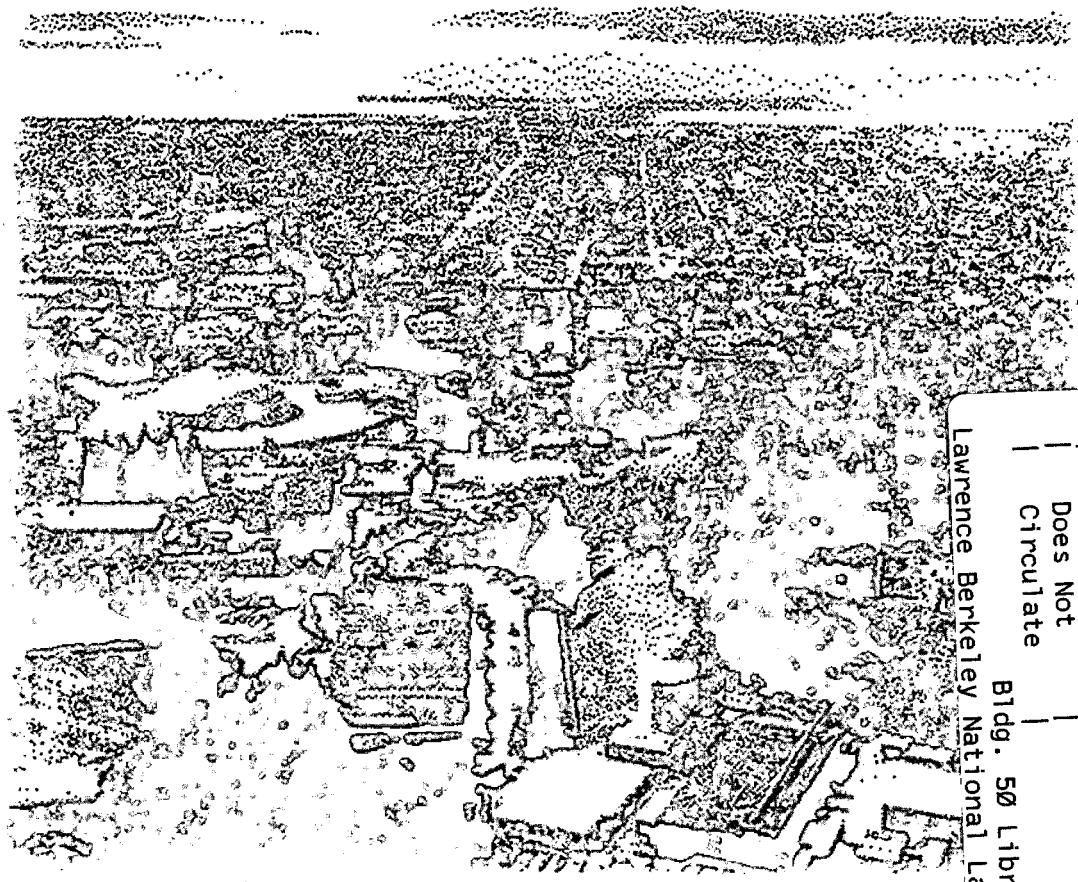
LBL-37030
UC-1320

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

The Science and Art of Valuing Externalities: A Recent History of Electricity Sector Evaluations

Stephen Wiel
Environmental Energy Technologies Division

May 1995



REFERENCE COPY
Does Not
Circulate
Bldg. 50 Library - Ref.
Lawrence Berkeley National Laboratory
Copy 1
LBL-37030

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

LBL-37030
UC-1320

The Science and Art of Valuing Externalities: A Recent History of Electricity Sector Evaluations

Stephen Wiel

Energy Analysis Program
Energy and Environment Division
Lawrence Berkeley National Laboratory

May 1995

This report is an outgrowth of work funded by the Assistant Secretary of Energy Efficiency and Renewable Energy, Office of Utility Technologies of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

The Science and Art of Valuing Externalities: A Recent History of Electricity Sector Evaluations

by
Stephen Wiel

All power plants emit substances which we have long known to be harmful to human health and welfare. Increasingly over the years, new generation technology and added emission controls required by environmental regulators have limited the amount of pollution coming from power plants. Yet, no matter how conscientiously we attempt to control power plant emissions, there will always be some level of residual pollution. When the harm caused by residual power plant pollution is not properly attributed in our resource decisions, economists call it an "externality".

Until the late 1980s, consideration of the residual pollution from power plants was separate from the basic economic evaluation of resource options. A geothermal power plant in close economic competition with a coal-fired plant might get the nod because of its lack of residual pollution, but historically this was not internalized into the economic calculations.
In the late 1980s a movement was initiated to internalize the environmental externalities of the power sector. This movement was sparked by research in both Germany and the United States. It soon spread throughout the U.S and to other European countries.

As largely an outgrowth of research independently conducted in the late 1980s by Olav Hohmeyer in Germany[1] and by Richard Ottinger in the U.S.[2], some utility regulators in the U.S. took heed. In the face of externality values reported to be in the range of 2.8¢ to 5.8¢ per kilowatt hour and for new natural gas-fired power plants on the order of 0.8¢ to 1.1¢ per kilowatt hour (in comparison to the then 6.5¢ per kilowatt hour average price of electricity in the U.S.), the New York Public Service Commission adopted a "new mathematics" for accounting for environmental costs in the selection of new electricity resources.

In 1989, the New York Commission assigned a dollar value to each pound of sulfur oxide, nitrogen oxide, carbon dioxide, and particulates. It applied these values to the residual emissions from a coal-fired power plant which met the U.S. Environmental Protection Agency's new source performance standards and, adding a value for water discharges and land use impacts, determined that the value of environmental externalities from such a plant total 1.4¢ per kilowatt hour and ordered this accounting to be used by New York's utility companies when selecting new sources of electricity to acquire.

---

[1]Hohmeyer, Olav, *Social Costs of Energy Consumption: External Effects of Electricity Generation in the Federal Republic of Germany*. Berlin:Springer-Verlag; 1988.
[2]Richard Ottinger, et. al., *Environmental Costs of Electricity*. New York: Oceana; 1990.

A year later, in August 1990, the Massachusetts Department of Public Utilities followed a similar path, setting the value for the externalities from a new coal plant (similar to the New York referenced plant) at 4.4¢ per kilowatt hour. In January 1991, Nevada became the third state to monetize residual environmental damage. California followed suit in June 1991. Since then, three other states (Minnesota, Oregon and Wisconsin) and the Bonneville Power Administration have taken action to monetize externalities to one degree or another.

In every case, these actions by U.S. regulators have been controversial. In general, electric utility companies and large industrial users of electricity have been opposing state regulatory commission's efforts to value externalities in electricity supply and generating decisions which accounts for the limited spread of environmental accounting in recent years. Furthermore, the monetized externality values specified for residual pollutants by U.S. regulators are used only in the *selection of new resources*. Such values are *not* being used in the *operational* decisions of any electric utility.

U.S.-EC Fuel Cycle Studies

Concurrent to much of the above activity and involving many of the same people, the U.S. Department of Energy (DOE) initiated in 1989 a study of the external damages and benefits of the major fuel cycles involved in electric power generation. In February 1991 DOE merged its efforts with similar work being undertaken by the European Communities (EC). Results of this historic collaboration are just now being published under the title *U.S. -EC Fuel Cycle Study*.

The results of the U.S. research show externalities from new coal-fired power plants at two rural sites for 40 damages for which the researchers specified numbers out of 66 types of damage listed as relevant.[3,4,5] Adding the incomplete valuations, one finds externalities for rural coal-fired power plants reported to be in the 0.03 to 0.19¢ per kilowatt hour range[6] While these values omit any contribution from carbon dioxide as is included in the

---

[3]ORNL and RFF, *Estimating Fuel Cycle Externalities: Analytical Methods and Issues, Report Number 2 on the External Costs and Benefits of Fuel Cycles: A Study by the U.S. Department of Energy and the Commission of the European Communities,* July 1994.

[4]ORNL and RFF, *Estimating Externalities of Coal Fuel Cycles, Report Number 3 on the External Costs and Benefits of Fuel Cycles: A Study by the U.S. Department of Energy and the Commission of the European Communities,* September 1994.

[5]As of late January 1995, Volumes 4 and 5 are at the printer and the final three volumes are expected to follow shortly.

[6]ORNL and RFF, *Estimating Externalities of Coal Fuel Cycles, Report Number 3 on the External Costs and Benefits of Fuel Cycles: A Study by the U.S. Department of Energy and the Commission of the European Communities,* September 1994.

Ottinger numbers, identical components are well below the Ottinger values for reasons described below.

On the European side, the project is know as the ExternE project and examines a range of power plants at reference sites throughout Europe.[7,8,9,10,11,12,13,14,15] In general, the ExternE project reports higher valuations than its U.S. counterpart. Like the U.S. study, the ExternE study provides only partial results, not quantifying damages from many of the relevant parameters including carbon dioxide. It reports externality values for fossil fuels in the range of 0.8 mECU (0.1¢) per kilowatt hour for natural gas fired electricity in the U.K. to 15 mECU (1.8¢) per kilowatt hour for coal fired electricity in Germany.

New York Environmental Externalities Cost Study

In response to the New York Public Service Commission's 1989 decision to monetize externalities, a group of New York agencies joined together to conduct a study to develop a methodology and a computer model that permit the estimation of environmental externality damages for new and relicenced electric supply and DSM resource options in New York. This New York Environmental Externalities Cost Study (New York Study), looking again at a new coal-fired power plant as a reference point, shows externality values

---

[7]European Commission, *Externalities of Fuel Cycles: ExternE Project Report No. 1, Summary Report.* 1994.
[8]European Commission, *Externalities of Fuel Cycles: ExternE Project Report No. 2, External Costs of the Coal Fuel Cycle.* 1994.
[9]European Commission, *Externalities of Fuel Cycles: ExternE Project Report No. 3, External Costs of the Nuclear Fuel Cycle.* 1994.
[10]European Commission, *Externalities of Fuel Cycles: ExternE Project Report No. 4, External Costs of the Oil Fuel Cycle.* 1994.
[11]European Commission, *Externalities of Fuel Cycles: ExternE Project Report No. 5, External Costs of the Natural Gas Fuel Cycle.* 1994.
[12]European Commission, *Externalities of Fuel Cycles: ExternE Project Report No. 6, External Costs of the Lignite Fuel Cycle.* 1994.
[13]European Commission, *Externalities of Fuel Cycles: ExternE Project Report No. 7, External Costs of the Wind Fuel Cycle.* 1994.
[14]European Commission, *Externalities of Fuel Cycles: ExternE Project Report No. 8, External Costs of the Hydropower Fuel Cycle.* 1994.
[15]European Commission, *Externalities of Fuel Cycles: ExternE Project Report No. 9, Economic Valuations of the External Costs of Fuel Cycles.* 1994.

ranging from 0.2 to 0.5¢ per kilowatt hour.[16,17,18,19] Like the Fuel Cycle Study, the New York Study lacks valuation for carbon dioxide but also shows numbers for specific externalities well below the Ottinger values. Putting it another way, the Fuel Cycle Study and the New York Study seem to indicate that the Ottinger numbers only represent power plants in the most highly congested areas.

EC/OECD/IEA Workshop on The External Costs of Energy

In January 1995, the European Commission (EC), in conjunction with the Organisation for Economic Co-Operation and Development (OECD) and the International Energy Agency (IEA), sponsored a Workshop on The External Costs of Energy. It convened over 50 experts in the field for a two-day assessment of the state-of-the-art on the subject in light of the recent completion of several major studies. Four relevant observations from the workshop are worth mentioning.

(1) Consensus is Building on Environmental Accounting

Most of the recent research cited above on the valuation of environmental damage from electricity generation is based on secondary analysis of an extremely vast body of primary research on environmental damage. The New York Study, for example, assembled and reviewed a literature database of over 1800 documents. The large uncertainty that exists in our understanding of how pollutants impact our health and welfare is not always the result of a lack of research on the subject. Rather it is often a testimony to the complexity of the issue. That we live with such a large uncertainty after so much research has been done is an indication that we will continue to live with substantial uncertainty for some time to come.

---

[16]Robert Rowe, et. al., *New York State Environmental Externalities Cost Study. Report 1: Externalities Screening and Recommendations.* Prepared by RCG/Hagler Bailly, Boulder, CO for the Empire State Electric Energy Research Corporation, Albany, NY, December 1993.
[17]Robert Rowe, et. al., *New York State Environmental Externalities Cost Study. Report 2: Methodology.* Prepared by RCG/Hagler Bailly, Boulder, CO for the Empire State Electric Energy Research Corporation, Albany, NY, November 1994.
[18]Stephen Bernow, et. al., *New York State Environmental Externalities Cost Study. Reports 3a and 3b: EXMOD User Manual and EXMOD Reference Manual.* Prepared by Tellus Institute, Boston, MA and RCG/Hagler Bailly, Boulder, CO for the Empire State Electric Energy Research Corporation, Albany, NY, January 1995.
[19]Stephen Bernow, et. al., *New York State Environmental Externalities Cost Study. Report 4: Case Studies.* Prepared by Tellus Institute, Boston, MA and RCG/Hagler Bailly, Boulder, CO for the Empire State Electric Energy Research Corporation, Albany, NY, January 1995 with summary results reported in Robert Rowe, et. al., *The New York Environmental Externalities Cost Study: Summary of Approach and Results,* a paper presented at the EC and IEA/OECD Workshop on the External Costs of Energy, Brussels, Belgium, January 30-31, 1995.

Nevertheless, acceptance of environmental accounting in the electricity sector worldwide appears to be increasing. Environmental accounting by utility companies and their regulators may not be the first choice for internalizing externalities from a societal point of view, but it is becoming more and more acceptable. Addressing all externalities comprehensively throughout our economy would provide a more balanced treatment. It would be desirable to have consistent treatment of externalities in all sectors of the energy industry (electricity, natural gas, gasoline, diesel fuel, coal, etc.), without geographic distinction (all states and international trading partners), and among all participants (investor-owned utilities, public utilities, and rural cooperatives in the electricity sector). But many people believe that optimizing welfare in a dominant portion of the electric utility industry is better than accepting the status quo. This principle was well stated in the foundational report of the U.S.-EC Fuel Cycle Study[20] :

> Introducing social costs into utility decision making is not the first best policy for internalizing damages associated with energy use. If this approach is applied to electric utilities only, energy markets could become distorted. It introduces possible anti-new source bias if applied to only new sources. It requires that other policies, such as potentially inefficient environmental laws, be taken as a given. It offers an inappropriate jurisdictional control for many issues, such as global warming or foreign policy, which will be a source of frustration for many advocates. And it could even result in increases in pollution (from non-electric energy sources). It would be preferable for federal and state laws to be set and designed efficiently affecting all sectors of the economy.
>
> Nonetheless, application and investment of the concept of social costing of electricity can lead to more efficient electricity generation choices. While the piecemeal problem is potentially significant, so are the benefits of social costing.

(2) Uncertainty In Externality Estimates is High

Environmental externalities from the production of electricity have been reported to be anywhere from 0.01 mils per kilowatt hour to over 100 mils per kilowatt hour, a range of four orders of magnitude.[21] Non-global damage cost uncertainties account for about one order of magnitude of this range. Site specific factors account for the other three orders of magnitude. The Fuel Cycle Study, for example, found that environmental externalities (excluding

---

[20]ORNL and RFF, *U.S.-EC Fuel Cycle Study: Background Document to the Approaches and Issues, Report Number 1 on the External Costs and Benefits of Fuel Cycles: A Study by the U.S. Department of Energy and the Commission of the European Communities,* November 1992, p. C-26.

[21]U.S. Congress, Office of Technology Assessment, *Studies of the Environmental Costs of Electricity,* OTA-ETI-134, September 1994.

climate change) from power plants depend most heavily on the following factors:[22]

1) type of fuel used to generate the power
2) the age and technology of the power plant
3) the location of people and their activities in relation to the power plant
4) the method of transporting the fuel
5) meteorological conditions and ambient air quality in the vicinity of the plant
6) applicable environmental regulations.

Even for a particular power plant, researchers reported values range over an order of magnitude in the valuation of damage from any pollutant. For example, estimates of environmental externality values by the Fuel Cycle Study for one reference case of coal-fired power show a factor of four and a half range for the largest contributing factor (coal transport rail accident deaths) and a factor of eleven range for the second largest contributing factor (mortality from airborne particulates). Even then the Fuel Cycle Study researchers felt comfortable in specifying values for only 40 of the 66 relevant damages they listed for coal-fired power plants.[23]

Fortunately, among all of the studies a few sources account for most of the damage. In practice, a practitioner who decides to monetize power plant externalities can do so using a manageable set of data. Still, there is an inherent and large uncertainty in power plant damage function values, an uncertainty which is likely to remain a characteristic of the electricity sector for some time to come.

(3) Climate Change Valuation Is The Biggest And Most Uncertain

Neither the Fuel Cycle Study nor the New York Study include valuation of carbon dioxide for its threat of global warming (although both provide in their methodology for it to be included). This is understandable because the uncertainty in the damage value from carbon dioxide is immense. No wonder it is the subject of an international debate as people propose to spend billions of dollars to mitigate its potential damage. Yet in the valuation of pollutants by state commissions in the U.S., it is generally the largest single contributor. For example, carbon dioxide comprises over 40% of the total externality value assigned by the Nevada PSC for 23 of 25 types of power

[22]ORNL and RFF, *Estimating Externalities of Coal Fuel Cycles, Report Number 3 on the External Costs and Benefits of Fuel Cycles: A Study by the U.S. Department of Energy and the Commission of the European Communities,* September 1994.
[23]Ibid.

plants evaluated.[24] The Wisconsin PSC ruled that only greenhouse gasses needed special environmental accounting, with carbon dioxide dominating their valuations.

Clearly, the dominant uncertainty at the present time in estimates of total damage from power plant environmental externalities comes from the valuation of carbon dioxide emissions. In explaining why no valuations are recommended for greenhouse gas emissions in its study, the ExternE program states:

> "It is concluded that global warming impacts may well be the most serious of the fossil fuel cycles, with potentially serious implications for sustainable development. However, the impacts cannot be calculated with any accuracy. Estimation of damages requires scenario definition and ethical judgments, which it is misleading to present as the results of a technical and objective exercise."[25]

(4) Valuation of Externalities is a Political Decision

This situation is unlikely to change in the near future. That leaves decisions on the treatment of such environmental externalities largely to the political arena. Without more definitive guidance from the technical community, legislators and regulators faced with factors of five or ten between alternative recommended valuations are left with substantial discretion in specifying how much money electricity customers will pay for reducing or avoiding pollution. Like it or not, by necessity, the final decisions about valuing environmental externalities are political.

---

[24]Testimony by Sierra Pacific Power Company in Nevada PSC Docket 89-752.

[25]European Commission, *Externalities of Fuel Cycles: ExternE Project Report No. 1, Summary Report*. 1994.

EXHIBIT 1
A RECENT HISTORY: 1988-1995

- RESEARCH BY HOHMEYER AND OTTINGER
  - 1988 Hohmeyer book says fossil externalities 2.5¢/kwh to 5.8¢/kwh
  - 1990 Ottinger book says coal externalities 2.5¢/kwh to 4.5¢/kwh *(natural gas externalities 0.8¢/kwh to 1.1¢/kwh)*

- ACTION BY STATE REGULATORS IN THE U.S.
  - In 1989 New York PSC sets coal externalities at 1.4¢/kwh
  - In 1990 Massachusetts DPU sets coal externalities at 4.4¢/kwh *(natural gas externalities 2.2¢/kwh)*
  - Since 1990 three more States and BPA monetize externalities

- U.S.-EC FUEL CYCLE STUDIES
  - 1991-1994 U.S. study finds coal externalities <0.2¢/kwh (sans CO_2) *(natural gas externalities <0.1¢/kwh)*
  - 1991-1994 EC study finds coal externalities <1.8¢/kwh (sans CO_2) *(natural gas externalities 0.1¢/kwh)*

- NEW YORK ENVIRONMENTAL EXTERNALITIES COST STUDY
  - 1992-1994 study finds coal externalities 0.2¢-0.5¢/kwh (sans CO_2) *(natural gas externalities 0.01¢/kwh to 0.2¢/kwh)*

EXHIBIT 2
THE ART AND SCIENCE OF VALUING DAMAGE
FROM ELECTRICITY SECTOR POLLUTION

- THERE IS HUGE VARIATION IN EXTERNALITY ESTIMATES
  - Reasonable people find electricity externalities from 0.001¢/kwh to over 10¢/kwh, a range of four orders of magnitude
  - Values of non-global externalities depend on:
  - type of fuel used to generate the power
  - age and technology of the power plant
  - location of people and their activities in relation to the plant
  - method of transporting the fuel
  - meteorological conditions and ambient air quality in the vicinity of the plant
  - applicable environmental regulations
  - Fuel Cycle Study results for one reference power plant show a factor of 4-1/2 range in the largest contributing damage and a factor of 11 in the second largest
  - Fuel Cycle Study researchers specified values for only 40 of the 66 relevant damages for coal-fired power plants. No value was specified for CO_2.

- CLIMATE CHANGE VALUATION IS THE BIGGEST & MOST UNCERTAIN
  - uncertainty in the damage value from CO_2 is immense
  - valuation by state commissions in the U.S. generally has CO_2 as the largest single contributor (e.g., 2¢/kwh, 40% of Nevada valuation)

- VALUATION IS A POLITICAL DECISION
  - damage is represented by the amount people will pay to avoid it
  - regulators have substantial discretion in specifying how much money electricity customers will pay for reducing or avoiding pollution
  - exercising that discretion is political judgment

ERNEST ORLANDO LAWRENCE BERKELEY NATIONAL LABORATORY
ONE CYCLOTRON ROAD | BERKELEY, CALIFORNIA 94720

Prepared for the U.S. Department of Energy under Contract No. DE-AC03-76SF00098