less than 10% of the market (30). If other firms present credible threats of entry to the market, it is less likely that anticompetitive behavior can thrive (31).

APPLICATIONS OF POLLUTION CHARGES

Pollution charges can address a variety of environmental problems at various levels of government. The list of potential applications includes many forms of air and water pollution, as well as many solid and hazardous waste problems. In the remainder of this paper, we consider two particularly promising areas for action—greenhouse-gas reduction and cleaner energy production—and briefly cover other applications.

Greenhouse-Gas Reductions

Few of the environmental problems that have arisen since the beginning of the industrial revolution have posed greater risks or uncertainties than the threat of global climate change due to the greenhouse effect. If emissions of carbon dioxide (CO_2) and other greenhouse gases (such as methane and nitrous oxides) continue to grow at current rates, many scientists believe that global mean temperatures may rise by 2 to 5 degrees Fahrenheit over the next century. Such an increase could cause widespread changes in precipitation patterns, storm frequencies and intensities, and ocean levels (32, 33).

International negotiations are focusing on how much to limit emissions and how to allocate the control burden among nations.[15] Given the importance of CO_2 to the global-warming phenomenon and the central role fossil fuels play in the US economy, cost-effective approaches would be an essential part of minimizing economic dislocations while complying with international agreements.

CO_2 CHARGES TO COMBAT GLOBAL CLIMATE CHANGE A properly designed CO_2 charge system could enable the United States to achieve a national CO_2 target cost-effectively. Such a system would increase the costs of CO_2 emissions via taxes and possibly reduce the cost of CO_2 sinks via tax credits (35). A charge based on the CO_2-releasing potential of fossil fuels (coal, oil, and natural gas) could use higher prices to internalize the anticipated costs of climate change. This would reduce direct demand for fossil fuels and would stimulate the development of new, less carbon-intensive technologies. Thus, both fossil-fuel use and emissions of carbon dioxide would decrease.

The CO_2 charge system would be far more cost-effective than conventional approaches. By encouraging low-cost controllers to take on added control burdens, it could reduce total industry costs. Its administrative costs would also be much lower than those of conventional regulatory approaches that must set different standards for each of the industrial, commercial, and residential uses of each fuel. Given the thousands of uses involved, determining, monitoring, and enforcing standards would be virtually impossible. By contrast, a CO_2 charge would require essentially one tax rate for each fuel type. CO_2 charges would also create ongoing incentives for technological innovation, since firms could use more efficient technologies to reduce their fossil fuel consumption and thus lower their tax obligations.

Although the ideal charge system would be based upon the quantity of CO_2 emitted, the vast number of individual sources of CO_2 emissions makes such a system impractical. One alternative is a charge on coal, crude oil, and natural gas, based on the fuel's carbon content[16] (carbon content is roughly proportional to the amount of CO_2 emitted upon combustion). This charge could be imposed at the point of entry for imported fuels and at the point of primary production for domestic fuels. There would be no need for additional

[15]The first round of negotiations was held in February of 1991, partly in preparation for the United Nations Conference on Environment and Development, to be held in Brazil in June of 1992. For an investigation of how a tradeable-permit system could lead to a cost-effective international agreement, see Stavins (34).

[16]Noncombustible feedstocks should be exempted.

charges on refined petroleum products or on other goods derived from fossil fuels.[17]

The charge level should encourage reductions in CO_2 emissions sufficient to achieve the country's national targets. This is easier said than done. While it is clear that a carbon charge could significantly reduce fossil-fuel use, the relative impacts of different charge levels are very uncertain. Projections by the Congressional Budget Office (37), for instance, indicate that a $100 per ton carbon charge, phased in over 10 years, would achieve emissions levels in the year 2000 that are 8% to 36% lower than the levels that would occur without a charge.[18] The EPA, on the other hand, estimates that a $25 per ton fee would, by the year 2000, reduce annual domestic carbon emissions by 8% to 17% (38).

How large a carbon charge would be needed to cut CO_2 emissions by 20% from their 1990 levels? According to one analysis (39), a $200–$400 per ton charge would be required to achieve such reductions between 2010 and 2040; maintaining emissions at this level for the longer term (2050 and beyond) would require a $250 per ton charge. However, the model used to derive these figures (Manne-Richels) has been criticized because of its conservative assumptions and failure to provide for endogenous technological change (40).

The impacts of a carbon charge on US economic activity cannot be overlooked. If a phased-in $100 per ton charge were unilaterally adopted by the United States, the Congressional Budget Office estimates, it could lead to a 2% annual loss in GNP (from baseline projections) by the time it was fully implemented; this 2% loss could, however, be greatly reduced by other nations acting in concert and/or a revenue-neutral policy that offsets carbon taxes with reductions in other taxes.

A revenue-neutral approach could also mitigate some of the tax's impact on low-income households. By some measures, lower-income households spend a larger share of their incomes on fossil-fuel-related products than do

[17]A viable alternative to the carbon charge is a Btu charge, with the tax being based on the energy produced in the burning of the fuel rather than on the fuel's carbon content. If the principal goal is to reduce CO_2 emissions, the carbon charge is theoretically superior, because it targets more effectively the source of emissions, but if the Btu charge is applied only to fossil fuels, the difference in cost-effectiveness between the two is not dramatic. See Jorgensen & Wilcoxen (36) for discussion.

[18]The phased-in $100 per ton charge would begin with a $10 per ton charge in the year 2000 (all figures in 1988 dollars). The models used for short-term projections to the year 2000 are the simulation model developed by the Energy Information Administration (EIA) of the US Department of Energy. the Data Resources Incorporated (DRI) quarterly econometric model of the US economy, and the Dynamic General Equilibrium Model (DGEM) developed at Harvard University by Dale Jorgensen and his collaborators.

more affluent households. As a result, a carbon charge might hit these households harder. Both a revenue-neutral approach and "lifeline rates" (lower rates for initial increments of energy use) could reduce the pressure on low-income households.

Regional distribution of the charge could also present some problems; preliminary studies indicate that the distribution of the carbon charge burden could vary regionally by as much as 50% (41). In particular, the high carbon content of coal, relative to other fuels, would translate into relatively greater costs/taxes for coal-producing regions. For example, a phased-in $100 per ton carbon charge could reduce coal use by 13% annually by the year 2000 (42). It should be recognized, however, that regional impacts would be essentially the same if a conventional emission-standard approach were adopted, and that this argument deals more with taking any action against fossil fuels than with the choice between market-based and conventional regulations.

THE SPECIAL CASE OF GASOLINE TAXES Increases in gasoline taxes are frequently discussed as a way to deal with a broad set of environmental and other problems (43). The attractiveness of this policy depends on its objectives; if the focus is purely on CO_2 emissions, a gasoline tax will be less attractive than a carbon tax, which is linked more directly with carbon emissions. However, gasoline taxes can be a legitimate instrument for dealing with some environmental problems directly related to the burning of gasoline (e.g. emissions of air pollutants) (44), recognizing the practical difficulties associated with a true emissions tax in this context.

In addition to reducing air pollution, gasoline taxes could provide significant energy-security benefits by reducing the nation's overall demand for petroleum products.[19] They should also reduce highway congestion (45). According to the Department of Energy, a 50-cent gas tax increase could eventually reduce gasoline consumption by 10% to 15%, reduce oil imports by 500 thousand barrels per day, and generate about $40 billion per year in revenue. Gasoline taxes could become even more cost-effective if the EPA changed its regulatory standards from "grams of pollutants per mile traveled" to "grams of pollutants per gallon of fuel burned" (46).

Gasoline taxes would also be far more effective than many of the current proposals for reducing gas consumption. While many of these proposals (e.g. "gas guzzler" taxes and "gas sipper" rebates) can help overcome the observed tendency of consumers to favor products with low initial (and high long-run) costs, these policies provide no incentives for people to modify their driving habits once they have purchased their cars and trucks (47). Some are actually

[19]More direct ways of internalizing the "national security externality" exist (e.g. import levies).

harmful; increasing the fuel-efficiency (CAFE) standards for new cars creates an incentive for owners to hold onto old gas guzzlers and leads to serious safety problems by encouraging auto makers to produce lighter vehicles (48, 49). A gasoline charge system would circumvent most of these problems.

This is not to say that gas taxes do not pose challenges themselves. In order for them to be feasible, a way must be found to address the greatest concern about higher gas taxes: that they would hit those workers who drive to their jobs the hardest. Fortunately, a revenue-neutral approach that transfers the revenue from the gas tax to the Social Security Trust Fund and credits it to current workers would alleviate this burden. If $40 billion per year from a new 50-cents per gallon gas tax were paid into Social Security, the payroll tax (the employee contribution to Social Security) could be cut by almost a third; a worker with annual wages of $30,000 would take home an additional $700 per year. The extra income would more than offset the cost of the gas tax, unless the worker drove more than 35,000 miles per year in a car getting 25 miles or less per gallon. Such a tax could also be phased in gradually (10 cents per year over 5 years), allowing individuals and firms to adjust their consuming and producing behavior. While gasoline taxes can make a significant contribution to environmental protection, it is unlikely that the public would tolerate both a carbon and a gas tax. This consideration, combined with the fact that many of the problems associated with gasoline consumption are local (e.g. smog and traffic congestion), may eventually suggest a split approach: a carbon charge at the federal level and supplementary gasoline taxes at the state level.

Cleaner Energy Production: Environmental Costing at Electric Utilities

Energy production is obviously a fulcrum for addressing many environmental problems, and the single most important point of leverage is probably the regulated utility sector that distributes electricity and natural gas. Such energy accounts for almost half of US carbon dioxide emissions and more than two-thirds of its sulfur dioxide emissions. However, the different sources of the energy distributed by utilities impose unequal costs on society. First, some sources of energy, such as natural gas, are "cleaner" than others. Second, in some cases, the most cost-effective and least environmentally harmful method for making up a projected energy shortfall will be through conservation rather than capacity addition.[20] One way to incorporate these differences is to adjust the bids in energy auctions to account for environmental externalities.

At most energy auctions, capacity proposals are judged solely in terms of

[20]Demand-side options include funding of conservation investments, promotion of appliance efficiency, audit services, and educational programs. See Goldman, Hirst, and Krause (50).

private costs to the energy utility; the environmental costs imposed on society (except insofar as environmental regulations have already raised a generator's costs) are left out of the equation. Adjusting bids to reflect the environmental externalities associated with energy alternatives (e.g. local and regional air pollution, contributions to global climate change, and risks associated with nuclear power generation and waste disposal) would ensure that the prices reflect both environmental and direct (internal) costs. State and federal planners and utilities might, when comparing alternatives for meeting long-term energy needs, assign each energy source a carbon-based penalty that varies with that source's relative level of CO_2 emissions, or, more broadly, penalties that vary with the environmental costs of some set of emissions, including CO_2 and SO_2. However, the effects of existing environmental regulations need to be taken into account when establishing these environmental "adders".

Despite the soundness of the basic idea of environmental costing, the difficulty of designing such systems properly ought not to be underestimated; serious flaws can be found in most of the mechanisms given serious consideration by state regulatory bodies. As outlined above, the damages associated with the combustion of a given fuel should form the basis of its "environmental cost" when comparing alternative energy options. Yet every state commission that ordered consideration of external environmental costs through 1990 chose to ignore these economic impacts in favor of a more easily obtained "proxy"—the cost of controlling pollutant emissions (51).

Unfortunately, pollution control costs cannot serve as an adequate proxy for pollution damages. Indeed, the costs of controlling a given pollutant do not necessarily bear any direct relation to the environmental damage it causes. Relying upon control costs instead of true economic measures of environmental damages may, at worst, offer less environmental quality; at best it offers environmental protection at far higher costs than necessary (52).

The right way to carry out environmental costing is to evaluate the environmental damages of alternative energy options in economic terms.[21] This is not a trivial task. It is essential that "emission fees" be placed on all sources of generation, both old and new; otherwise, an environmental costing system can provide incentives to maintain existing dirty plants, rather than building clean, new ones. The result can be a net increase in emissions from what would be experienced in the absence of such an environmental costing system (53).

Although the available methods for valuing environmental damages—pref-

[21]This charge would need to be adjusted for any pollution charges already being imposed. For example, if a carbon charge were in place, damages associated with CO_2 emissions would need to be reduced by the amount of the charge.

erence-revealing surveys, Hotelling-Clawson-Knetsch methods, hedonic pricing studies, and experimental markets—contain substantial uncertainty (54, 55, 55a), significant advances have been made. These methods are now used regularly to produce economic estimates of environmental damages in a variety of contexts, including: Executive Order 12291; the Natural Resource Damage Assessments mandated by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and environmental litigation, as in the Exxon *Valdez* Case. Thoughtful application of these methods can, in principle, produce appropriate environmental costing. EPA and other agencies can help states and their utility commissions develop correct procedures for evaluating the environmental costs of alternative energy options.[22]

Adoption of appropriate environmental costing by electrical utilities would likely bring significant benefits to society as a whole, but might have negative consequences for some segments of the population. Pricing mechanisms that more closely reflect the true social marginal costs of energy will probably raise electricity prices, as utilities shift away from relatively dirty to cleaner energy sources; price increases resulting from internalizing typical damage-cost estimates would likely range from 20% to 75% (56). Low-income households will likely be most affected by these changes. To the extent that electricity is vital to the well being of all members of society, an increase in energy prices to low-income households will be socially undesirable. One component of policy design, therefore, may be utility pricing schedules that set very low prices for initial increments of energy consumption (via "lifeline rates"). In this way, the ability of low-income households to meet essential needs would not be compromised.

Other Applications of Pollution Charges

The systems described in this article are just two examples of how pollution charges and user fees can deal with contemporary environmental problems; many other potential applications exist. Two of the most important are in solid waste and hazardous waste management.

SOLID WASTE MANAGEMENT The increasing volume of solid waste our society generates has emerged as a pressing problem in many parts of the United States over the past decade. Many areas are running out of designated landfill space (57), and numerous communities have effectively blocked the construction of new facilities. This situation has led to calls for reductions in

[22]A step in this direction was made in the Clean Air Act Amendments of 1990, which require the Federal Energy Regulatory Commission, in consultation with EPA, to develop models for incorporating net environmental benefits into the regulatory treatment of renewable energy.

solid waste generated. Doing this cost-effectively, however, can be a complex task.

Most waste reduction efforts to date have used conventional command-and-control regulations. These policies have raised costs, despite having little effect on targeted problems. Their failure is due in large part to flawed pricing mechanisms that do not reflect the real costs of generated wastes. Most individuals and firms never "see" the costs of waste disposal; these costs are simply embedded in other taxes. As a result, the cost of throwing away an additional item of refuse is essentially zero. By way of comparison, imagine what kind of cars we would buy and how much we would drive if our total annual bill for gasoline was independent of the quantity of gasoline we used.

Effective waste management strategies must "get the prices right." They must create incentives for consumers to generate less waste—either through greater recycling and greater reuse of materials, or by demanding less wasteful packaging and products from manufacturers. Decisions of individuals and firms should reflect the incremental costs of waste disposal. These costs can be inserted at any point in the product life cycle; three incentive-based approaches are: (*a*) curbside waste collection charges at the point of disposal; (*b*) retail disposal charges at the point of sale; and (*c*) virgin material taxes in the production process itself.

The first option explicitly links household charges to the real costs of collection and disposal; it charges citizens for the specific quantity of waste they generate.[23] The second option, retail disposal charges, incorporates the costs of disposal at the point of product purchase. Communities place surcharges on the sale of items that reflect the items' costs of disposal (58). Finally, virgin materials taxes impose disposal charges at the point of production.[24] This policy encourages switching to materials and products with lower costs of disposal and favors recyclable materials, as the costs of virgin materials would rise more than those of secondary ones.

HAZARDOUS WASTE MANAGEMENT Improved price signals can reduce the volume of waste reaching landfills and incinerators. In some cases, however, waste disposal, not waste generation, is the problem. Deposit-refund systems, which combine a special front-end charge (deposit) with a refund payable

[23]Unit pricing can lead to efficient (or cost-effective) levels of reliance on alternative waste disposal methods only if prices reflect accurately the real, incremental costs of these alternatives. Many municipalities, however, have underpriced waste disposal services by incomplete cost accounting and use of average rather than marginal-cost pricing. There have also been problems with the cost calculations associated with specific disposal alternatives. For example, landfilling was formerly underpriced, owing to weak environmental regulations. See Savas (57a).

[24]A frequently discussed example is newly mined lead. See Sigman (58a).

when quantities of the substance in question are turned in for recycling or proper disposal, represent a cost-effective way to manage some types of toxic wastes.[25]

Deposit-refund systems are most relevant for products with very high costs of improper disposal; in such cases, the costs of separation and redemption are usually outweighed by the benefits of proper disposal. The best regulatory sequence may involve initial experiments with deposit-refund systems for toxic but not officially "hazardous" wastes. As such systems are improved, they may alter or replace parts of the "cradle-to-grave" tracking system of the Resource Conservation and Recovery Act (RCRA). Deposit-refund systems would eventually focus on a variety of products, including lead-acid batteries, some industrial chemicals (e.g. chlorinated solvents), and used lubricating oils.[26]

AIR/WATER POLLUTION Pollution charges could be used to address the difficult problem of nonpoint source water pollution. An "environmental damage potential" charge on the sales of pesticides and other agricultural chemicals would encourage farmers to use these chemicals more efficiently and would provide incentives for manufacturers to find less environmentally harmful substitutes.

Similarly, the United States could follow the example of Germany and implement effluent charges on water pollution. Such charges would encourage firms to reduce emissions below levels currently allowed through discharge permits. Emissions charges could also be used for many air pollutants, even where standards are already in place.

A set of related policies could help address environmental problems associated with automobile use in major cities. In particular, "congestion pricing" with new electronic-scanner technology could be used to charge drivers a toll for rush-hour trips. Other mechanisms that could reduce total miles traveled in automobiles and therefore air pollution include employee parking charges, increased charges for public parking, and smog taxes (59).

RESOURCE MANAGEMENT Increased emphasis on user fees for public forests could reorient forest managers away from their dependence on timber revenues (60). Although estimates place recreational use at 41% of gross US Forest Service forest value, recreation generates only 3% of Forest Service revenues. Substantial precedent suggests that users of publicly owned natural resources should pay for a portion of the benefits they receive. For example, the Pittman

[25]For a detailed investigation of deposit-refund systems, see Bohm (58b) and Russell (58c).

[26]For an examination of deposit-refund systems and other incentive-based policy mechanisms for used lubricating oil, see Anderson, Hofmann, and Rusin (58d).

Robertson Federal Aid in Wildlife Restoration Act of 1937 levies an 11% manufacturer's excise tax on sporting rifles, shotguns, ammunition, handguns, and archery equipment.

CONCLUSION

The pollution charge mechanisms examined in this article can help begin to move the United States away from dependence on distortionary taxes, which discourage socially desirable behavior such as labor and the generation of capital, and instead towards greater reliance on "green taxes," which discourage and reduce socially undesirable behavior (e.g. environmental pollution and natural resource degradation).

These taxes accomplish this in a number of ways. First, they lower the total costs of control to society while achieving the same level of aggregate control as conventional regulations. Second, they encourage rather than hinder the development of alternative technologies, and third, they promote awareness of true environmental costs among both firms and consumers. In so doing, they provide an opportunity to capture the "double dividend" of increasing pollution control while raising government revenue in ways that do not distort markets.

Application of pollution charges to both the threat of global climate change and the need for cleaner energy production are possible. Charges linked to the carbon content of fossil fuels may provide a feasible alternative for reaching CO_2 emission reduction objectives at the lowest cost to society; and by properly realigning the price structures used by electrical utilities to include the environmental impacts of alternative fuels, energy producers can be led closer to the right mix of resource-use options.

As new environmental problems arise and old ones persist, the limited resources of government agencies and society at large will be stretched further and further. Pollution charges and other incentive-based instruments offer opportunities to continue environmental protection while cost-effectively leveraging existing resources.

ACKNOWLEDGMENTS

Editorial assistance was provided by Sarah Smith-Lee and Ilana Cohen. This article draws, in part, upon a paper originally prepared for the Progressive Policy Institute, Washington, DC. Comments provided by two anonymous referees and the editors of this journal are gratefully acknowledged. The authors alone are responsible for any remaining errors.

Literature Cited

1. Dunlap, R. E., Scarce, R. 1991. The polls—poll trends: environmental problems and protection. *Publ. Opin. Q.* 55:651–72
1a. Pigou, A. C. 1952. *The Economics of Welfare*. London: MacMillan. 4th ed.
1b. Russell, C. S. 1979. What can we get from effluent charges? *Policy Anal.* 5:155–80
1c. US Environ. Protect. Agency. 1990. *Environmental Investments: The Costs of a Clean Environment*. Report of the Administrator to the Congress of the United States. Washington, DC
2. Jorgenson, D., Wilcoxen, P. 1990. Environmental regulation and economic growth. *Rand J. Econ.* 21:314–40
3. Stavins, R. N., ed. 1988. *Project 88: Harnessing Market Forces to Protect Our Environment—Initiatives for the New President*. A Public Policy Study sponsored by Senator Timothy E. Wirth, Colorado, and Senator John Heinz, Pennsylvania. Washington, DC
4. Stavins, R. N., ed. 1991. *Project 88—Round II: Incentives for Action: Designing Market-Based Environmental Strategies*. A Public Policy Study sponsored by Senator Timothy E. Wirth, Colorado, and Senator John Heinz, Pennsylvania. Washington, DC
5. Hahn, R. W., Stavins, R. N. 1991. Market-based environmental regulation: A new era from an old idea? *Ecol. Law Q.* 18:1–42
6. Portney, P. R., ed. 1990. *Public Policies for Environmental Protection*. Washington, DC: Resourc. for the Future
7. Tietenberg, T. H. 1985. *Emissions Trading: An Exercise in Reforming Pollution Policy*. Washington, DC: Resourc. for the Future
7a. Crandall, R. W. 1984. The political economy of clean air: Practical constraints on White House review. In *Environmental Policy Under Reagan's Executive Order: The Role of Benefit-Cost Analysis*, ed. V. K. Smith, pp. 205–25. Chapel Hill: The Univ. of N. Carolina Press
7b. Landy, M. K., Roberts, M. J., Thomas, S. R. 1990. *The Environmental Protection Agency: Asking the Wrong Questions*. New York: Oxford Univ. Press
8. Hahn, R., Noll, R. 1982. Designing a market for tradeable permits. *Reform of Environmental Regulation*, ed. W. Magat, pp. 119–46. Cambridge: Ballinger
9. Willey, Z., Graff, T. 1988. Federal water policy in the United States—An agenda for economic and environmental reform. *Columbia J. Environ. Law* 13:325, 349–51
10. Bowes, M. D., Krutilla, J. V. 1989. *Multiple-Use Management: The Economics of Public Forestlands*. Washington, DC: Resourc. for the Future
11. Stavins, R. N. 1991. See Ref. 4, pp. 1–13
11a. Bohm, P., Russell, C. S. 1985. Comparative analysis of alternative policy instruments. In *Handbook of Natural Resource and Energy Economics*, Vol. I, ed. A. V. Kneese, J. L. Sweeney, pp. 395–460. Amsterdam: North-Holland
12. Burtraw, D., Portney, P. R. 1991. The Role of Compensation in Implementing Market-Based Environmental Policies. Presented at Project 88/Round II seminar series, John F. Kennedy Sch. Gov., Harvard Univ., Cambridge, Mass.
13. Schneider, K. 1990. Lawmakers reach an accord on reduction of air pollution. *New York Times*. Oct. 23, pp. A1, A18
14. Organ. for Econ. Coop. Dev. 1989. *Economic Instruments for Environmental Protection*. Paris: OECD
15. US Environ. Protect. Agency. 1991. *Economic Incentives: Options for Environmental Protection*. Washington, DC
16. US Congress. 1989. *The Omnibus Budget Reconciliation Act of 1989 Section 7506: Excise Tax on the Sale of Chemicals Which Deplete the Ozone Layer and of Products Containing Such Chemicals*. Washington, DC: US Congress
17. United Nations Environ. Programme. 1987. *Montreal Protocol on Substances that Deplete the Ozone Layer, Final Act*. Nairobi: United Nations Environ. Programme
18. United Nations Environ. Programme. 1990. *Report of the Second Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer*. Nairobi: United Nations Environ. Programme
19. Harrison, D. Jr., Nichols, A. L. 1990. *Tradeable Permits and Other Economic Incentives for Environmental Protection: Final Report*. The Canad. Electrical Assoc. Workshop on Tradeable Permits. Cambridge, Mass: Natl. Econ. Res. Assoc.

20. Organ. for Econ. Coop. Dev. 1989. See Ref. 14
21. Brown, G. M. Jr., Johnson, R. W. 1984. Pollution control by effluent charges: It works in the Federal Republic of Germany, why not the U.S.? *Natur. Resourc. J.* 24:929–66
22. Harrison, D. Jr., Nichols, A. L. 1990. See Ref. 19
23. US Congressional Budget Off. 1990. *Energy Use and Emissions of Carbon Dioxide: Federal Spending and Credit Programs and Tax Policies*. CBO Working Papers. Dec.
24. Goulder, L. H. 1991. *Effects of Carbon Taxes in an Economy with Prior Tax Distortions: An Intertemporal General Equilibrium Analysis for the U.S.* Discussion Paper, Stanford Univ., Stanford, Calif.
25. *Environmental Policy Alert*, June 27, 1990, p. 33
26. Terkla, D. 1984. The efficiency value of effluent tax revenue. *J. Environ. Econ. Manage.* 11:107–23
27. Dower, R., Repetto, R. 1990. *Use of the Federal Tax System to Improve the Environment*. Testimony to the Long-Term Strategy Hearing on the Environment, US House of Representatives Committee on Ways and Means. Washington, DC: World Resourc. Inst., March 6
28. Ballard, C., Shoven, J., Whalley, J. 1985. General equilibrium computations of the marginal welfare costs of taxes in the United States. *Am. Econ. Rev.* 75:128–38
28a. Weitzman, M. L. 1974. Prices vs. quantities. *Rev. Econ. Stud.* 41:477–91
29. Stavins, R. N. 1992. *Transaction Costs and the Performance of Markets for Pollution Control*. Discussion Paper, John F. Kennedy Sch. Gov., Harvard Univ., Cambridge, Mass.
30. Scherer, F. M. 1980. *Industrial Market Structure and Economic Performance*. Chicago: Rand-McNally College Publishing
31. Baumol, W. J., Panzer, J., Willig, R. 1982. *Contestable Markets and the Theory of Industrial Structure*. New York: Harcourt-Brace-Jovanovich
32. Houghton, J. T., Jenkins, G. J., Ephraums, J. J., eds. 1990. *Climate Change: The IPCC Scientific Assessment*. Report Prepared for the Intergovernmental Panel on Climate Change by Working Group I. Cambridge, England: Cambridge Univ. Press
33. Jaeger, J. 1987. *Developing Policies for Responding to Climate Change*. Summary of the discussions and recommendations of the workshops held in Villach (Sept. 28–Oct. 2, 1987) and Bellagio (Nov. 9–13, 1987) under the auspices of the Beijer Inst., Stockholm. Stockholm, Sweden: World Meteorol. Organ. and United Nations Environ. Programme
34. Stavins, R. N. 1991. See Ref. 4
35. Goulder, L. H. 1990. *Using Carbon Charges to Combat Global Climate Change*. Stanford Univ. Center for Economic Policy Research Publication No. 226
36. Jorgenson, D. W., Wilcoxen, P. J. 1990. *The Cost of Controlling U.S. Carbon Dioxide Emissions*. Discussion Paper, John F. Kennedy Sch. Gov., Harvard Univ., Cambridge, Mass.
37. US Congressional Budget Off. 1990. *Carbon Charges as a Response to Global Warming: The Effects of Taxing Fossil Fuels*. Washington, DC
38. Lashof, D., Tirpak, D., eds. 1989. *Policy Options for Stabilizing Global Climate*, Draft Report to Congress. Washington, DC: US Environ. Protect. Agency
39. Manne, A., Richels, R. 1990. CO_2 emission limits: An economic cost analysis for the USA. *The Energy J.* 11(2):51–74
40. Williams, R. H. 1990. Low-cost strategies for coping with CO_2 emission limits. *The Energy J.* 11(4):35–59
41. DeWitt, D. E., Dowlatabadi, H., Kopp, R. J. 1991. Who Bears the Burden of Energy Taxes? Discussion Paper QE91-12, Quality of the Environ. Div., Resourc. for the Future, Washington, DC
42. US Congressional Budget Off. 1990. See Ref. 37
43. Percy, C. H. 1990. The broad benefits of a gasoline tax hike. *New York Times*. July 8, p. 17
44. Khazzoom, J. D. 1991. The impact of a gasoline tax on auto exhaust emissions. *J. Policy Anal. Manage.* 10:434–54
45. Cameron, M. 1991. *Transportation Efficiency: Tackling Southern California's Air Pollution and Congestion*. Oakland, Calif.: Environ. Defense Fund and Regional Inst. of Calif.
46. Khazzoom, J. D. 1991. See Ref. 44, pp. 434–54
47. Khazzoom, J. D. 1991. See Ref. 44, pp. 434–54
48. Crandall, R. W., Graham, J. D. 1989. The effects of fuel economy standards on automobile safety. *J. Law Econ.* 32:97–118
49. Leigh, J. P., Wilkinson, J. T. 1991. The effect of gasoline taxes on highway

fatalities. *J. Policy Anal. Manage.* 10: 474–81

50. Goldman, C., Hirst, E., Krause, F. 1989. *Least-Cost Planning in the Utility Sector: Progress and Challenges*. Oak Ridge Natl. Lab.
51. Cohen, S. D., Eto, J. H., Goldman, C. A. Beldock, J., Crandall, G. 1990. Environmental externalities: What state regulators are doing. *The Electricity J.* 3(6):24–35
52. Krupnick, A. 1989. The Environmental Costs of Energy Supply: A Framework for Estimation. Unpublished manuscript, Resourc. for the Future, Washington, DC
53. Palmer, K., Dowlatabadi, H. 1991. *Implementing Environmental Costing in the Electric Utility Industry*. Discussion Paper QE91-13, Quality of the Environ. Div., Resourc. for the Future, Washington, DC
54. Mitchell, R. C., Carson, R. T. 1989. *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Washington, DC: Resourc. for the Future
55. Freeman, A. M. III. 1985. Methods for assessing the benefits of environmental programs. In *Handbook of Natural Resource and Energy Economics*, Vol. I, ed. A. V. Kneese, J. L. Sweeney, pp. 223–66. Amsterdam: North-Holland

55a. Braden, J. B., Kolstad, C. D., eds. 1991. *Measuring the Demand for Environmental Quality*. Amsterdam: North-Holland

56. Palmer, K., Dowlatabadi, H. 1991. See Ref. 53
57. US Environ. Protect. Agency. 1988. *The Solid Waste Dilemma: An Agenda for Action*. Municipal Solid Waste Task Force, Off. of Solid Waste. Washington, DC

57a. Savas, E. S. 1979. How much do government services really cost? *Urban Affairs Q.* 15:23–42

58. Menell, P. 1990. Beyond the throw-away society: An incentive approach to regulating municipal solid waste. *Ecol. Law Q.* 17:655–739

58a. Sigman, H. 1991. *A Comparison of Public Policies for Lead Recycling*. Dept. Econ., Mass. Inst. Technol., Cambridge, Mass.

58b. Bohm, P. 1981. *Deposit-Refund Systems: Theory and Applications to Environmental, Conservation, and Consumer Policy*. Baltimore: Johns Hopkins Univ. Press

58c. Russell, C. S. 1988. Economic incentives in the management of hazardous wastes. *Columbia J. Environ. Law* 13: 257–74

58d. Anderson, R. C., Hofmann, L. A., Rusin M. 1990. *The Use of Economic Incentive Mechanisms in Environmental Management*. Research Paper 051. Washington, DC: Am. Petrol. Inst.

59. Cameron, M. 1991. See Ref. 45
60. O'Toole, R. 1988. *Reforming the Forest Service*. Washington, DC: Island Press