Addressing Environmental Externalities from Electricity Generation in South Carolina

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This paper gives estimates of the externalities associated with the increased likelihood of health and environmental impacts that result from exposure to pollutants emitted by electric power plants in South Carolina. A new method for estimating externalities is developed, results are presented, and policy-related implications are discussed. The results suggest that the environmental externalities are noteworthy and would affect electricity consumption if they are internalized and passed on to consumers in the rates they are charged. Yet, if the externalities are internalized, they are not so great that they would dramatically alter the fuel mix in the state in the immediate future. Two policy options are discussed: incentives or disincentives for new merchant power plants and emissions permit trading.

1. INTRODUCTION

This is a time of unparalleled change in the electric power industry. Many states are changing, or seriously considering changes in, their regulations. Missteps, such as in California this year, can lead to disastrous consequences for companies and consumers alike. To be responsible to its shareholders, a firm must strive to increase its revenues while reducing its costs of providing electricity and related services. State governments also have a responsibility to the people they represent and must strive to improve the social well-being of their residents, which is affected by their health and financial condition, as well as by the natural environment which they enjoy. With widespread initiatives to deregulate the electric power industry and with the recent travails in California, attention has understandably focused on rates and the availability of electricity, and less on environmental considerations.

However, it would be myopic to ignore them. In electricity generation, the emissions, discharges, and other effects of power production affect the health of nearby and sometimes distant populations, as well as the natural environment. For example, emissions of particulate matter increase the likelihood of respiratory illness, particularly among the elderly and the young. Although these impacts have a direct bearing on individuals' well-being, the impacts are not factored into any of the decisions to generate or consume electric power. Such effects on public health and the environment, not fully taken into account by individuals and firms in their electricity consumption and production decisions, are termed externalities.

This paper provides information about the magnitude of the external costs associated with electricity generation in South Carolina. The paper has two objectives:

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- Provide estimates of the true cost to society of operating power plants in South Carolina, focusing on the external cost component.

- Based on these estimates, identify ways in which state government can address these external costs through policies and actions that will affect the market for renewable energy and energy-efficient technologies.

2. THE SITUATION IN SOUTH CAROLINA

2.1 Fuel Mix

Power plants in South Carolina have a combined capacity of 18,100 megawatts (MW) and generated 87,200,000 megawatt-hours (MWh) in 1998 (South Carolina Energy Office, 1999).[1] Utility-owned plants accounted for 97.3% of this capacity and 96.7% of the generation. Nonutility plants accounted for the balance. Of the utility-owned plants, nuclear power plants accounted for 35.5% of capacity in South Carolina and 55.9% of generation. Coal is the second largest energy source in the state. Overall, coal power plants accounted for 33.2% of capacity and 37.1% of generation in the state. Hydroelectric power capacity and generation grew most rapidly among the primary energy sources. Generation increased at an annual rate of 16.6% over the period 1988-1998. However, hydropower still only accounts for 3.3% of total generation. Generation from petroleum and natural gas power plants increased at annual rates of 14.8% and 7.0%, respectively. Total generation accounted for 0.4% and 0.5%, respectively, of the state total. Other types of power plants, including those using wood and wastes, account for very small percentages of the state's capacity and generation.

2.2 Sources of Externalities

Airborne emissions from coal and other fossil fuel plants account for most of the externalities which scientific studies have been able to quantify. The primary emissions of concern are sulfur dioxide, nitrogen oxide, and particulate matter. After sulfur dioxide is emitted into the atmosphere, it is dispersed and some is transformed into sulfate aerosols through a series of chemical reactions. These small droplets or particles are suspended in the atmosphere and affect human respiratory function in the same way as particulate matter. Nitrogen oxides are also similarly transformed into nitrate aerosols. Sulfate and nitrate aerosols are very small in diameter (less than 2.5 microns).[2] Together with fine particulate matter which power plants emit, sulfate and nitrate aerosols increase the incidence of respiratory illnesses in the exposed population. Sulfur dioxide and nitrogen oxide are also transformed into acids that damage ecosystems, though the impacts are difficult to quantify. Ozone is another pollutant formed from nitrogen oxides and it, too, increases the incidence of respiratory illnesses among the exposed population. Ozone also affects crop growth, reducing crop yield and sales revenue, and is a major contributor to haze, which reduces visibility, a special concern in scenic areas.

As detailed in the report by the Intergovernmental Panel on Climate Change (IPCC), greenhouse-gas emissions and climate change are also a major concern (Bruce et al., 1996). Climate change will have different impacts on different regions worldwide. These impacts will reflect differences among these regions in their proximity to low-lying areas near oceans, the types of forests and agricultural crops grown, the types and locations of man-made structures, and regional climatic factors. The impacts are uncertain, though they might very well be severe in some areas of the state, particularly the low-lying coastal regions.

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[1] Unless otherwise indicated, data in this paper are for the year 1998.

[2] One micron equals 10^{-6} meter.

Extremely low concentrations of radionuclides are released from nuclear power plants during the normal operation of these plants. Radionuclides are also found naturally in coal and very small amounts are released from stacks or remain in the ash. Neither source of radionuclides is considered to be of concern, however. There are no emissions of sulfur dioxide, nitrogen oxide, or particulate matter to speak of from nuclear power plants. The emissions from diesel equipment and vehicles operating at the plant are very small compared to emissions from fossil fuel plants. There are no data on these emissions for South Carolina. The most significant impacts of nuclear plants are not their emissions or discharges from normal operations, but rather the presence of the plants themselves. There are two key concerns. The first concern is the perceived risk among some in the public of a severe reactor accident. The second concern is about the disposition of spent fuel from these plants, and the long-term risk to future generations of accidental releases of radioactive material. No studies have been done on these issues for South Carolina.

The main environmental concerns about the operation of existing hydropower plants are related to sedimentation, erosion, alteration of normal water flow in the river, oxygen-deficient water, and injury to fish (e.g., from operation of the turbines). There are no data on these effects for plants in South Carolina.

Biomass includes forests, agricultural crops and residues, wood and food processing wastes, and municipal solid waste. The most noteworthy emissions from power plants that combust biomass are particulate matter and nitrogen oxides. Sulfur dioxide emissions are much lower than from fossil fuel plants, about an order of magnitude (i.e., ten times) less. Particulate emissions are the greatest concern from biomass plants, and emissions can vary considerably depending on the efficiency of the equipment for removing them (ORNL/RFF, 1996).

3. METHODOLOGY

In previous studies, externalities have been estimated in one of four ways:

- the marginal cost of reducing the emissions,
- aggregate damage cost estimates, on a dollar/ton basis,
- detailed damage cost estimates based on impact-pathway modeling, or
- simplified calculations based on generalizations of impact-pathway results.

The approach used in our study falls under the fourth category of methods. The study uses results from previous studies to develop equations to calculate externality values. The calculations are based on estimates of the emissions and the size of the population exposed to airborne pollutants at different locations. This paper focuses on developing quantitative estimates of externalities, to the extent possible. A report on which this paper is based also has discussions of externalities for which quantitative estimates can not be developed (Lee et al. 2001).

From a computational standpoint, this paper classifies externalities into two groups:

- external costs for which quantitative estimates are calculated; and
- costs of global climate change due to carbon dioxide emissions.

Estimates for the first category are limited to impacts on South Carolina. Health and environmental impacts from pollutants that are emitted from plants in South Carolina, and which are dispersed by winds to other states, are not included in the tabulated results. The impacts to other states are estimated to account for about half of the total externalities (Hagler, Bailly and Tellus, 1995, Report 4, Table 2-2), depending on the type of power plant.

A key feature of the methodology is the estimation of externality coefficients. The coefficients are in units of dollar/ton of pollutant emitted, per person exposed within a certain distance interval. The coefficients are specific to the type of energy source used, to reflect differences in plant size and design, which in turn affect dispersion of pollutants. Different pollutants have different coefficients. The coefficients also differ for different distance intervals from the power plant. The primary source of information for estimating the coefficients was the Hagler, Bailly and Tellus study (1995), which had a consistent set of numerical calculations of the external costs for the state of New York. This state is similar to South Carolina in area and in being on the east coast of the U.S., so that the two states' pollutant dispersion patterns might be expected to be similar. The externality coefficients account for power plant characteristics and technologies typical of the different types of plants. After the externality coefficients are estimated, the externalities are calculated using estimates of the emissions of each pollutant from each power plant and the population within pre-specified distance intervals.

The second category of external costs – those associated with climate change as a result of carbon dioxide emissions – is distinctively different from the other external costs because the climate-change costs are on a global scale, rather than to South Carolina. It is impossible to separate the portion of the global impacts that affects South Carolina itself. Thus, the tabulated external costs associated with carbon dioxide emissions are for overall global damages rather than for the state. To make this distinction clear, the external costs associated with carbon dioxide emissions are listed separately from those in the other category. The state's portion of the global damage from an incremental increase in carbon dioxide emissions would be a very small fraction of the total external cost.

To estimate the externalities associated with carbon dioxide emissions, we compiled estimates of carbon dioxide emissions from each power plant. Net emissions of carbon dioxide from biomass fuel cycles are about zero and emissions from hydro and nuclear power plants are negligible compared to fossil fuel plants (ORNL/RFF, 1994-1998; Hagler, Bailly and Tellus, 1995; European Commission, 1995). The external costs were calculated using these estimated emissions together with dollar/ton cost estimates from the literature summarized in the IPCC report (Bruce et al., 1996).

Lee et al. (2001) provide information on the sources of the data used in this study. Data were from the U.S. Department of Energy, Energy Information Administration (EIA), the state of South Carolina, the U.S. Environmental Protection Agency (EPA), and the U.S. Bureau of the Census. The South Carolina data were used for pollutant emissions and the EIA data were used for generation. EPA data were used to estimate carbon dioxide emissions. Census population data were used to estimate exposure of population to pollutants.

4. STUDY RESULTS

4.1 External Costs Associated with Nitrogen Oxide, Particulate Matter, and Sulfur Dioxide Emissions

Coal. In terms of their total externalities, coal power plants have much greater impact than other types of plants. The health impacts due to elevated sulfate aerosol concentrations account for the majority of externalities associated with coal plants. Sulfate aerosols are formed from sulfur dioxide emitted from these plants. Nitrate aerosols, ozone, and particulate matter also contribute to the externalities associated with coal plants. Figure 1 is a map of the estimated external costs from these plants.

Natural gas. In the case of natural gas plants, nitrogen oxide emissions contribute the most to their externalities. Particulate matter is also a factor. Sulfur dioxide is not, because of negligible emissions.

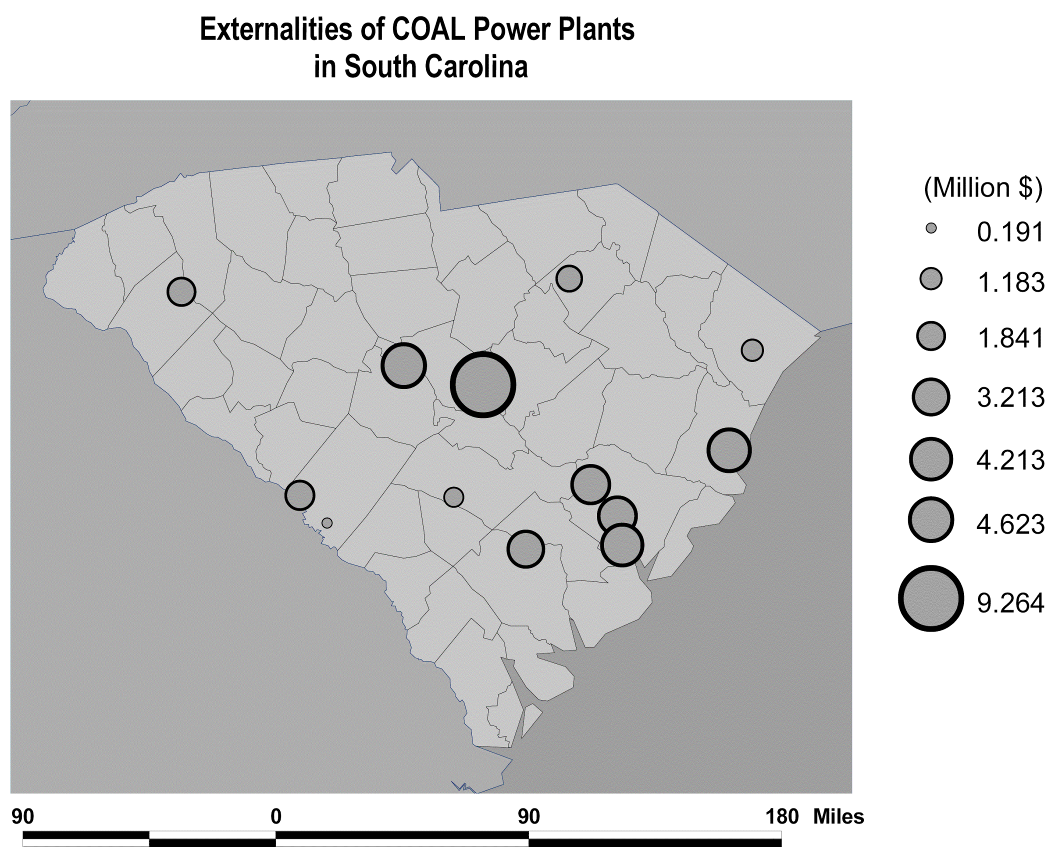
Oil. For oil power plants, the most significant sources of emissions are, in descending order: nitrogen oxides, sulfur dioxide, and particulate matter.

Biomass. For biomass power plants, nitrogen oxides are again the greatest source of externalities, followed by particulate matter.

The estimates of the externalities at different distance intervals implicitly reflect stack heights typical of the different types of power plants. Stack height affects the spatial dispersion of pollutants; the higher the stack, the greater the distance pollutants are dispersed, other things being equal. Coal power plants have tall stacks. The externalities associated with airborne pollutants from these plants are spread across the state. In fact, most of the external costs associated with coal power plants are borne by populations that live more than 80 km (i.e., 50 mi.) from the plants. The externalities associated with natural gas, oil, and biomass power plants on the other hand, are borne more by residents living within 30 km of these plants.

Table 1 summarizes the generation and externalities from coal, natural gas, oil, and biomass power plants. As expected, the annual external costs (measure in 1998 $) are greater for emissions from the larger coal plants. The externalities associated with natural gas plants were surprisingly high. This result is largely explained by the relatively high population density in the immediate vicinity of many of these plants. The externalities associated with oil power plants were about the same magnitude as those from coal power plants, if measured on a mills/kWh basis. Biomass power plants had the lowest externalities among plants that combust fuel. Nuclear and hydro power plants have negligible emissions of nitrogen oxides, particulate matter, and sulfur dioxide.

Figure 1. Externalities Associated with Generation from Coal Power Plants in South Carolina in the Year 1998, Measured in Dollars



There is not necessarily a direct relationship between generation and externalities (even among coal, natural gas, oil, and biomass power plants). The first reason for this finding is that the size of the population that is exposed to different concentrations of pollutants varies depending on the location of the power plant and the spatial distribution of the population. The second reason is that the quantities of pollutants do not directly correlate with the amount of generation.

In our calculations, we assumed that the emissions from each unit in the year 1995 were at the same rate in 1998 (on a tons per MWh basis). This assumption was troublesome for one particular natural gas unit. It generated only 12.5 MWh in 1995, but 201 MWh in 1998 (16 times more). This one unit accounted for 51% of the generation by gas units in 1998, and 65% of the calculated externalities from nitrogen oxides, sulfur dioxide, and particulate matter. The average 2.17 mill/kWh externality calculated for gas units was attributable largely to the 2.75 mill/kWh externality calculated for this one unit.

Yet, interestingly, there were two other, much smaller, gas units that had higher externalities ranging as high as 3.93 mills/kWh. One might speculate that many of the gas plants were used for handling peak load, and not for base load, and that the relatively inefficient peaking operation resulted in high use of fuel and emissions, relative to the amount of power generated.

Table 1. Generation and Externalities Among Power Plants that Combust Fuel

Power Plant Type	Generation (MWh)	Externalities ($ in 1998)	Externalities (mills/kWh)
Coal	32,400,000	41,000,000	1.25
Natural Gas	393,000	850,000	2.17
Oil	330,000	380,000	1.16
Biomass	653,000	250,000	0.39
Totals	33,800,000	42,000,000	1.25 [a]

[a] Average among all types of power plants across the state.

Source: Generation data from U.S. Department of Energy, Energy Information Administration, EIA F759YR98. Externality values calculated by authors.

4.2 Climate Change

As previously discussed, the impacts of climate change are highly uncertain. For the purpose of considering a possible scenario, our study considered the median value of the low- and high-estimates of each of the five studies listed in Table 6.11 of Bruce et al. (1996), for the time period 2001-2010 . This median value is an external cost of $3 per ton of carbon dioxide emitted. The range of values is from $2 per ton to $45 per ton. For comparison, Shell Oil (2000) has reported an average value of $4.50 to $6.35 per ton.

Using a $3/ton value, together with the estimated emissions of carbon dioxide from power plants in the state, our study estimated the global external costs. The results are listed in Table 2.

On a regional scale, EPA has suggested the possible impacts of climate change on South Carolina (U.S. EPA, 1998):

- Higher temperatures and increased frequency of heat waves might increase the number of heat-related deaths and the incidence of heat-related illnesses particularly among the elderly, and infectious diseases such as malaria and cholera.

- Sea level rise would lead to flooding of low-lying land, loss of coastal wetlands, erosion of beaches, saltwater contamination of drinking water, and structural damage to roads and bridges.

- In the northwestern part of the state, lower streamflows and groundwater levels could affect the water supply and increase growth of aquatic weeds in lakes.

- Higher rainfall, which would cause local flooding and increase pesticide runoff.

- The impacts on agriculture would be complex, with some areas benefitting from climate change, and other areas being damaged.

- Forests will adapt to changes in climate; for example longleaf and slash pine forests will likely expand northward and replace loblolly and shortleaf pines. Productivity of pine and hardwood plantations could increase by 10% or more.

- The state's coastal ecosystems, which are habitats for endangered and threatened species such as the American alligator, Bachman's warbler, bald eagle, loggerhead sea turtle, and other species, would be adversely affected by sea level rise.

Table 2. Global External Costs of Climate Change from Carbon Dioxide Emissions Emitted by Power Plants in South Carolina

Type of Fuel Used	Generation (MWh)	External Cost per Year ($)	External Cost (mills/kWh)
Coal	32,400,000[a]	101,000,000	3.13
Oil	330,000	2,240,000	6.78
Natural Gas	393,000	1,020,000	2.58
Totals	34,900,000	105,000,000	3.16[b]

Source: Calculated by authors.

Notes: (a) Figures in table are rounded, so totals might not match corresponding sums.

(b) The "total" external cost measured in mills/kWh is a weighted average of all plants.

5. DISCUSSION AND IMPLICATIONS OF THE RESULTS

The external costs, which this study calculates, account for a small proportion of all of the various types of impacts that can result from power plant operations. However, previous studies have shown that they account for a very *large percentage* of the damages when the impacts are converted into economic terms. Other externalities are generally less by at least an order of magnitude (i.e., ten times), in many cases two orders of magnitude less, than those calculated for sulfur dioxide, nitrogen oxide, and particulate matter (ORNL/RFF, 1994-1998; European Commission, 1995; Hagler, Bailly and Tellus, 1995).

The most significant externalities are those associated with emissions from fossil fuel plants. As in most of the U.S., coal-fired power plants generate considerable electricity, and thus contribute most of the emissions. Power plants that use oil, gas, and wood waste also have significant externalities associated with particulate matter and ozone. The questions for the state, then, are what these results mean in terms of its policies.

Notwithstanding the debacle in California this year, the deregulation of the electric power industry will continue in many states. South Carolina has been deliberate thus far, and has not proceeded with deregulation. Regardless, under any regulatory environment, utilities and nonutilities alike will need to be cost-competitive. Will this mean that they will abandon voluntary environmental programs, whose benefits reduce the external costs to the people and environment of South Carolina? There is a compelling reason why the answer to this question should be "yes." In a competitive market, utilities will no longer be regional monopolies. All generators will have to compete to provide low-cost reliable power. They can do this by decreasing unnecessary costs such as their voluntary environmental programs.

Thus, it will fall upon state government to assure that its energy policies address the health and environmental impacts of electric power plants. There are many policy options available to state government: encouraging or discouraging the location of new merchant power plants; decisions to re-license existing power plants; green pricing of renewable energy; renewable energy portfolios; research, development, and demonstration of renewable energy and energy efficient technologies; and participation in emissions trading programs. Lee et al. (2001) discuss many of these and other options, two of which are summarized below.

5.1 Encouraging or Discouraging the Location of New Merchant Power Plants in South Carolina

Natural gas turbines are expected to be more than 80 percent of new added capacity in the United States over the next 15 years. This trend is likely to apply to South Carolina as well. Gas power plants are less capital-intensive than coal plants, and even with the recent increase in natural gas prices, gas plants are expected to be less expensive to operate.

Compared to coal and oil plants, gas power plants are generally thought to have lower externalities (European Commission, 1995; Hagler, Bailly and Tellus, 1995; ORNL/RFF, 1994-1998). Sulfur dioxide emissions are minimal, and carbon dioxide emission rates from these plants are usually lower than rates from coal and oil power plants. Thus, over the next few decades, natural gas plants are expected not only to have cost advantages over coal and oil, but the external costs associated with gas plants are also generally thought to be less.

However, the results of this study were somewhat surprising in that the external costs of natural gas plants averaged 2.17 mills/kWh (refer to Table 1), greater than the average for both coal and oil power plants. These estimates are weighted averages. In contrast, the arithmetic averages across all power plants are given in Table 3. As is evident in Table 3, natural gas power plants have about the same external costs as oil power plants (with respect to their nitrogen dioxide, particulate matter, and sulfur dioxide emissions). As discussed in the previous section, the higher than expected external costs of the natural gas plants might be due to the fact that all but one appeared to be used for handling peak load. This inefficient way of operating the power plant could be a significant reason why the emissions rates were higher than the rates from coal power plants. Thus, the external costs associated with the operation of the natural gas power plants in 1998 might not be indicative of the external costs of new plants used for meeting base load.

Given the cost advantage of natural gas plants, the questions from a public interest standpoint are whether the state should encourage or discourage the location of new gas plants, or promote renewable energy sources. The relative social costs of these options, which include the external as well as financial costs, provide a justification for government initiatives and a specific basis for assessing the relative desirability of the options.

Table 3. Simple (Unweighted) Arithmetic Average Externality Values for Different Types of Power Plants

Type of Power Plant	Average Externality (mills/kWh)
Coal	1.6
Natural Gas	2.0
Oil	2.1
Biomass	0.73

Source: Calculated by authors.

5.2 Emissions Permit Trading

Many analysts favor a system of trading emissions permits as a way of managing the externalities of pollutants. The SO_2 trading program in the U.S. is perhaps the most well known of these programs. Polluters pay for their permits, which give them the right to emit pollutants equal to the quantity of permits the polluters possess. They in turn will recover the cost of their permits through the prices they charge for the electricity they generate. Thus, permit trading is a way of internalizing the externalities associated with these pollutants.

The most attractive aspect of emissions trading is that it avoids command-and-control regulations that are more restrictive and costly to firms. With emissions trading, they have the flexibility to install scrubbers or other pollution abatement equipment, use alternative energy sources and power plants, purchase power from other sources, or purchase permits that allow them to emit certain quantities of pollutants. However, there are several issues that should be addressed when emissions permit systems are designed.

One issue is whether emissions permit trading fully internalizes the impacts of the pollutant involved. The overall cap, or total number of permits, does not necessarily reflect the point where the marginal costs of reducing the total emissions by one ton equal the marginal benefit. There is also the question of how the permits are initially allocated among current polluters and what, if anything, they pay for these permits.

In addition, many studies, including our own, show that the types and magnitude of externalities depend on the type and density of the receptors (e.g, population density) and on the pollutant concentrations to which they are exposed. One ton of SO_2 emitted from a power plant in Ohio causes impacts different from those caused by one ton emitted in South Carolina. Of course the prices which utilities pay for emissions permits do not account for such differences. Thus, emissions permit trading does not perfectly internalize the externalities. Furthermore, there is no way of telling whether the externalities are over- or under-internalized. The non-uniform aspect of the impacts of pollution also raises environmental justice concerns (Solomon and Lee 2000).

Proposals to trade CO_2 permits have raised additional questions. One issue is about borrowing and lending permits across time periods; emissions will have different effects on overall atmospheric concentrations of greenhouse gases, depending on when the emissions take place. Another issue is about whether emissions permits or credits gained through the Clean Development Mechanism and Joint Implementation, if such programs are to be implemented through some agreement akin to the Kyoto Protocol, can be commingled and traded along with other CO_2 emissions permits.

5.3 Concluding Comments

The externalities estimated by our study – about $42 million in the year 1998 – suggest that they are non-trivial in magnitude, yet not so great that they would significantly alter the fuel choices and operations of power producers. Thus, attempts to internalize these externalities might be more politically acceptable than drastic high-cost measures. There are many policy options that can be used to address externalities. To proceed with any of them, there must be the public and political will to do so. No option is perfect, but second-best solutions might very well be better than no action at all.

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