ENVIRONMENTALLY RESPONSIBLE ENERGY PRICING

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EXECUTIVE SUMMARY

1. The purpose of this report is to ascertain the energy prices needed to reflect the environmental costs imposed by energy, thus providing economic incentives for energy usage that will reflect the full social cost.

2. The energy sources included in the analysis are: coal, gasoline, diesel oil, airplane fuel, heating oils, natural gas, and wood. Nuclear energy is not included, because of the absence of reliable social cost estimates, not because of a belief that these costs are low. Wind, solar, and geothermal energy are also excluded, but their social costs (i.e., externalities) should be minimal.

3. The principal externalities considered are those related to air pollution and acid rain. Energy effects on climate change are not included. The estimates consequently provide the basis for a "no regrets" energy policy, as they establish a lower bound on the appropriate energy price that reflects both the private costs of production and the social costs arising from energy usage.

4. The approach taken in this report is to analyze the cost subsidy currently given to energy users because they are allowed to diminish environmental resources without paying any resource cost. By calculating the damage inflicted by different energy sources, it will be possible to ascertain the user fee that must be charged so that energy users will fully recognize the environmental consequences of their actions.

5. The approach we use to set the user fee levels is to determine the unit externality cost values for emission reductions from the current level to a strict compliance with the current EPA regulatory standard. Earlier analyses of the benefits associated with EPA regulations are used to establish the appropriate price that must be charged for different types of environmental damage. These unit values are then applied to assess the externality costs between the level of the EPA standard and a background level of pollution.

6. The six sources of externalities considered in our analysis are the following: lead in gasoline, air toxics from motor vehicles, particulate, sulphur oxides excluding SO, mortality, sulphur oxides $S0_4$ mortality, and ozone.

7. The principal source of pollution costs varies with the particular energy source: gasoline (particulate), diesel (particulate), aircraft fuel (particulate), wood (particulate), coal (sulphur oxide mortality), and natural gas (ozone).

8. In setting the appropriate user fees, credit should be given to energy users for the charges they currently pay above the private costs of energy. These charges consist of various energy taxes, which serve in part as a user fee that discourages energy use and reflects some of the external social cost. These energy taxes are substantial. The largest taxes are on gasoline ($26.9 billion) and coal ($10.2 billion). As a percent of price, the largest taxes are on coal

(38 percent), diesel fuel (27 percent), and gasoline (25 percent). Many of these taxes are returned as subsidies (e.g., the highway trust fund). After netting out these subsidies returned to users of the energy source, the highest net taxes are on gasoline ($18 billion) and coal ($10 billion). As a percent of price, the largest net taxes are on coal (36 percent) and gasoline/diesel fuel/aircraft fuel/fuel oil (13-17 percent).

9. The report develops energy user fees under a variety of assumptions. The estimates presented below are the midpoint assessments for two variants --25 percent reduction in emissions due to current regulations and 10 percent reduction in emissions. These two scenarios reflect the influence of the extent of the emissions reduction that will be achieved by existing regulations. The greater the gains that will result from regulation, the smaller are the environmental costs that will be generated by the remaining pollution levels. A summary of the results appears below:

Fuel Type	Units	Current Net $Taxes as a Percent of Price	Externality Cost as a Percent of Price
Gasoline	gallon	16.6%	16.7%
Diesel fuel	gallon	12.9	50.4
Aircraft fuel	gallon	15.5	12.9
Heating Oil	gallon	14.6	63.7
Natural Gas	1000 cubic feet	6.4	1.1
Wood	short tons	0.0	152.4
Coal	short tons	35.9	528.0

Coal and wood are the greatest outliers in terms of the disparity between the current tax level and the user fee that should be imposed to capture the full social costs.

10. Figure 2.1 summarizes many of the key findings of the report with respect to current tax levels and the range of estimates of the externality damages.

11. A carbon tax is not ideally suited to addressing these externalities since the pollution damages are correlated in different ways with carbon content. The full social cost prices could, however, augment a carbon tax, but the levels of these charges should vary by fuel type. Specific estimates of these amounts are provided.

12. The demand for residential energy and its associated pollution also maybe inefficient because of housing tax subsidies.

13. The tax subsidy for housing capital has two effects on residential energy demand. First, by lowering the price of housing services, the tax subsidy increases the demand for housing services and the associated energy. House size is strongly related to energy demanded for space heating and cooling. Second, the subsidy for housing capital creates an incentive to substitute capital for energy in the production of housing services. This substitution effect encourages the purchase of energy-efficient capital (e.g., insulation).

13. Eliminating the tax subsidy for housing would increase the cost of housing capital by 23 percent, lower the demand for housing services by 11.8 percent, and residential energy demand by 6.8 percent. Alternatively, a 20 percent tax on residential energy would result in the same reduction in residential energy demand. Only eliminating the personal tax advantages of owner-occupied and rental housing would reduce residential energy demand by 3.2 percent. Only eliminating the deductibility of mortgage interest and property taxes for owner-occupiers would decrease residential energy demand by 2.1 percent.

14. These possible reductions in residential energy demand should be weighed against the increases in energy demand associated with the increased consumption of and production of other goods which would occur because of the switch from housing to other goods. Since housing is not a particularly energy-intensive good, these increases in energy associated with other goods might result in total energy demand not changing.

A READER'S GUIDE

The purpose of this report is to assess various aspects of the pricing of energy, with the ultimate objective being to determine how energy can be priced to promote its efficient utilization in the presence of the environmental externalities generated by energy. The environmental damages considered will be limited in scope. In particular, we will focus on conventional externalities associated with traditional forms of pollution regulated by EPA as opposed to the more controversial externalities linked to global warming.

Part I of the report provides an introduction to the full social cost energy pricing issue. Why is it that energy prices may not correspond to their efficient level, and what are the broad classes of external damages that must be taken into account?

Part II of the report represents the key component of the analysis. In it we outline the taxes paid by different sources of energy and compare these taxes to the appropriate tax amount that should be levied to take into account the external damages associated with each particular form of energy use. Concerns such as this are not entirely new. They have been raised by academics, by government organizations such as the National Academy of Sciences, and even by presidential candidates. What is new is that this report documents the appropriate level of taxes to bring the prices for these energy sources in line with their true cost to society. Perhaps the most surprising aspect of these calculations is that it is necessary to move beyond the myopic focus on a gasoline tax and consider more broadly-based charges that can be imposed on energy to reflect the associated environmental damages.

Appendix 2.1 provides a more detailed discussion of how the full social cost energy prices were calculated. This more technical assumption is intended to delineate the assumptions involved in the analysis as well as the specific EPA documents on which these estimates were based.

Appendix 2.2 considers related issues of less prominence, such as the relationship of our results to the Draft New York State Energy Plan.

Part III of the report addresses implementation issues. In particular, what different tax mechanisms are available to impose full social cost energy prices, and what are the comparative advantages of using these different tax schemes? Appendix 3.1 provides related tax tables.

Part IV of the report represents a departure in terms of the focus in that the market failure being addressed is not the external damages caused by energy but rather the implications of the variety of tax policies for housing that may distort energy usage. In particular, if these tax policies lead consumers to use an amount of energy that is more than efficient, then it may be the case that the government has in place policies that actually encourage energy use beyond its efficient level rather than discourage it. Thus, the task of an appropriate energy pricing scheme is not simply to correct for the damages inflicted by energy usage, but also to **rectify** the impact on the environment caused by government policies that foster energy usage. The housing analysis in Part IV indicates that these influences on energy usage are indeed quite substantial.

PART I:

OVERVIEW THE FULL SOCIAL COST' ENERGY PRICING APPROACH

Ideally society wants to promote efficient utilization of all resources. The nation's energy resources are among those for which we would like to establish efficient utilization. This concern is particularly great since energy consumption has been linked to a number of important environmental costs principally relating to air pollution. Because energy users do not pay for these costs, they are labelled as "externalities" by economists.

In any market context, it is desirable for economic actors to bear the full consequences of their actions so that their behavior will incorporate the social effects as well as the private benefits. In the case of energy usage, the consumers are not paying these costs since they are permitted to use an environmental 'resource without paying any explicit fee.

The economic objective is twofold. First, we want all energy producers to be supplying the appropriate amount of each form of energy given these social costs, and we want consumers to be consuming the amount of each energy source that reflects a balancing of the benefits to them of the energy and the social costs of their actions. To achieve this objective, which economists term an efficient energy usage objective, the incentives for energy production and utilization must be correct.

Consider, for example, the situation of a representative firm that produces energy. There is some level of energy production that represents the amount of energy that should be produced after recognizing the market value of the energy and all of the costs associated with energy production. This energy output level can be achieved in two ways. First, one could establish an environmental quality standard that ensures that the production or usage of energy resulted in the level of pollution that balances the benefits and costs of pollution reduction appropriately. Alternatively, one could charge a user fee for energy usage to promote the efficient outcome.' One can achieve the objective of having the firm generate the efficient amount of pollution using either a user fee or a standards approach. The emphasis of the U.S. Environmental Protection Agency and other regulatory agencies has been on the promulgation of regulatory standards.

Standards are also attractive to firms in that they involve lower compliance costs than do pollution fees, if these fees are imposed on all pollution, not just pollution above some regulatory standard. Under a standards regime, a firm must pay for the cost of meeting the standard, but once the standard has been met the firm does not pay for any of the pollution that it generates. Thus, in effect, the firm receives a free right to pollute up to the efficient level of pollution, and it is not charged for this pollution. In contrast, pollution fees that do not give firms some free pollution rights but will impose costs associated with control devices as well as additional fees imposed for whatever pollution remains after the control devices have been installed.

Although environmental standards promote short-run efficiency in terms of establishing the correct amount of pollution for any given firm in the industry, they do not establish incentives for long-run efficiency. In particular, the incentives to enter polluting industries are too great because firms do not have to pay for the implicit subsidy they receive by not internalizing the costs of the pollution that they generate. Pollution levels up to the standard are free to the firm, but impose real societal costs.

The focus of this report will be on establishing user fees that will lead energy users to incorporate the environmental costs of energy in their energy choices. The approach will be to determine what the price of energy should be to internalize all the costs and subsidies involved in the energy resource area. This calculation will indicate the appropriate user fee level that will give both consumers and producers the correct price incentives. However, because of the character of this form of policy the energy user fee will also provide correct economic incentives for long-run entry into the industry.[2] Thus, the overall purpose of this study is to establish a policy that economists would term an efficient energy policy.

This objective is obviously quite ambitious and obtaining a definite assessment could ultimately require a major resource commitment by EPA -- far greater than the cost of the current study. Because of resource constraints, the scope of this study will necessarily be more limited than this and, as a result, the analysis will adopt several simplifications. We will highlight the major features of our approach in the first section of the report. A detailed Appendix describes the methodology in greater detail. It should be emphasized that this research remains a work in progress. Additional research is underway to determine how use of an externality tax approach can be incorporated in a policy context in which command and control regulations are in place. Moreover, other second-best factors also enter. Housing tax subsidies distort energy usage, as the final part of this report indicates. Thus, eventually we hope to address the net effect of all market imperfections on the efficient utilization of energy, recognizing that society's objective is to achieve the proper amount of pullution control.

The emphasis will consequently be on only a subset of the adverse externalities created by energy. The most notable exception is the omission of the global warming externalities from the analysis. The reason for this omission is not that we believe these externalities to be unimportant. Rather, the magnitude and direction of the greenhouse effect impacts are now being debated in a number of arenas. One of the dividends of our analysis is to begin the process of ascertaining how much we can achieve the objectives of those who advocate policies to address the risks of climate change by adopting a user fee approach that recognizes externalities other than those associated with climate change.

This policy approach has already been widely discussed in the global warming literature. Some observers have designated the policy approach we are adopting as the "bootstrap" approach or the "no regrets" approach. As a society, we know we should go at least this far unless global warming will, on balance, be beneficial. Thus, our analysis is intended to solve the problem of ascertaining what user fee is needed to promote appropriate energy utilization, assuming that we did not take into account the role of climate change. These are the minimal measures that society should undertake to address the problems of climate change.

In subsequent project periods, we will explore the degree to which our broader climate change policy objectives can be achieved through appropriate recognition of the other externalities associated with energy usage. In particular, to what extent will a no regrets approach achieve the objectives of a more ambitious climate change policy?

1.1. BASELINE ESTIMATES

It is useful to put the scope of our analysis in perspective by comparing the focus of our study with a more wide-ranging study of energy externalities. Table 1.1 provides a summary of the estimates prepared by Darwin Hall in his article, "Social and Private Costs of Alternative Energy Technologies," Contemporary Policy Issues, July 1990. For the most part, this article does not overlap the categories that we are assessing using EPA benefit studies. This report does not consider wind, solar, geothermal, or nuclear power. The primary source of overlap is for natural gas, oil, and coal, where the overlap is in the areas of air pollution and acid rain. In these cases, we will rely on the EPA studies that we have compiled rather than adopting the approach used by Darwin Hall.

The omission of wind, solar, and geothermal power from our study is not consequential. These energy sources are believed to create few externalities. In contrast, the failure to assess the externalities associated with nuclear power are more problematic. The potential hazards posed by nuclear energy cannot be ignored simply because we lack good data on their magnitude.

The main reason why externalities can be assessed for environmental pollutants is that there are available building blocks for analysis. We observe emissions levels and, with the aid of health benefit assessments, can make some judgments pertaining to likely impacts.

Assessment of the costs of nuclear power is a quite different enterprise. In the absence of an EPA risk assessment for nuclear power or a comparably detailed regulatory analysis, we will exclude nuclear power from the analysis. We would not, however, wish our results to provide a relative subsidy to nuclear power simply by default. It would not be correct to impose energy user fees on only wood and fossil fuels and to leave nuclear energy affected. Before any energy user fee approach is implemented, there should be a comparably vigorous assessment of the expected externality costs associated with nuclear energy.

For the three major energy sources in Table 1.1 that we do consider -- natural gas,

Table 1.1

Damage Computation in Hall Study

	Cumulative Estimates of External and Total Social Costs or Energy (dollars/unit of energy)							
Source of Energy Service	Conaervat ion Efficiency	Wind	Solar	Geothermal	Natural Gas	Oil	Coal	Nuclear
Water Pollution	0	0	0	Minor	0	Omi tted	Cmi tted	Omi tted
Sol id Waste	0	0	0	0	0	Omi tted	Omi tted	1988S AC: 0.07¢/kWh
Air Pollution and Acid Rain	0	0	0	Minor	1988S IB: $0. 286/ MMBTU	1985S IB: $11 .59/ BBL	1985S IB: $16.80- $18.77/Ton MC: $7.23- $7.67/Ton	
Green House		0	0	0	1988s MC: $0-$2 .56/ MMBTU	1988s MC: s0-s3 .48/ BBL	1988s MC: $0-$4.50/ MMBTU	
National Security		0	0	0	Substantial Reserves: Soviet Union and 1 ran	1985S AC: S5.79/BBL AB: $4.20- $7.07/BBL	0	1986S AC: 0.85¢/kWh
Nuclear 1nsurance Subsidy	0	0	0	0	0	0	0	1985S AC: 0.49¢/kWh
Reactor Loss	0	0	0	0	0	0	0	1987S AB: 0.14¢/kWh
Additional Safety	0	0	0	0	0	0	0	1988S AB: 0.16a- 0.94¢/kWh
Cumulative External cost (1989 $)	0	0	0	Minor	S0.30-S2.85/ MMBTU	$16.85- S22.14/ BBL	$13.68- $124.75/ Ton	1.9¢-2.7¢/ kWh
Private Cost (1989 S)	0.5¢-2¢/kWh	8¢-10¢/ kWh	9¢-12¢/ kWh	5¢-11¢/ kWh	S2.50-S3.00/ MMBTU	$15-S18/ BBL	$35-s45/ Ton	14¢-16¢/ kWh
Total Social cost (1989 $)	0.5¢-2¢/kWh 36¢/Gallon Gasoline	8¢-10¢/ kWh	9¢-12¢/ kWh	5¢-11¢/ kWh	S2.80-S5.85/ MMBTU	$32 -s40/ BBL	$49-$170/ Ton	16¢-19¢/ kWh

Notes: IB=Incremental Benefit; AB=Average Benefit; AC=Average Coat; MC=Marginal Cost; BBL=Barrels of Oi 1, 42 gal ions or 6 MMBTU; Tons of Coal=2,000 pounds or 24.7 MMBTU; MMBTU=Million British Thermal Units; ¢/kWh=cents per ki lowatt hour level i zed over the l ife of a typical unit; M- Ton=Metric Ton=2,200 pounds.

Source: See Hal l (1990) for further explanation of the calculat i ens.

coal, and oil -- we will focus on the air pollution and acid rain costs. We will abstract from greenhouse effect costs and national security costs. Each of these costs is very uncertain. The precise allocation of defense costs is particularly difficult to assess because of the multiplicity of our defense policy objectives.

It is instructive to consider each row of Table 1.1 in turn. The first effect that Darwin Hall considers is that of water pollution. He indicates negligible externalities associated with the various energy sources so that omission of this component from our analysis will not have a major effect on the results. The second row of the table pertains to solid waste pollution. With the exception of nuclear energy, this is also not a significant component.

The third row of Table 1.1 deals with air pollution and acid rain. This is the emphasis of our study and also the largest cost component in Hall's study. The estimates that Hall developed will not be as reliable as those that can be obtained from the standpoint of national EPA policy. In particular, his report uses the unit benefit values derived from pollution in California, principally in Los Angeles. In contrast, our estimates will rely on national estimates of the air pollution costs of energy usage. Moreover, our assessment will be much more comprehensive in terms of the particular types of pollutants that we consider. This difference with the analysis by Hall is not a minor variant. In particular, the largest externalities associated with energy usage are those linked to air pollution and acid rain, The main adverse effects of acid rain are in the Eastern states so that a study based on California benefits will not capture this influence. To provide an entirely different analysis of these important benefit components as we do in this report is, in effect, to prepare an almost completely separate assessment of the energy externalities.

The fourth row of Table 1.1 pertains to the costs associated with climate change, As is indicated above, there remains substantial debate over the magnitude and even the direction of these effects. Our analysis will exclude these from consideration, not because they are unimportant, but because the focus of our analysis is to determine the pricing of energy that is required to achieve efficiency if we take into account factors other than global warming. In subsequent project periods we hope to address the global warming issue more fully.

The next row of the table pertains to national security. There remains substantial uncertainty over the appropriate allocation of defense costs to energy. To what extent was the war in the Persian Gulf intended primarily to influence the energy price as opposed to promote other policy objectives? In the absence of making such an allocation, the costs of operations Desert Shield and Desert Storm cannot be allocated to gasoline and related petroleum energy sources. There is no doubt an important linkage of such defense costs to energy, but the extent of this linkage is unclear. Moreover, the overall magnitude of the ultimate expenditure that the United States will incur is not yet determined. Even more uncertain is the extent of our future obligation. As a result, this analysis will focus on the air pollution effects of energy rather than on the national security effects.

The final externality component of the analysis by Hall consists of the assessments of the various aspects of nuclear energy, which lie outside the scope of our report.

1.2. ENVIRONMENTAL EXTERNALITY BENEFITS

The main focus of this report is to establish the environmental costs associated with various types of energy usage. All the estimates that will be discussed below are derived from benefit studies done for the U.S. Environmental Protection Agency. It is helpful to review the methodology that we are using since we hope that EPA officials will continue to comment on the appropriateness of our selection of various empirical estimates from the available range of possible EPA estimates. The Appendix to this report summarizes the methodology in greater detail.

The information currently available as calculated by EPA pertains to the benefits that will be achieved by reducing current emissions to a pollution standard. The first step of the analysis is to define what this standard is and how fast it will be met. The assumption that we have adopted in consultation with the OAQPS, is the following. We have assumed that the benefits associated with attaining compliance will be achieved in one year and that they will not be phased in over a long period of time. In addition, in situations where the pollution standard is not specified in units that are comparable to those needed for assessing benefits, we perform a sensitivity analysis assuming 10 percent and 25 percent reductions in pollution will ensure compliance with the current standards. In some cases, notably lead, we do have precise information regarding the standard level so that such an assumption is not needed. However, for pollutants such as particulate, sulphur oxides, and ozone, we must make this assumption in order to establish the compliance reference point.

After having determined the unit benefit value for reducing pollution from the current level of emissions to a pollution standard, we then apply these benefit values to assess the total benefit that will be achieved by going from the current emissions level to a background level of pollutants. We then use these benefit assessments in conjunction with the total energy amount to calculate the externality per unit of energy. In some cases the units are gallons, where in others they may be tons or cubic feet. The estimates that we have prepared thus far appear reasonable given the information we have been able to obtain from the OAQPS staff in Durham, NC.[3]

NOTES

1. In theory, the extensive literature in economics on the optimal Pigouvian tax is intended to provide guidance on the setting of optimal externality taxes.

2. It should be noted that the user fees should be regarded as only an initial approximation to such optimal fee levels. The theoretically correct user fee amount is based on a complex set of economic influences beyond the degree of refinement possible with available data.

3. Before considering the particular estimates, let us briefly review some of the sources that we used for our estimates. The benefit numbers for particulate, sulphur oxides, and NO_x are based on National Ambient Air Quality Standards (NAAQS) economic analyses. The ozone numbers are from an Office of Technology Assessment (OTA) study and a new study by Resources for the Future under contract to the OTA. The air toxics estimates are based on estimates derived by the Office of Mobile Sources. The lead estimates are derived from an economic analysis of restricting lead and gasoline prepared by the EPA's Office of Policy Analysis. The acid rain estimates are based on a study by the National Acid Precipitation Assessment Program (NAPAP). The air toxics numbers and the lead numbers are perhaps most reliable in that we have a well-defined reference point in computing the benefit values. Carbon monoxide and NO_x are omitted from the externality costs because of the absence of a definitive regulatory analysis of these pollutants. Because of the timing of these various studies, our estimates will pertain to 1986, the most recent year for which comprehensive estimates of externality costs could be generated.

PART II:
THE FULL SOCIAL COST ENERGY PRICING APPROACH TO GREENHOUSE WARMING POLICY

2.1. INTRODUCTION

Policies to prevent substantial climate change will impose potentially enormous social costs to address a problem for which the character and associated consequences are highly uncertain.’ At the most extreme, some scientists suggest that prospective climate changes may, on balance, be beneficial. Many observers have consequently recommended a more cautious policy approach, at least as an initial step. Until the pertinent uncertainties are resolved, they suggest that we should follow the minimal course of action dictated by our current knowledge. The stringency of policies consequently should reflect the non-global warming damages and costs associated with emissions of greenhouse gases. This policy prescription has come to be known as the “no regrets” approach since even the most favorable informational developments regarding the risks of global warming will not undermine the desirability of taking these minimal actions.[2]

In other words, a “no regrets” approach is to adjust current prices to reflect all non-global warming damages associated with the emission of greenhouse gases? To ensure that society adopts the most efficient mode of energy use, which is the most important source of greenhouse gases, and that the economically efficient amount of energy will be used, the prices of these energy sources should reflect their total social costs. On the basis of this principle, the 1991 National Academy of Sciences greenhouse warming panel recommended:

> Study in detail the “full social cost pricing” of energy, with a goal of gradually introducing such a system...On the basis of the principle that the polluter should pay, pricing of energy production and use should reflect the full costs of the associated environmental problems. The concept of full social cost pricing is a goal toward which to strive. Including all social, environmental, and other costs in energy prices would provide consumers and producers with the appropriate information to decide about fuel mix, new investments, and research and development.’

The results reported in this section establish a major component of the value of the full social cost prices. The environmental damages from fossil fuel use represent only a major component of the full social costs because they exclude the non-environmental social costs of fossil fuel use. Other possible cost components include: national security costs associated with ensuring uninterrupted oil imports and inefficiencies resulting from failure of electric utilities to use marginal cost pricing? Although we know of no systematic study of these non-environmental social costs, the magnitude of these costs may also be very large. . The results reported here, however, pertain only to the environmental damages of fossil fuel use.[6]

Our assessment of the full social cost prices of energy suggests that even a “no regrets” policy involves enormous dollar stakes. Shifting our focus from climate change to more conventional environmental effects does not eliminate the prospect of considerable economic costs. Policies based on the estimated environmental impacts would necessitate substantial expenditures, possibly hundreds of billions of dollars annually. Moreover, there is also considerable uncertainty with respect to environmental damages from energy uses other than greenhouse warming, although less so than with the valuation of global warming damages.

Even if full social cost energy pricing is never implemented, examination of these prices is a useful mechanism for identifying the divergence between private and social costs. Should our policy emphasis, for example, be on improving fuel efficiency of automobiles, or should we direct greater attention to decreasing pollution from coal? In terms of eliminating the underlying uncertainties, should analysts focus their attention on resolving the complexities of acid rain, or do the mortality risks associated with sulfur oxides represent an area in which there is much more to be learned? Examining full social cost energy prices highlights the salient open research questions as well as the broad outlines of what is currently known about appropriate pricing of energy. These issues are pertinent not only to climate change policy, but also to the debate over our national energy strategy.

2.2. ECONOMIC FOUNDATIONS

Ideally a society interested in the welfare of its citizens wants to promote efficient utilization of all resources, including energy resources. This concern is particularly great since energy consumption has been linked to a number of environmental costs, principally relating to air pollution. Because energy users do not compensate those who bear these costs as part of a market transaction, they represent a classic case of environmental externalities.

In any market context, it is economically efficient for participants to bear the full consequences of their actions so that their behavior will incorporate the social effects as well as the private benefits. Consumers of energy are not paying these costs since they are permitted to use an environmental resource (i.e., atmospheric waste disposal) without paying any explicit fee.

The economic objective is twofold. First, energy producers should supply the appropriate amount of each form of energy given these social costs. Second, consumers should consume the amount of each energy source that reflects a balancing of the benefits to them of the energy and the social costs of their actions. To achieve this efficient energy usage objective, the incentives for energy production and utilization must be correct.

This report estimates user fees that lead energy users to incorporate the environmental costs of energy in their energy choices.’ This objective is obviously quite ambitious. Obtaining a definitive assessment could ultimately require a much more extensive research effort. Because of resource constraints, the scope of this study will necessarily be more limited, and substantial reliance will be placed on previous government analyses of energy-related pollution.[8]

The incorporation of the environmental externality costs of energy will be undertaken by relying largely upon benefit assessments that have served as the basis for EPA standards. Perhaps more than any other available documents, these assessments represent an official governmental view of the environmental damages from energy use. This is not to say that these assessments should be accepted uncritically, as they have frequently been challenged by other government agencies, academics, and industry.' Our approach provides an approximation of these environmental costs.

The estimates reflect only a subset of the adverse environmental externalities created by energy use. The most notable exception is the omission of the global warming externalities from the analysis. The reason for this omission is not that these externalities are unimportant. Rather, the magnitude and even the direction of the greenhouse effect impacts remain under strenuous debate. The intent of the "no regrets" policy assessment is to determine whether many of the objectives of those advocating policies to address the risks of climate change can be achieved through a more limited approach that recognizes only those externalities other than climate change.

This assessment of the social costs of energy embodies several simplifying assumptions. Most fundamental is that the focus of the study is on the total social costs of pollution, which will generally be lower than the social cost that firms must pay for the right to pollute. These environmental costs do take into account the role of compliance with existing regulations, but do not incorporate charges that firms now pay or will pay under EPA policies being implemented. Under the acid rain trading system, new firms in areas that have not attained their air quality standards are required to purchase permits for their pollution from firms that have reduced pollution by a comparable amount. These permit costs in effect will serve as a price that should be counted toward the firm's payment of its full social costs.

Even when there are no permit changes, there generally are EPA regulations that frequently impose requirements that are more stringent than would be dictated on economic efficiency grounds. The difficulty is that even stringent standards do not solve all of the economic problems. Firms will still be given pollution levels up to the standard for free. Indeed, all of the estimates in this study are based on an assumption of compliance with regulations. The focus is, however, on existing regulations, not on all regulations that will emerge as a consequence of the new Clean Air Act. As a result, the incentive of firms to enter the industry will be too great.[10] The appropriate economic solution to achieve an efficient outcome requires the use of some kind of system to augment regulations. The level of these fees will, however, be influenced by the stringency of current regulations -- a complication not incorporated in the analysis. Continuing research under this project is exploring how the role of existing EPA standards can best be reconciled with the utilization of a full social cost energy pricing approach. It should, however, be emphasized that the results in this report do recognize that EPA regulations exist. In particular, compliance with existing regulatory standards serves as the principal reference point for analysis.

The nature of the full social cost pricing approach also must be refined before its ultimate implementation. Ideally, the tax should be on pollution, not on energy. The most obvious distinction that must be made is between anthracite and bituminous coal. However, generally there will be a need to reorganize differences in pollution associated with a particular energy source. One of the main purposes of an energy pollution-free system is to encourage innovation to reduce pollution, such as by introducing control equipment that will decrease pollution from a particular form of energy. Firms will have no such incentive if they are penalized based on the type of energy they use rather than on the damage that it generates. The ultimate objective is to establish fees for pollution not for energy use. The calculations in this paper present what such a fee structure would look like overall, but should not be regarded as providing a rationale for ignoring the level of damage associated with each energy source.

2.3. ENERGY SOURCES AND POLLUTANTS

Existing evidence on the costs associated with energy are most developed for various forms of petroleum (gasoline, diesel, aircraft fuel, heating oil, and natural gas), wood, and coal.” Excluded from this listing are three energy sources for which the environmental damages may be negligible. Wind and solar power generate virtually no adverse environmental effects, and the water pollution and air pollution damages associated with geothermal power are believed to be minimal.

Another energy source that we will not examine is nuclear power. Unfortunately, there is no comparable governmental study of nuclear hazards that enables us to include the associated nuclear risks in our analysis. In contrast, pollution emissions levels are observable, and with the aid of health benefit assessments, it is possible to make judgments pertaining to the likely impacts of pollution from coal, wood, and petroleum-based fuels.

Assessment of the costs of nuclear power is a quite different enterprise.” Major reactor failures are a rare event. How, for example, should we incorporate the Chernobyl experience in risk assessments for the U.S. nuclear industry? We observe signals of likely hazards -- faulty safety practices, minor mishaps, and near disasters -- but ultimately the risk assessment for nuclear power hinges on subjective assessments of human and engineering failures. Some observers claim that the risks have been overblown, whereas others view nuclear power as a serious threat. We do not view these uncertainties as insurmountable, but to date there have been no definitive assessments of the risks of nuclear power. In the absence of governmental risk assessment for nuclear power or a comparable definitive analysis, nuclear power will be excluded from consideration.

The social cost results below should not provide a relative subsidy to nuclear power simply by default. Before any environmental cost fee system is implemented, there should be a comparably vigorous assessment of the expected externality costs associated with nuclear energy.

Each of the columns in Table 2.1 list the different energy sources that will be the subject of the assessment. For each energy source, seven different components of external costs were considered. The importance of these categories differs by energy source. For gasoline, the most detrimental externalities are for particulate, in large part because EPA regulations have already greatly reduced the role of lead pollution from motor vehicles. Particulate are also an important category of pollution for diesel, aircraft fuel, and wood. For coal and heating oil, sulfur oxide mortality is of greatest import. Ozone is the most damaging pollutant linked to natural gas.

The externality costs associated with each pollutant are given both in terms of a contribution per unit of the fuel as well as a percentage of the 1986 retail price.[13] The year 1986 was selected to ensure the availability of the key data components. The estimates in Table 2.1 are based on the midpoints of the estimated EPA pollution benefit ranges. The degree of uncertainty in these estimates is explored below. These estimates also pertain to average benefit values over the entire range of remaining benefits. For the purpose of the analysis it was necessary to assume that marginal and average damage levels from pollution are equal since data are not available to permit estimation of the curvature of the relationships. As a consequence, these estimates may understate the marginal unit benefits of pollution reduction.

The role of the different pollutants varies by energy source. The remaining lead in gasoline imposes external costs on society that constitute roughly 1 percent of the retail price." Particulate emissions are pertinent to all the energy sources listed in Table 2.1. With the exception of natural gas, every energy source generates substantial particulate emissions. Both motor fuels as well as stationary source fuel combustion are involved.[15] Particulate emissions impose costs on society equal to 9 percent of the price of gasoline, 23 percent of the price of diesel, 11 percent of the price of aircraft fuel, 6 percent of the price of heating oils, under 1 percent of the price of natural gas, 147 percent of the price of wood, and 25 of the price of coal.

The next two categories of externalities in Table 2.1 pertain to sulfur oxides. Emissions of sulfur dioxide and resulting sulfate particles from motor fuels and stationary source fuel combustion impose losses that can be best distinguished in terms of those that affect mortality and those that do not.[16] Although significant sulfur oxide costs are

Table 2.1

Unit Value of Benefits of Emission Reduction to Zero Following Compliance with Current Standards"

Pollution Category	Gasoline $ per gal (% of price)	Diesel $ per gal (% of price)	Aircraft Fuel $ per gal (% of price)	Heating Oils $ per gal (% of price)	Natural Gas $ per 1,000 ft^3 (% of price)	Wood $ per short ton (% of price)	Coal $ per short ton (% of price)
Lead in Gasoline	0.0108 (1.16)						
Particulates	0.0831 (8.92)	0.2156 (22.94)	0.0679 (10.55)	0.0432 (6.23)	0.0181 (0.46)	91.0788 (147.43)	8.4069 (25.25)
Sulfur Oxides Excluding SO_4 Mortality	0.0005 (0.05)	0.0029 (0.31)	0.0003 (0.04)	0.0102 (1.48)	0.0001 (0.00)	0.1166 (0.04)	4.3005 (12.92)
Sulfur Oxides SO_4 Mortality	0.0169 (1.82)	0.1044 (11.10)	0.0091 (1.42)	0.3653 (53.09)	0.0026 (0.07)	0.9108 (1.48)	154.51 (464.00)
Ozone	0.0214 (2.30)	0.0176 (1.87)	0.0055 (0.86)	0.0021 (0.29)	0.0228 (0.58)	2.10766 (3.41)	1.0579 (3.18)
Visibility	0.0008 (0.09)	0.0051 (0.55)	0.0005 (0.07)	0.0178 (2.60)	0.0001 (0.00)	0.0425 (0.07)	7.54 (22.66)
Air Toxics from Motor Vehicles	0.0223 (2.40)	0.1281 (13.63)					

"These estimates are based on midpoints of the estimated range of values.

associated with both diesel and heating oils, by far the greatest relative cost of sulfur oxide externalities are those associated with coal. Sulfide damages excluding mortality constitute 13 percent of the price of coal, and the mortality effects constitute 464 percent of the price of coal. Put somewhat differently, the midpoint estimates of the sulfur oxide mortality effects of coal are almost 5 times larger than the market price of coal. As will be indicated below, the level of these costs is also very uncertain.

The next category of externalities are those associated with reducing ambient ozone concentrations resulting from motor fuels and stationary source fuel combustion." The costs of ozone pollution constitute 2 percent of the price for gasoline and diesel, under 1 percent of the price for aircraft fuel, heating oils, and natural gas, and 3 percent of the price for wood and coal. The visibility externalities are largely associated with reducing sulfur oxide emissions from coal-fired power plants.[18] These visibility costs constitute 23 percent of the price of coal.

The final environmental cost component in Table 2.1 consists of the quantities of potential cancer cases related to non-lead emissions from motor vehicles.[19] These air toxic effects constitute 2 percent of the price of gasoline and 14 percent of the price of diesel.

2.4. EXTERNALITIES AND NET TAXES

Ideally, the prices of these various energy sources should reflect the social costs they impose. To adjust for these costs one can impose an additional charge on the use of these energy sources. In effect, all usage of each energy type is treated as causing the same average amount of pollution. If this policy is implemental, some mechanism should be adopted to link the charge to pollution. It is emissions of polutants, not energy usage, that should be discouraged, such an approach will also provide incentives for pollution-reducing innovations.

One might view these charges as being a user fee for the environmental resource that is not properly recognized in market transactions. To the extent that there are existing taxes imposed on energy sources, these would correct at least in part for the disparity between the private price and the social price of the energy source.

Table 2.2 summarizes the current net taxes paid by various energy sources as well as the external costs that are generated. In situations in which the taxes equal the external costs, no additional charges on the energy source are appropriate.

Current taxes on gasoline are 17 percent of the price, roughly the same as the externality cost. In the case of diesel fuel, the current net tax per gallon is 13 percent, whereas the externality cost per gallon is 50 percent. In the case of aircraft fuel, the current net tax per gallon is 16 percent of the price, and the externality cost is 13 percent. Existing

Table 2.2

Summary of Energy Externalities and Taxes Assuming Compliance with Existing Environmental Regulations

	Current Tax per Unit 1986[a]	Current Tax as a Percent of Price (1986)	Externality Cost Estimate as a Percent of Price (1986)[b]	Relative Carbon Tax[c]
Gasoline (gal)	0.15	16.60	16.74	27.89
Diesel Fuel (gal)	0.12	12.80	50.40	52.88
Aircraft Fuel (gal)	0.10	15.50	12.94	NA
Natural Gas (1000 cu. ft.)	0.25	6.40	1.11	1.00
Heating Oils (gal)	0.10	14.60	63.69	47.99
Wood (tons)	0.00	0.00	152.43	0.00
Coal (tons)	11.95	35.90	528.01	104.87

a. Excludes taxes designated for Federal Highway Trust Fund, Superfund Tax, and Black Lung Tax.

b. Based on midpoint environmental damage estimates in Table 1.

c. Based upon carbon emissions per unit fuel. Relative carbon tax values are normalized with natural gas equal to 1, tax levels are below the amount of the appropriate user fee in the case of diesel fuel, but there is no such discrepant for gasoline and aircraft fuel.[20]

Heating oils represent a case similar to that of diesel fuel. The current tax level is 15 percent, whereas the environmental cost is 64 percent. Natural gas currently has taxes of 6 percent, whereas the environmental cost is 1 percent. Somewhat strikingly, the current tax levels for natural gas are in fact above the user fee level based on this analysis. Moreover, the environmental costs are very low in percentage terms.

Wood currently is not taxed, whereas the appropriate user fee for each short ton of wood is 152 percent of the price. Heat provided by wood stoves clearly is not a totally environmentally responsible solution to the energy crisis.

The case of coal is most dramatic. The current tax per ton of coal is 36 percent of the price, whereas the environmental costs are 529 percent of the price.

These taxes can be also put in different terms more closely linked to the current greenhouse debate. Advocates of policies to address greenhouse warming frequently propose that a carbon tax be implemented?' The externalities considered here can also be incorporated within the context of a carbon tax, but the level of the base carbon tax to account for the externalities other than greenhouse warming will not be uniform. The final column in Table 2.2 indicates how high the relative carbon tax on each fuel should be, where the level of the carbon tax has been normalized by setting the tax on natural gas equal to 1. The relative carbon tax for those gasoline sources for which estimates are available is much greater than it would be on natural gas, which is a comparatively clean energy source. The relative carbon tax levels range from 1 for natural gas to 28 for gasoline to 105 for coal, A uniform carbon taxis not an appropriate vehicle for addressing environmental damages other than global warming. One of the major advantages of our approach is that it adjusts for the substantial heterogeneity in environmental costs rather than relying on a simple carbon tax.

Irrespective of whether the tax is levied through a carbon tax or some other mechanism, the total price tag for the externalities will be quite high. Table 2.3 summarizes the total environmental costs associated with each energy source, assuming that there is no change in the quantity of energy used. There would, of course, be a substantial shifting away from energy sources whose relative price increased. The total tax amount is $208 billion, which is about two-thirds of the $281 billion projected budget deficit for fiscal year 1992.[22] Over two-thirds of the estimated energy tax amount is attributable to coal. Gasoline, heating oils, and wood would be taxed in the $10-$20 billion range, and coal would be $149 billion.

Imposing externality charges of this magnitude is certainly a daunting prospect. A major source of the relative popularity of regulatory standards as compared with taxes is that

Table 2.3
Total Tax Revenue for Each Fuel Type*

Fuel Type	Total Tax Revenues ($ billions)	Net Tax Revenues ($ billions)
Gasoline	26.87	17.98
Diesel Fuel	5.00	2.38
Aircraft Fuel	1.71	1.71
Heating Oils	4.72	4.70
Natural Gas	4.11	4.11
Wood	NA	NA
Coal	10.17	9.61
TOTAL TAX	52.58	40.49

*For midpoint of range
**Based upon most recent estimated consumption volumes. 1989 in most cases except wood, 1987. All figures in 1986 dollars.

firms do not currently have to pay for these costs. In effect, the imposition of regulatory standards allows firms to have a level of pollution up to the standard for **free.**[23] Standards can be effective in promoting the efficient degree of pollution control for any particular energy source, but they will not provide the correct incentives for the modal choice among alternative sources of energy.

Suppose, for example, that there are two possible sources of energy. Source A is a highly polluting energy source for which it is very difficult to reduce pollution levels. Source B is a **very** clean energy source for which it is possible to virtually eliminate the pollution level at little cost. Setting efficient regulatory standards, which is to say those that equate the marginal benefits to society of additional pollution reduction with the marginal costs of controls, will lead to very minimal pollution reduction for energy Source **A,** but may lead to the elimination of pollution for Source B. In each case efficient controls would have been imposed for the energy source, but what remains is an immense uncompensated environmental cost imposed on society for energy Source A. Notwithstanding these externalities, society perhaps should continue to use Source A. However, unless the price that consumers pay for this energy source reflects the remaining environmental costs that are generated, the price mechanism will not provide consumers with the appropriate incentive for making the appropriate energy choice.

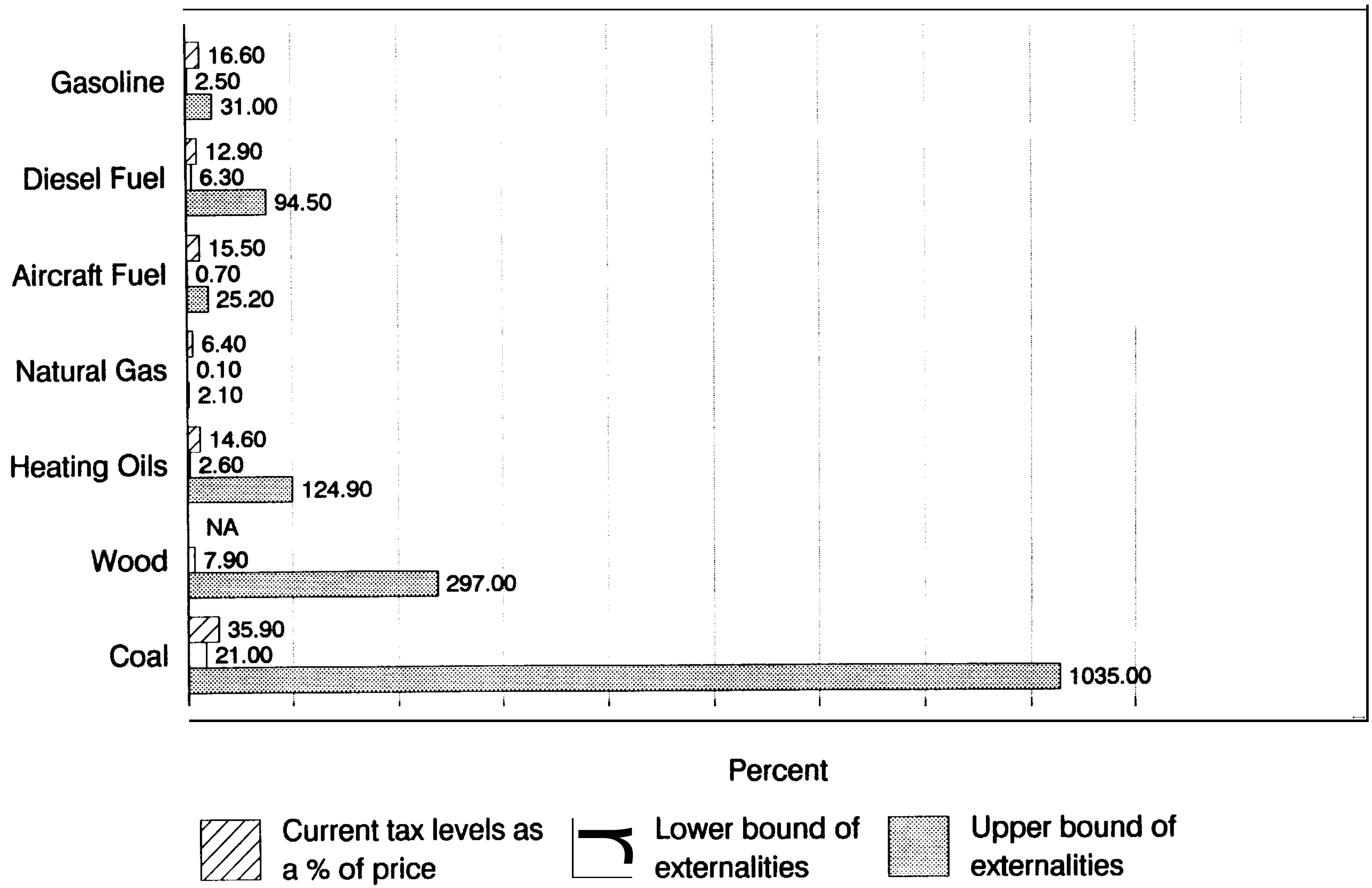
2.5. THE RANGE OF UNCERTAINTY[24]

One reason for caution with respect to implementing such externality charges is that there remains considerable uncertainty in the ranges of the cost estimates. The pollution effect estimates are disputed by private industry officials as well as by many independent analysts. Moreover, there remains a substantial range of uncertainty implied by the governmental studies on which this analysis has been based. Most of those analyses served as the economic framework underlying the justification of government regulations and, as a consequence, were the result of substantial research effort. The range of uncertainty that remains reflects, at least in part, the current imprecision of our scientific knowledge that may be costly to reduce.

Instead of focusing on environmental costs based on the midpoints of government analyses, Figure 2.1 indicates the current tax amounts, and the lower and upper bounds on the appropriate environmental cost surcharge. Gasoline has a modest range of uncertainty -- from 2.5 percent to 31.0 percent of its price. In contrast, the lower bound estimate for coal externalities is 21.0 percent, and the upper bound is 1,035.0 percent.

It is instructive to consider some of the sources of these uncertainties. In the case of gasoline, the principal uncertainty is the societal cost of particulate emissions, for which the estimates range from 0.5-17.4 percent of the price. Particulate costs are also the major uncertainty for diesel (1.2-44.7 percent of the price), aircraft fuel (0.5 -20.6 percent of the

Figure 2.1
Taxes and Air Pollution Externalities as a
Percent of Fuel Price



Sou e W. Kip V s us and Wesley A. Magat, "Interim Draft Report on Efficient Energy Pricing," Report to U.S. EPA, September 1991.

price), and wood (7.5 -287.4 percent of the price). The sulfur oxide mortality effect range is the greatest for two energy sources -- heating oils (0.0-106.2 percent of the price) and coal (0.0-928.0 percent of the price). Although one can make judgments regarding the appropriate estimate within these ranges, such as our reliance on the midpoints, the range of uncertainty signals the potential benefits of improving the informational base underlying full social cost energy pricing. The extent of uncertainty, our ability to resolve the uncertainty, the cost of resolving the uncertainty, and the benefits to the design of the energy pricing system all affect the desirability of acquiring this information.

Unless there is no potential for information acquisition, these results imply that adopting the "no regrets" social cost pricing approach may also involve substantial regret as well. The presence of uncertainty need not paralyze policy development since taking no action may be costly as well. It does suggest, however, that policies of information acquisition and refinement of these environmental damage estimates should be a high priority for additional research.

2.6. CONCLUSION

Reverting to an environmental strategy of "no regrets" that abstracts from the risks of global warming does not completely simplify the policy task. The remaining uncertainties involved are currently substantial, though they can potentially be reduced through additional scientific and economic research. There is a particular need for further knowledge of the nature of the relationship between the external costs on society and additional reductions in pollution. In addition, some of the most uncertain high stakes externality components, such as sulfur oxide mortality, merit detailed scrutiny so as to narrow the range of uncertainty.

Shifting the focus from greenhouse warming to more short-term air pollution problems also does not eliminate the need for bearing enormous economic costs. The levels of the environmental damages involved are substantial -- possibly on the order of hundreds of billions of dollars annually. Non-environmental costs may be significant as well. A society that is reluctant to incur an extra nickel/gallon tax on gasoline is unlikely to accept a substantial increase in its energy bill, particularly in the short run.

The difficulty is that there is no explicit market transaction that makes clear the immense implicit price for energy pollution that society is now paying. Adverse health effects, such as mortality, are diffuse. Many of these impacts occur with a long time lag, and their incidence cannot easily be linked to particular energy sources. As a result, their magnitude is widely debated. The certainty of an immediate expenditure for energy taxes consequently will tend to loom larger than the dimly understood prospects associated with environmental damages. These would be viewed more favorably if the government were to substitute energy taxes for other taxes that produce economic distortions, such as income taxes.

Even if society does not adopt a full social cost pricing system for energy, analyzing what the prices should be from an efficiency standpoint provides an illuminating framework for an analysis. Chief among the conclusions of this study is that the prices of the energy sources that seem most out of line with their environmental damage are coal and wood. Natural gas is a comparatively clean energy source that is currently taxed more than is warranted given the costs that its use imposes on society. Moreover, the almost exclusive obsession of the popular press and much government regulation with private motor vehicles appears to be misplaced. Gasoline pays its own way in the sense that the current gasoline tax equals the environmental damage imposed. Perhaps because of these efforts, the gap between the environmental costs resulting from gasoline and the taxes already imposed is much less than for energy sources such as diesel fuel and heating oils. Moreover, all of those adverse effects are dwarfed by the enormous, but highly uncertain environmental costs associated with coal.

Pursuit of a "no regrets" policy of full social cost energy pricing raises the same class of concerns as do proposals to address climate change, but to a lesser degree. The stakes are immense, the uncertainties are considerable, and the possibility of regret over controlling pollution by more than will prove to have been warranted is quite real. These parallels suggest that this entire policy area involves intrinsic uncertainties. Ultimately, decisions will have to be made without clear-cut guarantees regarding their effects. At the same time, these uncertainties suggest that the value to society of scientific and economic research that improves the environmental information base may be considerable.

NOTES

1. There remains a debate regarding the implications of climate change for greenhouse warming. Some areas may be affected differently by climate change. In addition, some researchers hypothesize that there may be global cooling. The emphasis of this paper will be on greenhouse warming, recognizing that there are diverse scientific views. See the National Academy of Sciences, Policy Implications of Greenhouse Warming (Washington: National Academy of Sciences, 1991). Some states share these concerns. See the New York State Energy Office, Draft New York State Energy Plan, Executive Summary, July 1991.

2. Others have labeled this the "bootstrap" approach. See Stephen H. Schneider, Global Warming: Are We Entering the Greenhouse Century? (San Francisco: Sierra Club Books, 1989).

3. Our analysis of this "no regrets" approach does not imply an endorsement of it. If the effects of current actions are irreversible, waiting for uncertainties to be resolved may impose considerable costs.

4. National Academy of Sciences (1991), p. 73.

5. Some other omitted cost categories are those related to the following: urban vehicle congestion due to non-pricing of road use during peak hours; overbuilding (from an economic perspective) of housing (and hence overuse of heating and cooling) due to the home mortgage deduction; possible overuse of energy due to the inclusion of costs for energy-using utilities in the rents charged for many apartments; possible overuse of highways to haul freight in heavy trucks that may not pay the full cost of the damages they cause to the highways; and possible adverse effects of dependency on foreign oil on U.S. trade policy. An issue arises as to what extent some of these externalities should be attributed to the general activity or the energy source. The analysis also excludes total life cycle environmental costs and only examines costs associated with energy use. Total costs for the fuel cycle also are likely to be greatest for coal.

6. The main building blocks for our assessment are past U.S. Environmental Protection Agency (EPA) studies of the economic damages from environmental pollutants resulting from fossil fuel use that the agency prepares as part of its major regulatory initiatives. Although these estimates can clearly be debated and possibly refined, they have received substantial internal and public review since they provide the analytical foundation for U.S. regulatory policies.

7. It should be noted that the user fees should be regarded as only an initial approximation to such optimal fee levels. The theoretically correct user fee amount is based on a complex set of economic influences beyond the degree of refinement possible with available data. See Carlton and Loury (1980).

8. These studies in turn have sometimes relied on the academic literature. The upper bound of the damage estimates is based on Lave and Seskin (1978). The energy cost estimates are based on Evans (1984).

9. See Nichols and Zeckhauser (1986), Lave (1982), and Zeckhauser and Viscusi (1990).

10. Thus, we will have achieved short-run efficiency, not long-run efficiency.

11. See Hall (1990), Schelling (1983), and Schelling (1991).

12. See Hall (1990) for a review of the literature on these effects.

13. These calculations also assume that compliance with existing EPA standards will achieve a 25 percent reduction in current pollution levels. To ensure comparability, the analysis uses 1986 as the reference year.

14. These estimates were based on information from the U.S. EPA, Office of Policy Analysis, Costs and Benefits of Reducing Lead in Gasoline. Final RIA, February 1985, chapter VIII.

15. The underlying externality estimates are based on information from the U.S. EPA, Strategies and Air Standards Division, Regulatory Impact Analysis of the NAAQS for PM, Second Addendum, December 1986.

16. The basis for these estimates is the U.S. EPA, Office of Air and Radiation, Regulatory Impact Analysis of the NAAQS for Sulphur Oxides (Sulphur Dioxide), Draft Report, March 1988, Executive Summary, Appendix B.

17. Resources for the Future, "The Health and Agricultural Benefits of Reduction in Ambient Ozone in the United States," December 1988, chapters 3 and 5.

18. National Acid Precipitation Program, Integrated Assessment Question One Economics, June 11, 1990.

19. U.S. EPA, Office of Mobile Sources, Air Toxics Emissions From Motor Vehicles, September 1987, Executive Summary.

20. This tax would be even larger if we knew the externalities for NO,.

21. See Nordhaus and Yohe (1983), Poterba (1991), and Nordhaus (1991).

22. See Council of Economic Advisors (1991), p. 375.

23. See Crandall (1983).

24. Uncertainty is an inherent component in other risk regulation contexts as well. See Wilson and Crouch (1991).

PREFACE TO THE APPENDICES TO PART II

At this time, the **full** social cost pricing study considers only air pollutants resulting from combustion of fuels. The scope of the study could be expanded in two ways, one, by adding other pollutants and pollution endpoints of concern, and two, by including other relevant points in the fuel cycle (e.g. wastes created from the exploration, development and production of fuels). We have considered several such extensions of the study's scope, but in most cases we were unable to identify quantitative assessments of benefits sufficient in detail to derive unit benefits estimates.

Many different approaches have been used to investigate optimal energy taxes. This study follows a direct method of estimating the potential benefits from fuel consumption at current emissions levels and fuel use rates. Benefits of other levels of emissions are then calculated assuming a linear no threshold model. One study incorporating a similar approach was recently reported by the New York State Energy Office. The methodology incorporated in that study is briefly described in appendix 2.

Appendix 2.1 is a detailed discussion of the sources of information used in this report and the assumptions and calculations used to derive the benefits estimates. It is the intent of this discussion that a researcher could duplicate the estimates in this report by following the same steps as described in the appendix. Appendix 2.2 is a brief review of the method followed in the recent New York State study. Appendix 3.1 draws upon the unit benefit estimates generated here to compare a number of different approaches for implementing social cost energy pricing. These results are presented in tabular form for the following implementation approaches, a consumption tax, a production/import tax, a carbon tax to recover air pollution externalities, a coal output **tax,** an electricity tax, a gasoline and diesel fuel tax, and a comprehensive emissions fee system. A number of different implementation and institutional issues are raised for each approach.