Coal or Nuclear in New Power Stations: The Political Economy of an Undesirable but Necessary Choice

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Where gas and hydro are not available and power capacity needs to be expanded, the choice will be between coal and nuclear, for there are few viable alternative options. This paper analyzes the factors that will determine the choice. The internal costs of power generation using coal and nuclear show no clear edge for one or the other. A tilt in favor of nuclear emerges when the external costs, as assessed by experts in the field, are added to the internal ones. Laymen's evaluations of the external costs appear to be at least an order of magnitude higher than the expert assessments, however. Given their high level and strong influence on energy policy making, these evaluations will ultimately determine the choice. But since the laymen's views in this regard are formed in an unsystematic manner and are unstable over time, it is not possible to use economic analysis to determine what that choice will be.

1. INTRODUCTION

Global power generation is assessed to increase by 58% between 1995 and 2010 (IEA, 1998). Natural gas is widely regarded as the most attractive option among fuels, both in economic and environmental terms. Wherever gas is available, it is likely to be the first choice in expanding the power generation capacity. The share of gas is therefore seen to be greatly expanded, as is apparent from Table 1. The economics of oil-generated power, in contrast, are bleak, and renewables other than hydro are projected to remain insignificant over the period under review. Where gas is not available, and undeveloped hydropower resources are limited, therefore, much of the expansion in power

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generation will have to rely on coal or nuclear, which together currently account for more than half of global power generation. Though both technologies have acquired a negative environmental image in public perceptions, the IEA deems (on the basis of national government forecasts, no doubt) that between the two, coal will gain the upper hand, increasing more than ten times as much as nuclear between 1995 and 2010.

The IEA projection of the expanding roles of coal and nuclear in power generation is a guess at best, and actual outcomes might turn out very differently. The purpose of the present paper is to review the considerations that will determine the choice between the two fuels, when the other sources listed in Table 1 are inadequate or unattractive for the satisfaction of the required power sector expansion. An underlying premise in the 10-20 year time perspective adopted here is that coal and nuclear together are so important that it will be prohibitively expensive to forgo both in situations where economic supplies of gas are inaccessible, undeveloped hydro sites are absent, energy efficiency drives have been exhausted, and yet capacity expansion is needed. Coal or nuclear will then have to be chosen even when both appear to be undesirable.

Table 1. Global Power Generation by Fuel

	TWh			Percent share		Ann. growth
	1995	2010	Change	1995	2010	1995-2010
Total	13204	20852	7648	100	100	3.1%
Nuclear	2332	2568	236	18	12	0.6%
Coal	4949	7795	2846	37	37	3.0%
Oil	1315	1663	348	10	8	1.6%
Gas	1932	5063	3131	15	24	6.6%
Hydro	2498	3445	947	19	17	2.2%
Other renew	177	319	142	1	2	4.0%

Source: IEA (1998).

The discourse proceeds in three steps. Section 2 analyzes the private cost of new power generation employing coal and nuclear, respectively, to determine the relative competitiveness of one versus the other. In section 3, qualified expert assessment of the external costs, environmental and other, caused by coal-generated and nuclear power production, are added to the private costs, to clarify if their relative competitiveness is altered in consequence. Section 4 discusses how public and political opinion of what these external costs are, is influencing the choices, and what the impact of this opinion is likely to be in future. A summary of conclusions from this three-step analysis is presented in section 5.

2. THE PRIVATE COSTS OF NUCLEAR AND COAL FIRED POWER GENERATION

The cost of generating power, using alternative fuels, has been repeatedly assessed in joint studies by the Nuclear Energy Agency and the International Energy Agency. The numbers in the latest cost update (NEA, 1998) have been derived from cost estimates relating to specific plants in different countries, to be commissioned by 2005. The nuclear plants under review comprise exclusively the proven light and heavy water technology. All figures are expressed in constant 1996 dollars. A consistent levelized 40-year lifetime cost methodology for base load technologies is applied throughout. The assessments include the costs associated with environmental regulations in place, and with the hurdles of the accompanying regulatory process. The cost of spent fuel disposal and/or reprocessing is comprised in the nuclear fuel cycle. Alternative discount rates are applied to the capital component. Uranium prices are assumed to remain unchanged, while coal prices are envisaged to rise by an insignificant 0.3% per year through the life time of the facilities.

The NEA study provides estimates for Western Europe, North America, Japan and several non-OECD countries too. Table 2 provides a rough summary of the maximum and minimum estimates of the cost of power generation in new coal and nuclear facilities, mainly under West European conditions. My choice of the West European numbers is prompted, first, by the likely lesser reliability of the non-OECD estimates, and second, by the fact that the external costs discussed in the following section, relate to conditions in Western Europe.

Earlier versions of the NEA study have been criticized for biased assumptions about lead times and load factors in new nuclear power stations, and about capital costs and coal price developments, all in favor of nuclear (Virdis and Rieber, 1991; MacKerron, 1992; both neatly summarized in Söderholm, 1998). Some of this bias may persevere in the 1998 issue, e.g., in the coal price projections, where the World Bank (World Bank, 1999) and a leading multinational mining company (private communication with David Humphreys, Chief Economist of Rio Tinto) envisage slow long run declines.

Table 2. Cost of New Base Load Power Generation under Western European Conditions in 2005, (1996 US cents/KWh)

	Coal		Nuclear	
5% discount				
	Max	Min	Max	Min
Investment	1.3	1.0	2.2	1.8
Operating	1.0	0.7	0.8	0.7
Fuel	2.3	1.5	1.1	0.7
Total	4.6	3.2	4.1	3.2
10% discount				
	Max	Min	Max	Min
Investment	2.6	1.7	4.5	3.5
Operating	1.0	0.7	0.8	0.7
Fuel	2.4	1.5	1.1	0.7
Total	6.0	3.9	6.4	4.9

Source: NEA (1998).

The cost compilations of Table 2 are unexciting, and any remaining bias of the NEA analysts is unlikely to cause any dramatic change in the results. The costs of power generation are highly site specific both within and across countries, and this is the dominant explanation to the wide cost range for each of the two technologies. The figures show the cost ranges of the two technologies to be comparable, with nuclear power stations exhibiting higher investment costs and lower fuel costs than those that burn coal. They also show the mean cost of nuclear power to be somewhat below that generated by coal when a 5% discount is applied, but significantly higher when the discount rate is raised to 10%. Even at that higher rate, however, the ranges exhibit a substantial overlap, suggesting that nuclear power generation could compete with coal in many locations and circumstances. The numbers can be regarded as rough guidelines providing a first rod for the power companies' investment choices.

3. THE EXTERNAL AND TOTAL COSTS OF NUCLEAR AND COAL FIRED POWER GENERATION

External costs are fiendishly hard to identify, and even more difficult to value in monetary terms. The ExternE study (1995) represents a very ambitious attempt at providing an expert assessment of the overall external costs of power generation using alternative fuels, mainly under West European conditions. The study contains an extended methodological discussion aimed at clarifying the approaches, and to assure uniformity when the external costs of alternative fuel-power chains are evaluated. The life cycle vista is applied throughout, so that all external effects arising through the entire process, from mining the fuel until the ultimate treatment of coal ashes and storage of spent uranium fuel, are comprised. Market values of external damage are employed wherever available. A variety of alternative assessment tools, e.g., contingent valuation, or the cost of measures to avoid the damage, are used where market values are missing. State of the art conventions are applied in the evaluation of life and health detriment. The value of life is set at about $3 million in the assessments.

The results of ExternE's external cost assessments are summarized in Table 3. As with the internal costs, the ranges in each fuel cycle are importantly due to site location, but variations in the technological solutions in each case, and in the sources of the respective fuels also influence the external cost levels. Alternative assumptions about the economic impact of a large scale nuclear accident explain the cost range on that count. There is no doubt that considerable uncertainties prevail in the valuation of major external effects arising from coal-fired electricity and nuclear power. This is particularly true of the climate effects arising from CO_2 emissions due to coal burning, of the nuclear catastrophes that might conceivably occur, and of the long-run implications of storing spent nuclear fuel. Nevertheless, the given numbers are based on the best scientific knowledge currently available, and more likely to overestimate than to underestimate the economic impact of plausible externalities, especially for coal. For instance, the climate impact represents the present value of future events, obtained by applying a zero discount rate. Furthermore, some double counting is likely to be involved in the externality numbers, which appear to aggregate the overall environmental and health detriments of the respective technologies (ExternE, 1995), while at the same time, the private costs of power generation (NEA, 1998) include existing environmental taxes. The latter, presumably, should have internalized some of the environmental costs.

The ExternE assessments of external costs are corroborated by other scientific work. The UN's Intergovernmental Panel on Climate Change (IPCC, 1996) and Tol (1999) provide somewhat but not greatly lower evaluations of the climate damage cost from carbon emissions, while Hirschberg et al. (1996), Nordhaus (1997) and Radetzki and Radetzki (1997), after reviewing a number of Probabilistic Safety Assessments and other scientific investigations of nuclear power, land at total external cost estimates quite similar to the ExternE result.

ExternE's assessment shows the external costs of coal fired power generation to be quite substantial, ranging between 1.9 and 4.1 US cents per KWh, hence constituting a high proportion of the internal costs. More than half of the total (1.2-2.2 US cents per KWh) is represented by a variety of costs related to climate damage. Nuclear (the dominant light water technology), in contrast, is seen to generate very small external costs, corresponding to much less than 1% of the internal costs. There is no external climate impact from nuclear power, and the cost to society from nuclear accidents works out at exceedingly small numbers. Extremely costly nuclear catastrophes are taken into account in the assessment, but they are deemed to be so exceedingly rare, that their costs become barely perceptible when spread across all the kilowatt-hours produced.

Table 3. External and Total Costs of Coal and Nuclear Power Generation under West European Conditions, (US cents/KWh)

	Coal			**Nuclear**	
	Max	Min		Max	Min
External costs					
Climate	2.2	1.2	Accident	0.012	0.00024
Other	1.9	0.7	Other	0.012	0.00600
Total	4.1	1.9	Total	0.024	0.00624
Internal costs (10% discount)	6.0	3.9		6.40	4.90
Sum total	9.1	6.9		6.42	4.91

Note: Only two decimal points are provided for the nuclear sum totals.
Source: ExternE (1995); IEA (1998).

The internal costs of power generation, identified in Table 2, are added to the external ones in Table 3, to provide the total cost to society from using the respective technologies for power generation, an important measure of their competitiveness. Although the table shows the internal cost assessments based on a 10% discount, biasing the totals against nuclear, there is a strong tilt in favor of nuclear on account of its low external cost values. In this assessment, nuclear power generation appears to provide more attractive cost levels than does power based on coal. The numbers should constitute a rough guideline to society's choices in this area. In reality they don't as will become clear from the discussion in section 4.

4. PUBLIC AND POLITICAL PERCEPTIONS OF THE EXTERNAL COSTS OF COAL-BASED AND NUCLEAR POWER GENERATION

An extended research tradition (see for instance Slovic, 1987; Kunreuther and Slovic, 1996; and Boroush et al. 1998) has pointed to the attributes of risk whose cost typically tends to be exaggerated by lay people, media, and, in consequence, by politicians. Thus, the public tends to find it especially hard to accept risks that:

- are hard to identify because they arise from novel circumstances or technologies;

- have a catastrophic potential and may constitute a threat to future generations;

- involve consequences that are particularly dreaded;

- are not voluntarily assumed by the exposed individuals and are not controllable by them.

Viscusi (1992) adds to the list by noting that lay people have great difficulty comprehending extremely low probability events. It follows that a once in a ten million probability of a particular event tends to be assigned a cost similar to the cost of an equivalent event with a once in a hundred thousand probability, even though objectively, the former should carry a cost one hundred times smaller.

All the above characteristics apply with full force to the risks of potential detriments from greenhouse warming, and of nuclear catastrophes. The public appears to be particularly fearful of the uncertainty coupled with the oft-publicized drama of catastrophic events with long-lasting consequences that might be triggered by the two power technologies, and so the "precautionary principle" often comes into play (May, 1997). In consequence, the layman's aversion to climate and nuclear risks appears to be exceptionally strong, and this in turn impacts on his valuation of the external costs of the two technologies. These risks therefore stand out in terms of the difference in cost assessments made by experts and lay people, respectively.

Attempts have been made at adjusting the expert assessments to tally with the public evaluation in such cases, for instance by allocation of extra weights to *catastrophic* events. Thus, employing the "square" approach, one event causing ten deaths is valued the same as 100 events with one death each (Hirschberg et al. 1996). The same approach could be applied to the measurements of physical damage.

Research in the field also demonstrates that lay people are prepared to accept risk from an activity that they have not voluntarily chosen, but only if the benefit from its pursuit exceeds the cost of risk by a wide margin. At the same time, the research studies show the perceived benefit from coal fired and nuclear power generation to be small. It is not surprising, therefore, that the public and political opposition to new coal fired and nuclear power production is widespread and strong.

In contrast, there is much less systematic difference in the assessment of risk costs when it comes to, e.g., road traffic and smoking, while the risk cost of police work and fire fighting, or voluntarily chosen activities like skiing and hunting, tends to be valued by laymen at levels much below the costs derived in expert assessments.

When laymens' evaluations of risk costs differ substantially from those obtained from experts' assessments, they often raise serious problems to the professional. In a nuclear physicist's words: "...the public has been driven insane over fear of radiation (from nuclear power). I use the word 'insane' purposefully, since one of its definitions is loss of contact with reality. The public's understanding of radiation dangers has virtually lost all contact with the actual dangers as understood by scientists." (Cohen, 1983). Economists too, experience difficulties with laymen's evaluations, when different unit costs are attributed to a particular damage, depending on the overall size of the event that caused the damage. Handling of the layman's risk aversion profile by the use of the "square" approach remains a controversial matter among specialists in risk analysis. A further problem arises from the fact that laymen's evaluations tend to vary over time, in line with fashions and trends, even when the factual risk information remains unchanged. There is reason, therefore, to refer to such evaluations as idiosyncratic.

Public opinion cannot be easily dismissed, however, even when it differs from the experts' assessments. First, it cannot be precluded that experts, too, pursue implicit agendas with questionable objectivity when they assess the costs of risk. Even when they don't it could be that the different results may be due to a wider array of considerations underlying laymen's evaluation, where not all can be easily included in the formalized assessments undertaken by the experts. Second, one can argue that even when the laymen's evaluations are based on whim, they should be respected in democratic societies in the same way as consumer choices are in a market economy, also in cases when to an outsider these choices may rightly be viewed as idiosyncratic. Education and information could of course sometimes, but not always influence these evaluations and choices. And third, the laymen's evaluations must be seriously treated because they in turn influence political opinion and actual policy choices in the field of energy and elsewhere.

In what follows, I juxtapose the expert assessments of the risk costs due to climate change and nuclear catastrophes, respectively, as given in the preceding section, with some indirect evidence of the layman's evaluation of the same costs. The comparison is important, for, as just noted, the latter is likely to have a much greater influence than the former on actual energy policy formulation.

Climate Change

ExternE's assessment of climate cost from coal-based power generation was given in Table 3 at 1.2-2.2 US cents per KWh of electricity. After transformation, this works out, roughly, as the equivalent of $26-46 per ton carbon emitted to the atmosphere. The range is clearly, but not greatly, above the average of the marginal social cost assessments for the first decade of the 21st century in the studies commissioned by the Intergovernmental Panel on Climate Change. Three of the seven studies quoted provide only point estimates, the average of which is $12 per ton C; the minimum and maximum average for the four studies that provide ranges works out at $14-53 (IPCC 1996, page 215). A more recent study by Tol (1999) yields a range of $9-23 per ton C. On this evidence it is safe to conclude that expert assessments, based on state of the art scientific insights, estimate climate damage from coal fired power at a maximum of $50 per ton C (2.4 US cents per KWh of electricity) with a substantial downward spread.

How does this compare with the views among the public and the politicians about the cost levels of climate damage? The answer is that we don't know, but some indirect evidence can be derived from the commitments by the rich market economy countries to cut emissions, entered into at the Kyoto conference in December 1997. In that meeting, the US and Canada, Japan, Australia and Western Europe in aggregate, agreed to reduce their 2010 emissions of greenhouse gas by 7% from the actual 1990 level. This corresponds to a contraction of 28%, or 1 billion tons C from the estimated business as usual (BAU) level of emissions in 2010 (IEA, 1998a).

Though the details of the Kyoto commitments remain to be determined, it is possible to gauge the dimensions of the policy effort needed to fulfil the task. One half year after the Kyoto conference, the International Energy Agency analyzed the policy implications of the commitments (IEA, 1998a). The gist of its conclusions run as follows. Abstracting from emission permit trading and joint implementation, tools on the use of which international agreement has not yet been worked out, the commitment could be reached by a two-pronged approach, with each prong reducing emissions by about 500 million tons C. The first would employ commands and controls to enforce substitution of nuclear and renewables for fossil fuels in power generation. The second would apply an across the board carbon tax in all energy uses, inducing a further shift from fossil to other energy sources as well as substantial energy savings. The required tax to accomplish the goal, half of the Kyoto commitment, has been assessed by the IEA at \$250 per ton C. A related recent analysis (Ellerman and Decaux, 1998), again abstracting from trade, derives the marginal cost of CO_2 emissions reductions to attain the whole Kyoto commitment, at similar levels, i.e., \$186 per ton C in the US, \$273 in the EU and \$584 in Japan.

To rational policy makers, the cost of the commitments agreed to in Kyoto, measured per ton of C emission reduction at the margin, should correspond to the marginal benefit of avoided climate damage. If this cost could be determined, it would provide an indirect measure of the laymen's assessments of the climate damage cost, since these assessments can plausibly be seen as the underlying determinants to the political decisions in Kyoto. I conjecture that the tax of \$250 per ton C, derived by the IEA, reasonably reflects the marginal climate policy cost to society, and implicitly, the marginal benefit of emissions reduction, as valued by the public. Regarding the tax as equivalent to the damage from climate change, per unit of C, follows an old fiscal tradition in which emissions taxes are set equal to the damage caused by the emissions. My conjecture may exaggerate the policy cost to society, for the revenue of the tax could be used to lighten other tax burdens. But even if the cost of the tax were to be smaller, one has to add the cost to society from the first policy prong, involving command and control, which is hard to measure, but likely to be substantial, to provide the full policy cost.

If the conjecture is in the right ballpark, it follows that the layman's evaluation of the damage to climate from carbon emissions is at least five times, and possibly as much as twenty-five times higher than the numbers emerging from the expert assessments that were presented above. The climate costs of coal fired power generation based on the layman's evaluation would be in a range of 6-11 US cents per KWh of electricity, making coal completely uncompetitive with nuclear (see Table 3).[1]

This is not the end of the story, however. Before jumping to any conclusions, on the competitiveness of the respective modes for power generation, it is necessary also to explore how the public and the politicians value the external costs of nuclear power.

Nuclear Power

The discrepancy between experts' assessments of the external costs of nuclear power and laymen's evaluations of these costs are even more striking, though harder to quantify. The expert assessments, as noted, yield extremely small numbers. At 0.0024 US cents per KWh electricity, or less, they

1. In an alternative interpretation, the Kyoto commitments can be seen as the result of forceful lobbying by green groups, and not representative of the broader public's views.

correspond to less than one percent of the external costs assessed by experts for coal fired power.

I have not found any widely accepted measure of what laymen and politicians believe the external costs of nuclear power to be. But the political opposition in a widening group of countries comprising Austria, Germany, Italy, Sweden and Switzerland, to existing or potential nuclear power, on account of its purported dangers, can be taken as a reflection of the high external costs attributed by laymen and politicians in the countries listed, to the industry under review.

Some of those opposing nuclear power do it on account of the rare possibility of catastrophical accidents with damage costs of tens of billions of dollars, for which no insurance coverage is available. Though the governments have implicitly assumed responsibility for the "top risk" of such catastrophes, and so provide a subsidy to the nuclear industry, possibilities exist to create private markets to which this risk could be offloaded (Radetzki and Radetzki, 2000). In any case, the external costs of nuclear power given above, do comprise the damage caused by very costly but exceedingly rare nuclear catastrophes.

The premature dismantling of nuclear power stations in Italy and the decision in principle to close them down in Germany and Sweden, indicates that the perceived cost to society posed by the danger of catastrophe, by hazards involved with the storage of spent fuel and by the possibility of nuclear weapons proliferation, is so high that it cannot be compensated for by taxes and fees, and that it motivates outright closure. In this sense, the lay and political views on the social costs of nuclear power in some countries are much more extreme than they are with regard to coal-fueled power. The particular dangers of nuclear power that so excite the public and politicians in these countries, are all part of the expert assessments too, but there is a stark difference in the conclusions about their significance.

A further complication in handling the discrepancy in the political and experts' assessments of nuclear risk is that the former clearly vary between countries. The political readiness to accept an expanding role for nuclear power in e.g., France, Japan and Korea, suggests that the public evaluation of the external costs of this technology may not differ much from the low levels established by the experts. This could be the result of education or tradition, or the public's awareness in these countries of the geopolitical necessity to employ nuclear power. But the complication arising from the different public views across countries could be resolved if one takes into account that France, Japan and Korea is a group of countries "where the decision making is left to a small and powerful group, and the opposition is left little access to the political and legal system..." (Söderholm, 1998). In this interpretation, the political acceptance of nuclear power in this group of countries is a result of the political system setup, and does not necessarily reflect the public's values.

5. CONCLUSIONS

Where gas is not available and unutilized hydropower sites are wanting, the choice will be between coal and nuclear when power capacity needs to be expanded. Despite rising public and political resentment against the coal-fired and nuclear power technologies on environmental grounds, their combined importance would make it prohibitively expensive to forgo both. The paper has attempted to clarify which of the two will gain the upper hand, and on what grounds.

A review of the evidence about the internal costs of power production in new coal fired and nuclear power stations yields unexciting results. The cost ranges have a wide overlap, and, unsurprisingly, the relative competitiveness of nuclear is weakened when high discount rates are applied.

Adding on the external costs, based on expert assessments, tilts the balance in favor of nuclear, but not overwhelmingly. The external costs of coal fired power are high, with climate damage dominating the total. In contrast, the external costs of nuclear are quite small. Even though very large scale nuclear catastrophes could conceivably occur, their cost per unit of power is insignificant because they are deemed to be so rare.

Indirect evidence suggests that laymen's evaluations of the external costs of coal fired and nuclear power are at least an order of magnitude higher than the level derived in expert assessments. These high implicit values are importantly due to the uncertainty and the dramatic nature of rare but plausible events, and hence of the application of the "precautionary principle" referred to above.

I assert that the public's views about the level of external costs will be the ultimate determinant for choosing one or the other of the technologies, for these views exert a strong influence over public energy policies. It would seem, however, that the public perceptions are formed in an unsystematic manner and are unstable over time. For these reasons, they appear to be idiosyncratic. This makes it hard to determine what the ultimate choice will be.

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