Environmentally Responsible Energy Pricing*

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This paper assesses the value of the non-global warming externalities associated with energy use. The estimates of the full social cost energy prices based on this "no regrets" approach imply environmental costs that often greatly exceed current tax amounts. The midpoint estimates suggest that the price of coal is most out of line with its efficient level. Natural gas is currently overtaxed, and gasoline is appropriately taxed. There is also a substantial range of uncertainty embodied in the no regrets estimates.

INTRODUCTION

The Clinton administration made energy taxes prominent matters of policy debate, although no major taxes have yet been enacted. Energy taxes share with other forms of taxes the attractive property of raising funds for the government, but they have an additional feature as well. Typically, taxes create efficiency losses by creating distortions in economic decisions. However, in the case of energy taxes, higher taxes may serve a constructive function by promoting energy conservation and shifting the types of energy use toward less polluting energy sources.

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One potential use of these taxes is to incorporate recognition of the adverse externalities generated by energy use in energy prices. Conventional pollution damages, such as the visibility loss associated with air pollution, may be reduced through tax incentives. Imposition of an energy tax will also discourage the generation of gases that lead to possible adverse long-term consequences for the global environment. This paper focuses on assessing the energy taxes to address the costs associated with conventional forms of pollution. This tax can be viewed as a first step toward addressing the broader environmental damages associated with greenhouse warming.

The main reason for abstracting from the role of climate change is that the character and associated consequences are highly uncertain.[1] 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, or what has come to be known as the "no regrets" approach. Others have labeled this the "bootstrap" approach (Schneider, 1989).

The "no regrets" approach has been characterized as follows: "Reducing pollution now makes sense whether or not global warming occurs. And at the end of the decade, with the benefit of more information and new technologies, the U.S. could decide whether more aggressive actions were warranted." (*New York Times,* 25 May 1992, p. A16.)

"The Administration's approach, reasonable in principle, is to adopt multi-purpose measures that enhance the environment or energy security while also reducing greenhouse emissions. That way there will be 'no regrets' even if global warming proves a false alarm.

But in practice the Administration is doing far less than is should...Its failure to propose a 'no regrets' carbon tax, the strongest weapon available, shows more commitment to rhetoric than results." (*New York Times*, 24 May 1992, p. E10.)

Our analysis of the "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.[2] Presumably, even favorable informational developments regarding the risks of global warming will not undermine the desirability of taking these minimal actions. The results reported in this article seek to establish a major component of the value of the full social costs of energy prices.

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[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 National Academy of Sciences (1991), and the New York State Energy Office (July 1991)].

[2] More generally, see Schmalensee (1993) for a recent perspective on these issues.

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. (NAS, 1991, p. 73).

Our assessment of the full social cost prices of energy suggests that even a "no regrets" policy involves enormous dollar stakes. 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 ambient particulates arising from sulfur oxides represent an area in which there is much more to be learned? These issues are pertinent not only to climate change policy, but also to the debate over energy strategies more generally.

ECONOMIC APPROACH

This article estimates energy taxes that lead energy users to incorporate the environmental costs of energy in their energy choices.[3] This objective is

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[3] Note 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).

obviously quite ambitious. Because of resource constraints, substantial reliance will be placed on previous government analyses of energy-related pollution.[4]

The incorporation of the environmental externality costs of energy will be based largely upon benefit assessments that have served as the basis for U.S. Environmental Protection Agency (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 (Nichols and Zeckhauser (1986), Viscusi (1992)).

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. 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.[5] Although we know of no definitive 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.

Before being implemented, the full social cost pricing approach must be refined. 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.

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[4] These studies have in turn sometimes relied on the academic literature, such as Lave and Seskin (1978).

[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.

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 Clean Air Act Amendments. As a result, the incentive of firms to enter the industry will be too great. 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.

Ideally, the tax should be on pollution, not on energy. One prominent distinction that must be made is between anthracite and bituminous coal. Pollution control efforts should also be taken into account since 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.

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.[6] 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. 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.[7] 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

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[6] Discussion of other damages can be found in Hall (1990, 1992), and Schelling (1983, 1991), and Cline (1992).

[7] See Hall (1990) for a review of the literature on these effects.

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. 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.

ENERGY SOURCES AND POLLUTANTS

Each of the columns in Table 1 lists 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 emitted particulates, in large part because EPA regulations have already greatly reduced the role of lead pollution from motor vehicles. Emitted particulates are also an important category of pollution for diesel, aircraft fuel, and wood. For coal and heating oil, mortality resulting from ambient particulate conversion products of sulfur oxides 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.[8] The year 1986 was selected to ensure the availability of the key data components. The estimates in Table 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. As a consequence, these estimates may understate the marginal unit benefits of pollution reduction but may overstate total benefits if incremental damages are subject to thresholds at low emission levels.

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[8] These calculations also assume that compliance with existing EPA standards will achieve a 25% reduction in current pollution levels. The sensitivity of the results to this assumption is discussed in Viscusi and Magat (1992). To ensure comparability, the analysis uses 1986 as the reference year.

Table 1. Unit Value of Benefits of Emission Reduction to Zero Following Compliance with Current Standards[a]

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)
Residual Lead in Gasoline	0.0108 (1.16)	-	-	-	-	-	-
Emitted 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 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 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)	2.1076 (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)	-	-	-	-	-

[a] These estimates are based on midpoints of the estimated range of values.

Table 2. Summary of Energy Externalities and Taxes Assuming Compliance with Existing Environmental Standards

	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	12.90	50.40	52.88
Aircraft Fuel (gal)	0.10	15.50	12.94	n.a.
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] Includes Federal, state, and local excises, severance taxes, public utility taxes and windfall profits taxes. Excludes taxes designated for particular uses, the 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.

frequently propose that a carbon tax be implemented.[19] 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 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 one. 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 one for natural gas to 28 for gasoline to 105 for coal. A uniform carbon tax is 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.

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[19] See Nordhaus and Yohe (1983), Poterba (1991), and Nordhaus (1991).

Table 3. Total Tax Revenue for Each Fuel Type[a]

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	n.a.	n.a.
Coal	10.17	9.61
TOTAL TAX	52.58	40.49

[a]Based on most recent estimated consumption volumes. 1989 in most cases except wood. 1987. All figures in 1986 dollars.

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 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.[20] 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 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 (Crandall, 1983). 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.

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[20] Council of Economic Advisors (1991).

Figure 1. Taxes and Air Pollution Externalities as a Percent of Fuel Price

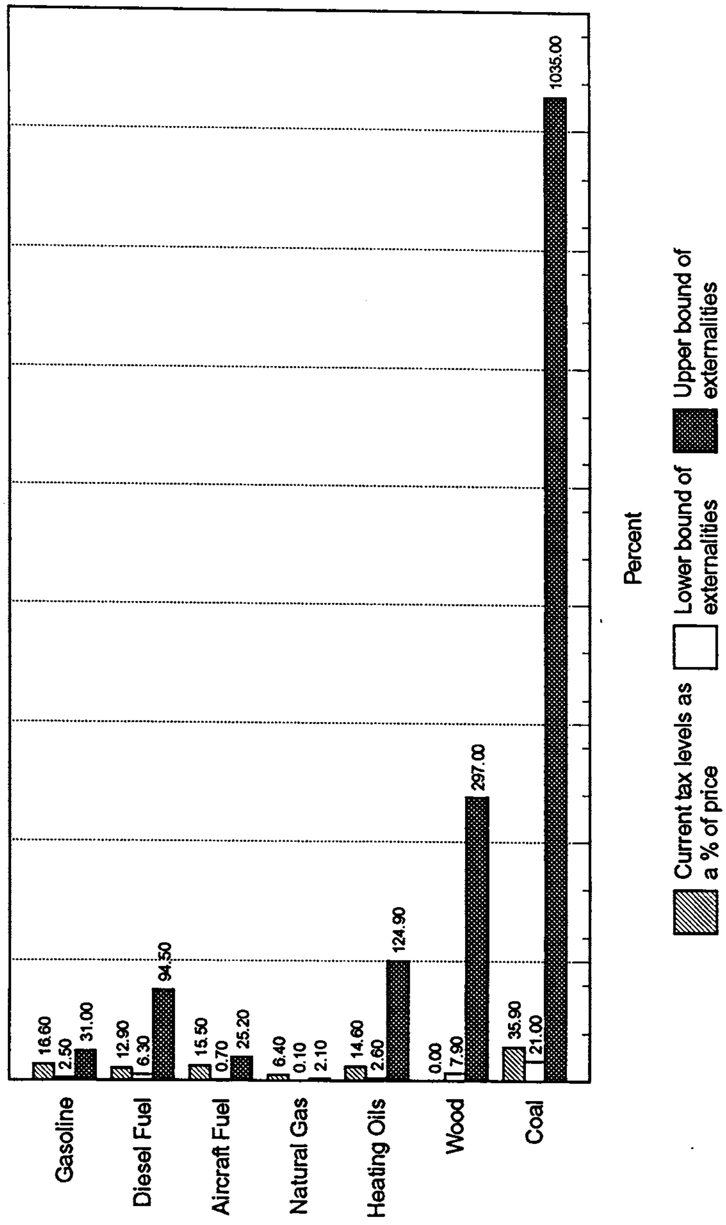

Table 4. Alternative Tax Structures

	Consumption Tax	Carbon Tax[b]	Ad Valorem Tax[b]	BTU Tax[b]
Description of Tax	Tax assessed at retail level for all fuel types.	Tax assessed at retail level for all fuel types. Tax amount determined by carbon content of each fuel.	A uniform tax at a rate of 1.02% of retail price.	Tax assessed based on BTU content of each fuel type.
Level of Tax				
Gasoline	$ 0.28/gal	$ 0.25/gal	0.953/gal	0.54/gal
Diesel Fuel	0.61/gal	2.81/gal	0.962/gal	0.59/gal
Aircraft Fuel	0.12/gal	NA	0.658/gal	0.52/gal
Coal	232.71/ton	142.30/ton	34.094/ton	92.03/ton
Heating Oils	0.58/gal	1.43/gal	0.704/gal	0.62/gal
Natural Gas	0.06/1000 cu. ft.	0.06/1000 cu. ft.	4.054/1000 cu. ft.	4.42/1000 cu. ft.
Wood	134.11/ton	n.a.	63.253/ton	n.a.
Total Tax Revenue for 1989 estimated consumption volumes (in billions $)[a]	284.99	259.38[c]	281.72	267.80
Range of Tax Revenue: lower and upper bounds (in billions $)	21.41 - 548.36	21.51 - 497.53	22.22 - 541.04	21.80 - 513.59

[a] Sum over all fuel types of optimal tax (midpoint estimate) for each fuel multiplied by most recent estimate of consumption of that fuel.

[b] Tax constraint calculated as sum of optimal consumption tax on gasoline, diesel fuel, coal, heating oils, and natural gas multiplied by 1986 consumption volumes for each fuel. Aircraft fuel and wood fuel were deleted due to insufficient carbon content data.

[c] Excludes carbon taxes on aircraft fuels and wood fuel.

ALTERNATIVE TAX APPROACHES

Thus far we have examined energy taxes in terms of the percentage of the product price that must be levied as a tax to account for the conventional pollution damages. The character of this tax can be better understood by comparing it to a variety of other tax approaches that could be taken. Rather than assessing an energy tax based on conventional environmental pollution damages, suppose that we attempted to raise the same amount of revenue through taxes with a different basis, such as the carbon content of the fuel, the price, or its BTU level. The implications of these approaches will be examined in two ways. First, what is the effect of these taxes on the product price? In Table 4, we summarize these results for different tax approaches. Damage and tax estimates relative to product price are instructive, but they abstract from the substantially different energy content of different fuels. The second set of comparisons (Table 5) presents each of the tax levels in terms of the BTU content of each fuel.

Consider first the consumption tax set based on the level of the externality associated with consumption of each particular energy type. This is the tax that we have focused on thus far, and the value of this tax per unit of each product appears in the first column of Table 4. A tax of, for example, 28 cents per gallon on gasoline would be warranted.

The comparable tax per million BTU's appears in the first column of Table 5. The relative differences in the taxes are quite striking. Natural gas and aircraft fuel involve relatively low damages and consequently low taxes per million BTU's, whereas coal remains an outlier. On a BTU basis, coal damages are just over twice as great as the inputs associated with diesel fuel and heating oils so the energy content approach leads to a narrowing of the differences from those shown in Figure 1.

The second approach is to levy the tax based on carbon content. The information in the second column of Table 4 indicates how high the carbon tax level would need to be for each particular energy source in order to generate the same revenue as would the consumption tax, and this tax is put on a BTU basis in the second column of Table 5. These taxes would not be set to link each energy source to conventional pollution damages. Because of the absence of data on the carbon content of aircraft fuel and wood, the total tax revenue raised for these calculations will be for all of the energy sources for which data are available. As the results in the second column of Table 4 indicate, the carbon tax levels will be quite different than that implied by the consumption tax in many cases. For example, diesel fuel will be much more heavily taxed under a carbon tax approach than a consumption tax approach. Indeed, based on the tax per BTU results in Table 5, a carbon tax will have its greatest impact on diesel fuel. In addition, coal will be substantially undertaxed under a carbon tax approach, although it will still be heavily taxed. The tax implied for gasoline is roughly similar either under a carbon tax or a consumption tax system whether viewed in price terms or relative to BTU context.

Both the consumption tax, which is based on conventional pollution externalities, and the carbon tax, for which the rationale can be traced to greenhouse warming concerns, are much more explicitly linked to models of environmental damages than the tax policies that played a prominent role in the 1993 US policy debates over energy taxes. The most prominent policy option was a BTU tax linked to the BTU content of each fuel type. Another possibility that was considered was an ad valorem energy tax, which would impose a uniform tax on energy use based on its price. As before, let the objective be to raise the same amount of revenue as would be raised using a consumption tax. Although the revenue objectives of actual policy proposals are more modest, maintaining symmetry in terms of the revenue raised facilitates comparison across the different tax types.

The ad valorem tax, which is linked only to product price not any damages measure, has a disproportionate impact on several energy sources that are considerably overtaxed relative to the externalities they generate. Chief among these are natural gas, gasoline, and aircraft fuel. In contrast, coal is taxed at one-seventh of the rate that would be appropriate from the standpoint of conventional externalities and less than one-fourth of the amount that would be taxed under a carbon tax approach. On a BTU basis, the ad valorem tax imposes a burden on the relatively clean energy source, natural gas, that is three times as great as on coal. Although the ad valorem tax may offer an advantage of administrative simplicity, it is not well-linked to the economic rationales for imposition of a tax.

The BTU tax summarized in the final column of Tables 4 & 5, comes much closer to an optimal tax than does the ad valorem tax. Coal is taxed three times as heavily under a BTU tax as it would be under an ad valorem tax, and fuel sources such as gasoline and diesel fuel are taxed less heavily. Unfortunately, the relatively clean energy source—natural gas—is taxed even a bit more stringently under the BTU tax than under an ad valorem tax. Moreover, all of these taxes on natural gas are considerably out of line with what is appropriate given the externalities generated by this gas source.

Although there appears to be a substantial misallocation in terms of the distribution of the tax burden, much of this difficulty arises from the substantial estimates of the damages associated with coal. Moreover, as was indicated above in the discussion of Table 1, the costs associated with coal are largely due to sulfur oxide mortality. The degree to which one could confidently move forward with a particular energy tax structure depends in large part on the firmness of this evidence, which we will now explore in some detail.

Table 5. Alternative Tax Structure Measured in Dollars of Tax per Million BTUs[a]

	Consumption Tax	Carbon Tax	Ad Valorem Tax	BTU Tax
Gasoline	$2.24	$2.00	$7.26	$4.28
Diesel Fuel	$4.40	$20.26	$6.94	$4.28
Aircraft Fuel	$0.89	n.a.	$4.89	$4.28
Coal	$10.83	$6.62	$1.59	$4.28
Heating Oils	$4.04	$9.95	$4.90	$4.28
Natural Gas	$0.06	$0.06	$3.92	$4.28
Wood[b]	n.a.	n.a.	n.a.	n.a.

[a] Procedures used to calculate the tax are the same as was described in footnotes to Table 4 except that the tax reference point has been altered.
[b] n.a. for wood implies that no consistent BTU value was available for wood fuel.

THE RANGE OF UNCERTAINTY[21]

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. New studies—not yet incorporated in the government benefit studies used in this effort—such as recent time-series epidemiological studies of ambient PM-10 mortality (see for example Schwartz and Zeger, 1990) may substantially reduce the range of uncertainty.

Instead of focusing on environmental costs based on the midpoints of government analyses, Figure 1 indicates the current tax amounts and the lower and upper bounds on the appropriate environmental cost surcharge. Gasoline has

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[21] Uncertainty is an inherent component in other risk regulation contexts as well. See Wilson and Crouch (1987), Krupnick and Portney (1991), and Hall, Winer, Kleinman, Lurmann, Brajer, and Colome (1992).

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 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). The wide variability in the environmental damages for coal is due to the uncertainty in linking mortality risk to exposure to the conversion products of SO_2. The EPA regulatory impact statements upon which our estimates are based rely on a number of "cross section" studies of the mortality risk of SO_2 conversion products. Because of underlying methodological questions about these cross section studies, their results have remained controversial. In their analysis of the National Ambient Air Quality Standards (NAAQS), EPA declined to evaluate the individual studies, choosing instead to make benefit estimates based on the range of results in the various studies. Since the last revision of the NAAQS, researchers have reported new mortality results from time series studies of daily mortality rates observed in different cities (see for example Schwartz and Dockery (1992) and Schwartz and Marcus (1990)). These time series studies show surprisingly consistent results that may narrow the range of uncertainty and may significantly improve analytic estimates of the mortality risks associated with SO_2 conversion products.

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.

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 mortality associated with the ambient conversion products of sulfur oxides, 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.

The financial pressures to reduce the budget deficit may make economists' discussion of the role of energy taxes more than hypothetical. However, there has not yet been an explicit attempt to link these taxes to the damages caused by use. One difficulty is that there is no explicit market transaction that makes clear the 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.

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 analysis and for ranking alternative tax approaches. 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.[22] 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

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[22] Acquiring further information on the links between nitrous oxides and carbon monoxide emissions and damages could potentially alter this conclusion.

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.

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