Some American electric utilities have been required since 1989 to incorporate environmental costs into their assessment criteria of competing projects for a given required capacity. In doing this, their local regulators are trying to reduce the competitive disadvantage faced by DSM programs and renewable-source electricity production. It is obvious, though, that this requirement, other than being heavily criticized, has not produced expected results. Selected values, as well as the existence of an unfavourable bias towards new facilities, have created a number of controversies. Above all, the ongoing reorganization of the Californian electric industry has led to the complete disappearance of this requirement.

Depuis 1989, certaines compagnies électriques américaines doivent intégrer des coûts environnementaux dans leur critère d'évaluation des projets en compétition pour un besoin en capacité donné. Leur régulateur local cherche ainsi à réduire le désavantage compétitif dont souffrent les programmes de DSM et la production d'électricité à partir des énergies renouvelables. Force est de constater cependant que cette obligation ne produit pas les résultats escomptés, sans compter qu'elle est fortement contestée. Les valeurs retenues mais aussi l'existence d'un biais en défaveur des nouvelles installations soulèvent de nombreuses controverses. Surtout, la réorganisation en cours de l'industrie électrique californienne a conduit à sa totale disparition.

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The External Costs of Electricity Generation: Lessons from the US Experience

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Introduction

Behind the controversy over the externalities of electricity generation, which has occupied energy circles in various countries since the end of the 1980s, lies the need to agree on a way to evaluate and integrate them in the decision-making process. While the importance of incorporating the environmental externalities of the electricity sector is generally well accepted, we still have a long way to go when it comes to the question of "what" and "how" to pay. Will a universal method of evaluation and integration eventually emerge from the vexed question of the external costs of electricity generation? The question is worth asking because, although the standard theoretical line of argument long ago established the need, no internalization procedure has yet emerged as standard practice.

It is interesting to look at the situation in the United States, because of the very active position adopted by American regulators in the evaluation and integration of external costs in the decision-making process. Since the early 1980s, a special regulatory procedure has evolved from this debate. Environmental costs are now being incorporated into the long-term decisions of some public utilities (i.e., the regulated electricity companies). Their local regula-

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tors, the Public Utility Commissions (PUCs), take these costs into account in choosing new investments, by adding them to production costs. The generating plant whose social cost (production cost and environmental cost) is lowest is then the one selected. This integration is only carried out at the time of the selection process and is therefore not reflected in tariffs. It is used by the regulators in an attempt to overcome the competitive disadvantage of renewable energy, without causing a subsequent rise in electricity tariffs (NARUC, 1993).

It is especially interesting to study this problem in the American context because of the myriad controversies surrounding the regulatory procedure implemented by the PUCs. These debates have prevented this procedure from being adopted on a wider scale, and may even cause it to be dropped entirely. The controversy is not limited to the evaluation of environmental costs but also concerns the integration of these costs in the decision making process, regardless of what the actual values might be. This debate is not specific to the US context — another reason why this American case study is interesting. By highlighting the limits to a specific procedure it shows, by default, the general features which we should be looking for in this kind of procedure.

The first section of this paper analyses the nature of the regulatory procedure developed by PUCs. The second part identifies the existing controversies surrounding the evaluations that have been made as well as the corrections planned. The third section describes the current debate over integration in the decision-making process, the planned corrections and their relevance. This makes it possible to assess the future prospects of the current procedure. In the conclusion, we identify the lessons to be learned from the US experience and we raise questions about the future role of these calculations of environmental costs.

1. The Emergence of a Regulatory Procedure

The redefinition of the regulation of public utilities in the 1980s—which gave regulators an increased role—provided the framework for the internalization of environmental externalities. Three factors played an important role; 1) the readiness of regulators to influence the incentives behind investment decisions, 2) the slowing down in the development of renewable energy sources toward the end of the 1980s, 3) the quantification of environmental externalities undertaken by Hohmeyer (1988) and Pace University Center for Environmental and Legal Studies (1990).

The readiness of regulators to influence investment incentives emerged when the electricity companies' interest in electricity conservation began to taper off in the middle of the 1980s. This had been a concrete factor in the 1970s because conservation cost next to nothing and seemed relevant in a heavily degraded environment, but this enthusiasm had waned considerably by the middle of the next decade (Garcia, 1992; Sioshansi, 1995). This falling off can be attributed to the difficult economic choice, which generators faced, of needing to limit their outlets while in a situation of excess capacity, low electricity consumption and low energy prices, with the cost of limitation rising as the potential for conservation went down. Under the close scrutiny of environmentalists, regulators felt it necessary to alter investment incentives to lead public utilities to invest again in the sale not so much of electricity as of energy services (specifically, demand side management (DSM) programmes). The cost of these programmes and the subsequent loss of revenue had to be made up, and companies and their shareholders had to make a profit out of them (Sioshansi, 1992, 1995).

Similarly, renewable energy started going down in relative terms in the mid-1980s, after a growth spurt at the beginning of the decade. The favourable conditions offered by the PURPA of 1978[1] and the dramatic increase in

1/ The *Public Utility Regulatory Policy Act*, voted through by the Carter Administration in 1978 in response to the energy crisis, sought to promote renewable energy and energy efficiency. It required all public utilities to pay a price based on their own avoided costs for electricity generated by producers using either renewable energy (plants below 80 MW) or cogeneration (with at least 5% of energy used in the form of heat), while supplying electricity energy prices in 1979-80 considerably increased the investment appeal of these forms of energy. Generous federal and local tax incentives, attractive recovery prices and forecasts of guaranteed high energy prices in the first long-term contracts, assured them a rapid take off. But in the mid-1980s, when energy prices started to drop and public utilities found themselves with excess capacity, the long-term contracts negotiated under the PURPA became very disadvantageous for them. Renewable energy lost much of its appeal for potential investors, especially since the technology for the generation of electricity from natural gas became very competitive (Nola and Sioshansi, 1990).

Against this background, the work of Hohmeyer (1988)[2] together with that published by Ottinger and his team at Pace University (1990) were well received (Nola and Sioshansi 1990). By bringing out social cost as opposed to private cost alone, these studies (together with other less systematic works) paved the way to regulatory intervention designed to overcome the competitive disadvantage of renewable energy and increase its share in the energy balance sheet (Beutier, 1995). This intervention was all the more natural in a context where "Least Cost Planning" (LCP) had become the methodological backbone for the re-organization of regulation. By adopting the criterion of total cost or social cost, LCP could be made into Least Social Cost Planning or Integrated Resources Planning (IRP)[3] (NARUC, 1993; Krupnick et al., 1994).

From 1989 onwards[4] regulators developed various procedures to reflect the environmental impact of competing options, within the framework of IRP, when appropriate, or within the traditional framework of long-term decisions. These procedures started operating at the point of new investment selection, and ranged from rate of return differentiation according to impact, to the addition of environmental costs to the generation costs. These costs, integrated into long-term decisions on new investments, are thus called "adders." The basic objective was to ensure the selection of the investment project with the lowest total or social cost (cost of production plus adder).

Since this procedure is only invoked at the time of investment selection, adders are not reflected in electricity tariffs. In 1992, six PUCs incorporated environmental costs into long-term decisions; five used straightforward percentages (i.e., 15% of generating costs extra for standard thermal) and seven differentiated between rates of return (Woolfe, 1992). The environmental costs of competing options are obtained by adding the emission coefficients of pollutants (e.g., kilogram of per kilowatt-hour generated) multiplied by the damage value of the pollutant in question (e.g., dollars per kilogram of SO_2 emitted). PUCs use various studies which have estimated these values. The tables below give the estimates obtained by different research teams (Table 1) and those adopted by some PUCs (Table 2).

The differences in these evaluations can be traced to differences in the identified environmental damages, as well as in the methods of their money valuation. The studies by the Tellus Institute, Chernick and Schilberg use marginal reduction costs on the basis of existing regulation,[5] while the Pace University

in the case of interruptions. These conditions were supplemented by numerous subsidies and other tax breaks (Nola and Sioshansi, 1990).

2/ Which suggested that the inclusion of externalities (in the wider sense of effects on health, the environment, employment, state R&D budgets, *etc.*) could make renewable energy more competitive than coal or nuclear energy.

3/ "Integrated Resources Planning (IRP) helps utilities and state regulatory commissions to consistently assess a broad range of demand and supply resources to meet consumer energy-service needs cost-effectively. Key characteristics of this planning approach include: explicit and fair treatment of a wide variety of supply and demand options; consideration of the environmental and other social costs of providing energy services; public participation in the development of the resource plan; and analysis of the uncertainties associated with different external factors and resource options" (Hirst, 1994, p. 141).

4/ This is the date when the first PUC, in New York State, developed a procedure. This involved integrating the environmental costs quantified by Ottinger's team, into competitive biddings (Wiel, 1995).

5/ This method of valuation is easy to implement. The value of a marginal damage due to a pollutant is identified as being the marginal cost of its reduc-

Table 1: Damage Values from Different Studies (1990 US$/ tonne)

	Studies			
Pollutant/Impact	Tellus	Chernick	Pace	Schilberg[1]
CO_2	23	24	14	15
NO_X	6767	3251	1707	25504
SO_X	1562	1907	4226	19050
Particulates	4164	-	2477	-
VOC	5517	-	-	18218
CO	906	-	-	-
CH_4	229	758	-	390
N_2O	4122	-	-	3852

1/ 1989 US $/ton
Source: Woolfe (1992)

Table 2: Damage Values Adopted by some PUCs (1990 US$/tonne)

	PUCs					
Pollutant/Impact	BPA	California	Massachusetts	Nevada	New Jersey	New York
CO_2	-	30	23	23	14	1.1
NO_X	884	28524	6767	6767	1707	1832
SO_X	1500	4226	1562	1562	4226	832
Particulates	1540	2477	4164	4164	2477	333
VOC	-	3842	5517	1180	-	-
CO	-	-	906	906	-	-
CH_4	-	-	229	229	-	-
N_2O	-	-	4122	4122	-	-
Land,Water (US¢/kWh)	0.1-0.2	-	-	*	-	0.5

* determined according to site
Source: Woolfe (1992)

study developed a method of estimating damage (damage is the monetary measure of the welfare loss due to the environmental impact of the emission of a pollutant). In spite of these differences in marginal costs, the associated environmental costs lead to considerable adjustments in the ranking of the different processes once environmental costs are added to generating costs: both are of the same order of magnitude, thus penalizing thermal coal fired stations, even when "clean." Table 3 gives environmental costs for different technologies.

2. The Controversies over Environmental Costs

Although by 1992, six PUCs were taking environmental costs into account in selecting new investments, only two PUCs, in Minnesota and Oregon, have since joined this list. The figures they have adopted as costs are merely provisional in the case of Minnesota, and in Oregon their use is for guidance only. Furthermore, the PUCs in Massachusetts and Wisconsin have seen their environmental costs successfully disputed in the competent courts.[6] Others, such as those in the states of Colorado and Maine, have given up on the idea of integrating these kinds of costs in the selection of new investments (NARUC, 1993; *Electrical World,*

tion by existing *ad hoc* techniques (*e.g.,* $1500 per tonne of SO_2 reduced by the flue gas desulfuration process).

6/ In the case of Wisconsin, only the environmental costs of greenhouse gases are included.

Table 3: Environmental Costs (US¢/kWh)

Generation Technologies	Value in New York	Value in Massachussetts	Value in Nevada	Value in Pace Study
Coal-fired (meeting standards)	1.4	4.4	4.3	4.5
Coal fluidized bed	-	3.0	2.9	3.3
Gas turbine combined cycle	-	1.1	2.2	1.1
Geothermal	-	-	0.001	-
DSM	0	0	0	0

Source: Power Engineering (1992)

1993). The spread of this regulatory procedure has therefore come to a virtual halt, chiefly because of the controversies surrounding environmental costs.

The Dispute Over the Methodology of the Current Evaluation Studies

While the need for internalization is not questioned, there is a dispute as to whether the environmental costs evaluated by PUCs are external costs that have to be internalized (Joskow, 1992; Sioshansi, 1992; Krupnick et al., 1995). Two arguments are generally put forward.

First, in standard economic analysis, there is no systematic relationship between the extent of environmental damage and the cost to be internalized. Where emissions of pollutants have an impact on the environment the associated damage may have already been taken into account partially in prices. The extent of this depends on existing environmental regulation, rules on ownership and responsibility, the distribution of rights of ownership, and the cost-price relationship (i.e., the degree of vertical and horizontal integration of the industries involved) (Joskow, 1992). In the case of electricity generation, 25 years of legislation and regulation on atmospheric emissions, and of major R&D drives for cleaner technology, have led generators and consumers to include at least part of the environmental damages of their economic decisions. Therefore, the environmental costs of additional generating plants are not fully comparable to external costs that have to be internalized.

Second, the two methods used to quantify them are not satisfying. The first one estimates the environmental cost of a new generating plant by adding up the marginal reduction costs of the different pollutants using existing *ad hoc* reduction techniques (e.g., $1500/tonne of SO_2 reduced by FGD), multiplied by the different emission factors of the technology used (e.g., kg of SO_2 emitted/kWh generated). The second method works out environmental cost by adding the damage calculated individually for each unit of pollutant, and multiplying it by the same emission factors:

$$\text{Environmental cost (\$/kWh)} = \Sigma_I \, x_i{}^* y_i,$$

where x_i = damage associated with the marginal emission of a pollutant I (e.g., $/lb.) and y_i = amount of pollutant I emitted per unit of output generated (e.g., lbs./kWh)). But these two methods do not properly evaluate what really needs to be evaluated.

The first method is only valid if the reduction strategy leads to an optimal level of pollution, for only at this level are the marginal damage and the marginal reduction cost equal. But the fact is that this is rarely the case (Kneese and Schultze, 1975; Ringleb, 1986; Joskow, 1992; Tietenberg, 1992), even if some regulators are convinced that it is indeed so (Woolfe, 1992; NARUC, 1993). Except by coincidence, it is at the very least doubtful that this even approaches the sought-after environmental cost that needs to be internalized. That is why studies which evaluate environmental costs using reduction cost methods are pulled apart by economists: these have no serious scientific foundation (Krupnick et al., 1995). There is even a tautology here: the reason for making the two marginal costs (external and reduction) equal is that the strategy for their reduction is efficient, while we know by definition that the efficient reduction strategy is given by this equalization anyway!

With reference to the second method (mainly developed in the Pace University study) the main criticism is about the "displacement" in the aim of the evaluation. In the first stage, the various potential and theoretical impacts of the emissions of each pollutant are identified (visibility, morbidity, mortality, etc. for SO_2 emissions) and the associated damage is estimated on the basis of different unconnected pieces of research (mortality and morbidity due to SO_2 emissions by one study, visibility by another, etc.). In the second stage, the valuation of damage due to emissions of a pollutant is obtained by adding up all the previous values. It is only after this operation has been carried out that the environmental cost of a generating plant can be calculated by adding the numerical values multiplied by the corresponding emission factors. This does estimate damage but, unless there is a coincidence between real conditions (population, dispersion of pollutants, pollution reaction function, etc.) and the underlying assumptions of the quantification studies used, it is at the very least doubtful that this will ultimately approximate the damage of an electricity plant operating under real conditions. It is even less likely if we take into account that in these pieces of research some maximalist assumptions (on mortality and morbidity in particular) overestimate certain forms of damage (Beutier, 1995). The Pace University study has been strongly criticized for the displacement of the object of the evaluation, which led to the overestimation of the environmental costs of electricity generation using different technologies (Wiel, 1995).

The Damage Function Approach and its Limitations

The environmental costs used by some PUCs are therefore fiercely contested on a methodological ground. As a result, many states today are reluctant to develop a regulatory procedure which uses them (Krupnick et al., 1995; Wiel, 1995). To defuse the controversies, at the end of the 1980s, both the US Department of Energy (DOE) and the State of New York launched studies on the appropriateness of using the damage function approach to evaluate environmental costs. These aimed to address the main perceived sources of problems; 1) the sequencing: emissions, dispersion, variation in concentration, impact and monetary evaluation, and 2) the idea that this is the only legitimate method of evaluation.

THE DAMAGE FUNCTION APPROACH GIVES LOWER COSTS

These studies model the dispersion and the impact of pollutants in the light of the characteristics of the reference site, and incorporate recent results on the dose-response functions (modeling of impacts as a function of the variation in concentrations). They give numbers for the environmental damage which are lower than the environmental costs used by the PUCs. The study carried out by Oakridge National Laboratory and Resources for the Future (ORNL/RFF) shows, for example, that for all the different generation processes this damage is below the figure of 6 mills/kWh, and less than 1 mill/kWh for those using natural gas (Krupnick et al., 1995). Similarly, the results for the Sterling1 site (New York) show that these costs are all below 3 mills/kWh, 0.3 mill/kWh in the case of gas (Beutier, 1995).

These evaluations deduct the damage due to greenhouse gases (particularly CO_2), because in the present state of knowledge it is impossible to predict their future impacts. But even by reintroducing the cost of $1.1US (90) /ton of CO_2 emitted which is used by the New York PUC (that is about 1 mill/kWh for coal-fired units) and less than 0.5 mills for gas) or $23US (90)/ton of CO_2 emitted which is used by the Massachusetts PUC (that is, 20 mills/kWh for coal and less than 10 mills/kWh for gas), these costs are still well below those now in use. In the same way, if we deduct from the numbers published in the Pace University study the cost used for CO_2 emissions ($14US (90) per ton of CO_2 emitted), these are more then ten times higher than those given for

New York's Sterling1 site.[7]

The numerical values given by these studies show that the environmental costs of a power plant are much lower than the costs hitherto used. This is corroborated by the "Externe" project, run jointly by the European Commission and the US DOE, to evaluate the environmental costs from extraction of fuel to its use ("Fuel Cycle Study"). Will the existing gap be corrected by the PUCs? Will they revise their costs using the models developed by these studies? Above all, will this revision put an end to the controversies? Without predicting the future, there are several indications that the chapter on the valuation of the environmental costs that to be internalized is far from closed.

THE DEPENDENCE OF RESULTS ON CONDITIONS AT THE REFERENCE SITE

In the first place, although the damage function approach has the advantage of highlighting the relationships and environmental impact of new generating capacity, the numerical values obtained are not always external marginal costs. The authors of these studies are aware of this (Krupnick et al., 1995), but we need to find out to what extent environmental impacts has already been internalized in order to deduct from these values the amount of damage already taken into account. Furthermore, we need to calculate how much is attributable to the extra capacity alone. Synergies with other pollutants, as well as the threshold effect or the background concentration of pollution, make it difficult to accept that impacts should be solely attributable to the last pollutant emitter on the scene. Until these issues are resolved, the approach will continue to be queried.

In the second place, this approach gives costs which are strongly dependent on the characteristics of the reference site. This dependence is such that for two plants using the same technology under identical operating conditions but in different places, the numerical estimates can vary by an important factor.[8] Similarly, the ORNL/RFF study shows that for several sites in a rural environment, costs for a coal-fired plant vary between 0.3 and 1.9 mills /kWh (Wiel 1995). Obviously, there was never any intention of using this methodology to produce universal values (Valette, 1994; Krupnick et al., 1995). The original aim was simply to provide a fairer idea of the order of magnitude (generic costs) as well as a framework for evaluation which would only require the recalibration of some parameters (dispersion, ambient concentration, dose-response functions, technology, operating characteristics, etc.) to produce more reliable estimates of the damage associated with a new capacity. But the sensitivity of the results to the characteristics of the individual site and technology, as well as operating conditions, casts doubt on the transferability of values from one site to another. It also undermines any hope of developing a transferable matrix for each pollutant emitted (i.e., x dollars/tonne of SO_2 emitted). This means that the PUCs—should they ever commit themselves to correcting the costs they use —will have to adapt the model for each new project.

THE IMPOSSIBILITY OF EVALUATING SERIOUS DAMAGE

The political acceptability of values obtained by the damage function approach is the final element which suggests that the debate on evaluation is far from over. None of the evaluation studies based on this approach are conclusive because of the numerous scientific uncertainties, like chronic (latent) effects and future impacts of greenhouse gases. At a broader level, this method of evaluation cannot cope with all of the numerous impacts that American regulators seek to take into account: impact on ecosystems and biodiversity, on envi-

7/ That is (in 1990 values) about 29 mills/kWh for coal fired thermal, 4 mills/kWh for combined cycle with natural gas, 29 mills/kWh for nuclear, from 0 to 7 mills/kWh for biomass, and from 0 to 1 mill/kWh for wind.

8/ Curtiss and Rabl (1995) show that the induced mortality due to the atmospheric emissions of a coal-fired plant, which is the main damage (approximately 80 % of the total cost), may vary by a factor six depending on the location of the plant.

ronmental-cultural icons (for native Americans), on climate change and unique natural sites (NARUC, 1993). The variation in welfare due to these impacts cannot be obtained since individual assessment. This is one of the reasons why this method of evaluation is controversial with American regulators, even if, from the economic point of view, it is the only justifiable method (Woolfe, 1992; NARUC, 1993).

However, if in the future consensus were to be reached on environmental costs in the region of 2 mills/kWh—without considering CO_2 emissions impacts—(E. Wiel, 1995), what would be the point of a procedure to integrate them into the selection of new investments? Two mills/kWh only represents a 3-5% variation in the generation costs of coal- or gas-fired units. It would thus require no more than a tiny change in their underlying assumptions (discount rate, fuel prices, expenditure, amortization, etc.) to overcome the disadvantage introduced by the integration of environmental costs, a change which no-one would notice. Because, apart from the generators themselves, who really knows the cost of generation in the present structure of the electricity market? The integration of these agreed environmental costs in the selection of new investments will then plainly have no influence on the final choice, and thus on the improvement of environmental quality. And the debate about external costs in the United States would simply be yet another re-run of "Much Ado about Nothing."

3. Questions about the Consequences of the Current Integration

The controversies surrounding the regulatory procedure established by some PUCs are not restricted to the choice of environmental costs. Questions arise regarding its potential; 1) to encourage investment in new renewable energy and improve the quality of the environment, 2) to lead to adverse effects on the quality of the environment.

Limited Impact on Investment Decisions

The inclusion of environmental costs merely at the point of selection of new investments does not provide much of an incentive to invest in new renewable energy. Even at high values (which is currently the case), this inclusion does not dramatically alter the dimensions of the problem. Certainly, when applied to earlier coal-fired or oil-fired technology, it makes it possible to narrow the gap between generating costs significantly, sometimes even to the advantage of wind energy.[9] But with the emergence over the last few years of gas turbine combined-cycle technology, the gap has re-emerged, and this time not only between relative private generating costs but also between relative social costs. In a model developed to simulate the development of the generating capacity of a standard company, Palmer and Dowlatabadi (1993) show that a value of at least $100US/ton for CO_2 is required to act as a real incentive for wind power investments, in preference to combined cycle using natural gas and integrated gasification. The dynamic of technical progress obviates the need to differentiate between renewable and non renewable energy in terms of their environmental costs; the need for this differentiation stemmed from a static analysis made at a time when this progress was not anticipated. This leaves us, of course, with the greenhouse effect emissions, but the gas turbine combined-cycle methods now being marketed (with 45% efficiencies) emit 2.5 times less CO_2 than the classic coal-fired thermal stations, and their efficiencies in the next few years will be of the order of 55-65%, which means that three times less CO_2 will be emitted.

Adverse Impact on the Quality of the Environment

In addition to this weak incentive to invest in renewable energy, the integration of environmental costs in the public utilities' long-term decisions will not lead to a significant improvement in environmental quality in the medium term (20 years). The main reason is the long time it takes to renew the existing generating units which are responsible for a

9/ Between 7 and 9 US¢/kWh for wind in favourable sites, as against 9 US¢/kWh for coal-fired with its environmental costs.

major share of the overall volume of emissions. A simulation for the New England states[10] shows that by 2010 only a third of the generating plants that existed in 1990 (20 gigawatts) will have been renewed. Annual emissions of SO_2 will stabilize around 400,000 tons (that is 30,000 tons more than in 1990) as compared to a level of 420,000 tons for investments which does not integrate environmental costs (Andrews 1992). Further, since this approach cannot be expected to produce a drop in electricity consumption (given that its impact on tariffs remains very weak and that demand is still fairly inelastic), the overall volume of emissions is not likely to go down in the medium term.

But beyond the issue of its ineffectiveness at improving the quality of the environment in the medium term, other questions arise. Paradoxically, in practice, such integration seems to entail deterioration in this quality (Joskow, 1992; Sioshansi, 1992; Andrews, 1992; Palmer and Dowlatabadi, 1993; Krupnick et al., 1995). Taking environmental costs into account only at the point of choosing new investments introduces a bias into the dispatching of the power plants and the rate of renewal of invested capital. And this bias leads to a deterioration in environmental quality, as compared to the situation where choices are made on the basis of private costs alone.

INCREASED DISPATCHING AND PROLONGED LIFETIME FOR EXISTING PLANTS

In relation to dispatching, the selection of investments on the basis of social cost can favour plants with higher variable (private) costs. This is what happens, for example, when a choice has to made between a coal-fired and a natural gas-fired plant, to provide a given increase in capacity. In terms of the entire generating stock, the plant selected will be less used than were the choice to be made on straightforward grounds of private cost. As a result, existing power stations will be dispatched more in the former than the latter case (for a given total electricity production). This can then lead to environmental deterioration as existing power plants are generally many times more polluting than new installations.

The integration of environmental costs solely at the point of the selection of new investments also disturbs the natural renewal of invested capital. It can make it attractive to prolong the life of existing plants (Andrews 1992; Palmer and Dowlatabadi 1993). There are at least two reasons why this leads to a deterioration in environmental quality, in comparison with selection on the straightforward basis of private costs. Firstly, as in the previous example, the operation of a given generating stock with old plants whose lifetime has been prolonged can increase the volume of emissions. Secondly, this prolongation - which is synonymous with delaying the decision to build a new plant - interferes with existing regulations, which were introduced to enhance environmental quality.

Under the Clean Air Act, the US government has divided the national territory into about 250 zones, reflecting the concentration of seven atmospheric pollutants. [11] Since 1977 an offset policy has sometimes been instituted in zones where the concentration of one of the pollutants is above the ambient concentration standards ("non attainment areas"). This means that any new source in the zone emitting the incriminating pollutant must not only meet strict technical standards, but also compensate for its remaining emissions by reducing emissions of this pollutant from sources already in place, in a ratio above or equal to one. In this example, any delay over an investment decision is translated into a slowing down of the reduction in the overall volume of emissions and, therefore, of improvement in environmental quality. In fact, the integration of environmental costs in the selection of new investments, by encouraging a prolongation in the life span of existing power stations, interferes in a negative manner with existing federal legislation. It delays improvement in the environmental quality that this legislation

10/ The majority of New England PUCs take environmental impacts into account when selecting new investment projects.

11/ SO_2, NO_Xs, particulates, lead and its compounds, CO, ozone and organic compounds (Ringleb, 1986).

seeks to achieve.

THE BIAS INTRODUCED INTO THE RELATIONSHIP BETWEEN EXISTING AND NEW PLANTS

The integration of environmental costs in the long-term decisions taken by public utilities introduces a bias into the relationship between new and existing plants. As this bias can sometimes lead to a deterioration in environmental quality, it is worth looking into. The model drawn up by Palmer and Dowlatabadi (1993), simulating a profile for investment in capacity for a standard utility—with cost-minimizing behaviour—shows that this has little impact, except in taxing new investments on their environmental costs. However, the model also shows that the investment profile, which is developed on the basis of social costs, is exactly the same as that obtained on the basis of private costs alone.

However, a simulation of the investment profile, not for one standard utility, but for the whole of the New England capacity (DSM as well as supply) clearly shows this bias (Andrews, 1992). If additional investments of 400 megawatts were done on the basis of social costs the preference would be (in order): DSM programmes, gas turbine combined cycle (GCC), then integrated gasification combined cycle (ICC). But the amounts of SO_2 emitted from the total generating stock under each of these scenarios reverses the ranking: the largest volume for DSM programmes and the smallest for the biggest emitter (i.e., ICC, as shown in Figure 1). This result —which flies in the face of common sense since DSM and GCC do not emit any SO_2—is due to the fact that at least 800 gigawatt-hours (GWh) more are generated by existing plants when the ICC option is not chosen, the ICC generates 3050 GWh and the existing plants emit more than four times the amount of SO_2 per kWh than the ICC does.

Advantages and Limitations of a More Complete Integration

A downward correction in the numerical values used for environmental costs would obviously offset the negative environmental repercussions that could result from prolonging the lifetime of existing plants or increasing their dispatching. However, a correction like this would also serve to undermine further the efficacy of a form of integration, which aims ultimately at improving environmental quality. It is therefore not a satisfactory correction. This effect is exaggerated by the fact that while the numerical values have an effect on impact, these two phenomena remain separate; they occur because environmental costs are only integrated when it comes to the selection of new investments.

To boost the efficacy of the environmental costs integration, while at the same time trying to avoid the bias, there have been proposals to apply this integration not only to long-term decisions (choice of new investments), but also to short-term decisions (operation of the existing generating stock). Under such a regime, dispatching would no longer be triggered by private costs, but by social costs (Palmer and Dowlatabadi, 1993; Krupnick et al., 1994, 1995). Depending on the numerical values used for environmental costs, two forms of dispatching can be envisaged. The first takes into account the values now used by PUCs; the second, those obtained by means of evaluation using damage functions. The negative repercussions noted above obviously disappear for these two forms of dispatching, as they abolish the asymmetric treatment of existing and new plants in terms of the integration of their environmental costs. However, both encounter major obstacles in implementation.

THE 'PIECEMEAL' PROBLEM

In the case of the first kind of dispatching, which takes into account the (high) numerical values used today by PUCs, it is not its efficacy so much as its repercussion on tariffs which is under dispute. Since all the generating plants have to face up to their respective environmental costs, the replacement of the "dirtiest" existing plants is accelerated and there is a noticeable improvement in environmental quality and an increase in the incentive to invest in new renewable energy (Palmer and Dowlata-

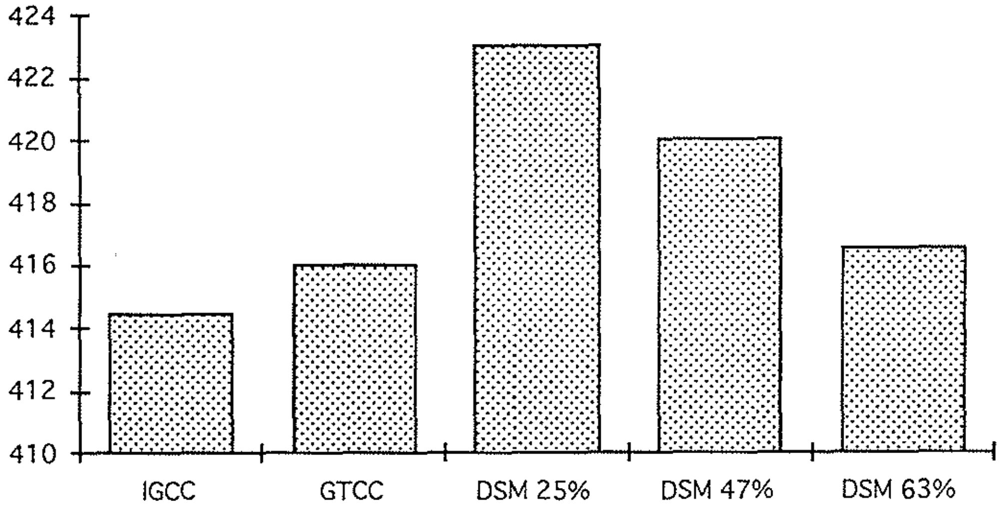

Figure 1: Annual SO_2 Emissions in 2010 from Utilities in the New England Region, with Five Alternative Investments Made in 1995 (thousand tonnes/year)
Source: Andrews (1992)

badi, 1993). But—in contrast to the situation when integration is restricted to long-term decisions—this replacement means an increase of 15 to 20% in electricity tariffs. This would then serve to increase the tariff differential between the public utilities, which are subject to this procedure, and the other power producers that are not. This includes independent power producers or public utilities in adjacent states where the PUC does not incorporate environmental costs. This increase in tariff differential would strengthen the incentive for "bypassing" by distributors who are in a position to do this. From the consumer's perspective, this is yet a further argument in favour of increasing third-party access to the network (total retail wheeling).

This form of piecemeal incorporation (i.e., developed in isolation by a few regulators for the regulated electricity sector and showing high numerical values) would increase the pressure on these same regulators to deregulate electricity generation completely. In such a liberalized framework, the regulatory procedures implemented by PUCs to monitor the activities of public utilities become obsolete. Applying the integration of environmental costs to short-term decisions is counter productive, unless the consequences of the piecemeal approach are corrected at the same time. This widening of the scope of integration is only possible if the PUCs of adjacent states develop dispatching on the same basis of social costs and if all generators (public utilities and non-utility generators) are covered.

But, going back to the Joskow (1974) model on the adoption of new regulatory techniques, one could be forgiven for thinking that a case like this is, to say the least, improbable. A regulatory procedure developed by "leader" PUCs[12] is only adopted by the majority of the PUCs (the "imitators") if several other preconditions are satisfied. These preconditions are; *effectiveness* at settling the problem at issue, *absence of objections* by the various participants in the regulatory process, *no illegality encountered* by federal or state courts.

The regulatory procedure developed by specific PUCs can therefore be adopted on a grand scale, provided there is no dispute about its development. If this kind of adoption scheme turns out still to have some relevance, it may be that the PUCs would not be able to

12/ Because of their own resources, the leader PUCs are those which are able to develop new procedures to deal with a new problem that is affecting all PUCs in more or less the same way. Amongst the leader PUCs are California, New York, Wisconsin, as identified earlier by Joskow (1974).

take on this form of dispatching, since they would have to commit themselves before all the controversies were settled. The debate attached to piecemeal approaches will continue until all PUCs—without exception—carry out this dispatching in concert. But such an event will never come as long as the debate is going on!

A PROBLEM OF FEASIBILITY

This piecemeal problem is a crippling obstacle to all "social cost dispatching," bearing in mind the high numerical values used by PUCs for environmental costs. However, this obstacle can be eased if the numbers are corrected downwards, using, in particular, those obtained from damage evaluation (Palmer and Dowlatabadi 1993). However, this second form of social cost dispatching, even when accompanied by "fairer" environmental costs, encounters a serious obstacle to its implementation (i.e., "feasibility"). If one day the regulators decide in favour of this form of dispatching, the amount of information needed will make the task somewhat complicated. Firstly, it is necessary to utilize a system of complex equations to set the operating conditions for the power stations. These are obtained from the environmental costs (dispatching on the basis of social costs) but they also serve to evaluate these same environmental costs (they depend on the site selected, technology, and working conditions). Secondly, the problems arising from the synergies between pollutants and the non-linearity in the pollution reaction functions then become particularly hard.

In the case of the damage caused by emissions from additional capacity (i.e., the marginal environmental cost of the entire generating stock), some kind of an answer can be given to these questions. Obviously, this is no longer the case when it is a question of identifying the environmental impact of all the installed and additional capacity in this total stock. To whom do we allocate the damage due to pollutant ambient concentration? How do we distinguish the impacts of one plant from those of another? When a threshold is not crossed by any one source in isolation, but by a combination, how do we allocate the subsequent damage? etc. Dispatching on the basis of real social costs means the regulators must collect and process an unprecedented amount of information. The cost of collecting and processing this naturally raises questions about its feasibility (Krupnick et al. 1995). But the need to correct the regulatory procedure to improve effectiveness and, above all, eliminate negative impacts is unavoidable.

A Radical Challenge to Current Regulatory Procedure

But will this remain the case for long? The overall regulatory framework, within which the integration of the environmental costs has been developed, is evolving in such a way that the power sector will rely more on market forces in the future. For example, the California PUC proposal made in December 1995 undermines the rationale for using a regulator outside the market to monitor the producers' investments. Investments will be planned on the basis of the market price (given here by a pool). It means that all regulatory procedures the California PUC has hitherto implemented will eventually disappear, particularly IRP.

This dismantling of IRP (or of any other form of outside control over the planning of utilities' investments) means an end to the current integration of environmental costs. It constitutes then a really radical challenge to the regulatory procedure, more radical than any of the challenges hitherto encountered. It is all the more radical given the fact that the California PUC is one of the "leaders" (in the sense of Joskow) in the elaboration of this regulatory procedure. It provides a strong signal to all the Commissions who are more or less involved in such a procedure.

However, this does not mean that the need to protect the environment will vanish in this new institutional framework. To ensure that generating units work well from an environmental point of view, tradeable permits and/or taxes could always be instituted, in addition to existing environmental regulations (which will be maintained). In the same way, the competitive disadvantage of DSM and renewable energy projects could be overcome with incentive subsidies or tax credits. Regulators could also implement a system of tradeable obligations to produce electricity from renewable energies.

Within this system, each generator in the pool gets the obligation to produce a certain amount of electricity from renewables. However, it can trade this obligation with other generators who can produce electricity from renewables cheaper than it does. To the extent that administrative and transaction costs do not undermine the functioning of this system, it constitutes an approach to the production of electricity from renewable sources that is more cost-effective than a uniform price or quantity obligation for each producer (in the PURPA style, which is generally the current practice). Moreover, this system would surely strengthen those technologies no longer in their infancy, but too weak to compete with advanced fossil-fired plants (e.g., gas turbine combined cycles). It ensures a competition between renewable producers and offers a stable environment to earn revenues from this activity.

Nevertheless, if there are no theoretical difficulties to promote a clean environment, renewables and DSM in a more competitive and liberalized electricity market, it must be stressed that such a promotion could be more complex to implement. Two examples suffice to show how difficult it could be. First, the regulatory task would be more difficult since the control would no longer be exerted on few, large and identified utilities, but on numerous, sometimes small and not well identified producers. In such a context, the control of numerous small biomass plants—competitive at the pool's price, but with large impacts on the environment—does not seem to be a simple routine.

Second—and most important of all—reductions in the price of electricity to final users is the main justification for the current restructuring of the industry. How then will the regulators manage politically an increase in this price if an urgent need, such as a massive reduction in CO_2 emissions, arises? This important question needs to be answered before an urgency manifests itself. That a more liberalized and competitive context makes easier the promotion of the environment and new technologies has to be demonstrated empirically, not in a stylized manner.

4. What Lessons Can We Draw from the American Experience?

Beyond the controversies, at least three lessons can be drawn from the treatment of external costs in the US electricity sector. These lessons are important because they are of relevance to the situation of electricity industries outside the boundaries of the United States.

In the first place, attempts to get better estimates of environmental costs have produced disappointing results. The only reliable figures damage function approaches can provide are those for damages which are now more or less completely under control. That is to say acute effects on health and vegetation of emissions of SO_2, NO_X, and particulates, which are now under control with "cleaner" technologies. Thanks to real technical progress (admittedly spearheaded by twenty five years of environmental concerns), these technologies are now available and show very low emission factors for these three pollutants.[13] However, in the case of damages associated with background pollution and greenhouse gases (particularly CO_2) no reliable evaluation can be made at the present state of knowledge. In other words, some really significant damages cannot be valued, whereas those which can be valued play but a small role in the current cost structure. The environmental cost of a natural gas combined cycle is less than 1% of its production cost.

The second lesson that can be drawn from the American experience is that the incentive to invest in renewable energy is still very weak, or even non existent, if the criterion for selection is that of social cost. With the arrival

13/ In comparison with existing coal-fired units, emissions of SO_2 have been reduced by 99% for AFBC, 99.7% for ICC using coal, and 100% for GCC. NO_X emissions have been reduced by 95.8% for GCC, 97.5% for AFBC, and 99.2% for ICC. Emissions of particulates are down by 99% for AFBC, 99.8% for ICC, and 100% for GCC.

of natural gas technologies, wind energy is still not competitive, even when the high environmental costs used by the US regulators are added to the costs of different technologies. It would require a value of \$100US/tonne of CO_2 emitted to (slightly) alter the result. With the exception of CO_2, current valuation methods give much lower environmental costs, so this result can only get worse. The argument in favour of least external cost cannot by itself differentiate renewable energy from traditional fossil energy; either the costs which can be evaluated are too low or those which are significant are not measurable. As a result, a policy of active support for renewable energy should not expect too much from the evaluation of environmental costs.

The third lesson that can be drawn is that choosing investments on the basis of social cost can have a negative effect on environmental quality, independently of the numerical values chosen for environmental costs. If this seems *a priori* paradoxical it can be explained by the fact that an economic precept is being applied outside its valid framework. In theory, all those who 'generate' externalities should bear the external marginal cost in their economic decisions. It then becomes clear that if only some of these generators are forced to reflect these costs, it can have the opposite effect to that sought.

This is exactly what happens when environmental costs are incorporated into the selection of new investments made by some public utilities. The double exclusion which results from this form of integration (neither existing stations nor many of the generators are subjected to it) provides an incentive to substitute electricity, which could be generated with a new plant, with; 1) that generated with existing plants of the generator subjected to this requirement, 2) that produced by other generators not subjected to this requirement. And in the US case, this accentuates the pressure for deregulation of electricity generation, exerted by major consumers which cannot "bypass" or take advantage of this substitution.

Although real progress has been made in the valuation of damage resulting from the environmental impact of electricity generation, the US experience shows that partial implementation of a Pigovian policy, using these valuations, encounters difficulties and has adverse effects. It is therefore not a question of establishing such a policy but of introducing incentives and making it possible to achieve given environmental goals at least cost. The time has come to move on to policies that attempt to match ends and means, rather than seek to apply theoretical principles that are somewhat dated even, by the standards of conventional environmental economics.

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