Surrey Energy Economics Centre

PROSPECTS FOR NUCLEAR POWER IN THE UK AND EUROPE

by

M Barrett, J-C Charrault, P M S Jones
and C Robinson

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The paper arose out of a Seminar on 'Prospects for Nuclear Power in the UK and Beyond' held at the University of Surrey in June 1990

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REVIEWING NUCLEAR POWER

Colin Robinson, University of Surrey

1. INFORMATION MONOPOLIES, CENTRALISED DECISION-MAKING AND NUCLEAR POWER

Twenty three years ago, Duncan Burn published a monograph about nuclear power in Britain (1). It was not long after a team from the Atomic Energy Authority (AEA) and the Central Electricity Generating Board (GEGB) had concluded that a British Advanced Gas Cooled Reactor would be a better choice than a US-designed Pressurised Water Reactor for the second nuclear station then planned for Dungeness. Construction work on Dungeness 'B' had indeed just begun when Professor Burn wrote his paper. Although he was very critical of the assessment, which as he said "...had given the benefit of many doubts to the AGR...", he would have been surprised to find that, so far as I know, Dungeness 'B' is still not fully in commission.

The main burden of Burn's paper, however, was not so much to criticise a particular decision, as to point out that the way in which decisions about nuclear power were made in Britain was bound to lead to error. He argued that the policy of centralisation of the "best brains" gave power to a "... small group of persons whose work is not subject to effective external check", that the AEA's monopoly should go, that there should be "real competition" in the development of reactor types by several consortia and that the CEGB should be divided into three parts so there should be no dominant buyer to confront the consortia.

In effect, Duncan Burn was pointing to the unfortunate effects of the monopolisation of information and the centralisation of decision-making. Placing all the "best brains" in one organisation or a small number of closely-associated organisations (such as the AEA and the CEGB's research laboratories) is unlikely to produce socially desirable results. Instead, it inevitably produces a powerful pressure group, backed by the scientific establishment, which uses its information monopoly to extract funds from the public via government.

It is fashionable today to criticise the CEGB and the AEA for misleading the public about the costs of nuclear power. I do not subscribe to that view. No doubt the public was misled. But that was primarily a consequence of the regime under which the electricity supply and nuclear industries operated, not of evil intent on the part of individuals within the two organisations. Industries where there are state-erected, impenetrable barriers to entry, whether they are in the Soviet Union, Eastern Europe or

Britain, supply what they think people should have rather than meeting consumer demand. The outcome is usually disastrous.

Although it would be both painful and unhelpful to dwell on past British civil nuclear programmes, it is important to extract some lessons from the past so that we can see why such poor decisions were made. There seem to me to have been two related problems.

First, there was no buyer with a genuine interest in keeping down generation costs on behalf of the consumer. Electricity consumers themselves had the power neither of exit from the market for nuclear electricity nor voice in political decision-making about nuclear power. The CEGB was the sole customer for nuclear power stations. It operated in a highly politicised regime in which it was not allowed to choose fuels freely and in which it could pass on to consumers virtually any costs it incurred: not surprisingly, it had little incentive either to keep down the costs of nuclear generation or to invest resources in checking what those costs were really likely to be.

Second, because of the information monopoly virtually all the information on nuclear costs received by government came from nuclear enthusiasts. Realistic estimates of future nuclear generating costs failed to come out into the open, until the privatisation process forced some revelations, because all the information resided with those in the AEA and the CEGB who were also the project champions. In competitive circumstances, appraisal optimism also exists but it is kept in check because there are competing views; it can run riot when there are no such views around.

I recognise, of course, that estimates of comparative generating costs are not to be taken too seriously because our forecasting ability is so poor. Comparisons, say, for new nuclear versus fossil-fuelled power stations, can only give the vaguest guidance to what costs will actually turn out to be over the thirty years or so project life Nevertheless, the long-established tendency (going back to 1957 (2)) to under-estimate the costs of nuclear generation versus fossil generation is highly significant. It is exactly what one would expect given that the source of the nuclear cost estimates was an information monopoly and that there was no effective consumer voice. The costs were huge. By the time of electricity privatisation, forty years of state-backed centralised nuclear power development in Britain had resulted in an electricity supply system in which around 20 per cent of electricity was nuclear-generated. That same regime had also produced a collection of power stations which was evidently unsaleable.

The lesson I would draw from Britain's past experience with nuclear power is not so much that we concentrated on the wrong reactor types, nor that we were too nationalistic, nor that the government interfered too much, nor that we have an inefficient construction industry which cannot build nuclear stations at the speed the

French manage. Those may have been the proximate causes. But underlying them were deeper problems relating to the organisation of the electricity supply and nuclear industries.

2. THE PROMISED REVIEW

Given the past history of nuclear power in Britain (and elsewhere), and the uncertain future which now faces the nuclear and associated industries, the review which the government has proposed - to take place in the mid-1990s - seems to me very important. By then the new regime in electricity supply - which is intended to promote competition in generation and supply and to allow freer choice of fuels - will have been in operation for several years. If it works as the government evidently intends, decision-making in electricity supply will be decentralised. That should include decisions about nuclear power and, if it does, one of the problems which I suggested has plagued nuclear decision-making in the past will become much less serious. No longer will a "policy" be laid down from the centre and implemented by a cost-plus single generator. Whether the chance will be taken is as yet uncertain; there will no doubt be pleas that "nuclear power is different" and a hankering, despite past experience, for clear-cut centralised decisions by government.

The fate of the nuclear information monopoly is also unclear: though temporarily undermined by leaks during the privatisation debates and the Hinkley 'C' Public Inquiry, it still resides in the AEA, and the two new state nuclear companies, Nuclear Electric and Scottish Nuclear.

Mr Wakeham proposed the review in his statement of November 9th 1989 (3) in which he halted the PWR programme, announcing that government policy would be satisfied by the construction of Sizewell 'B' alone rather than the previously planned "small family" of four PWRs. In considering the review, there seem to me three issues particularly worthy of attention - when will it occur?, with what issues should it be concerned? and how should it be conducted?

3. WHEN WILL THERE BE A REVIEW?

According to Mr Wakeham's statement, the government "...will wish to review the prospects for nuclear power as the Sizewell B project nears completion in 1994". Although it is generally assumed that the review will be in 1994, his statement could be taken to mean that the date of review depends on the date of completion of Sizewell 'B'. Thus a delay in completion might delay the review. Or if Sizewell is never completed, perhaps there will never be a review. A change of government would also influence whether there is a review and, if there is, when it occurs. Labour seems so set against new nuclear building that a Labour government in the mid-1990s might consider a review to be pointless.

Thus there is some uncertainty about the timing of any review. It is, however, likely that one day some future government will decide to review nuclear power policy if only because of the powerful element of the scientific establishment which will press hard for reconsideration. If and when it comes, with what issues should the review be concerned?

4. ISSUES FOR THE REVIEW

In considering these issues, the best starting point is to ask - what is so different about nuclear power that it merits a special review? Why should nuclear power not be valued by the product and capital markets like other products? The British capital markets did, in fact, carry out an unsolicited review in the period when the government still believed that it could incorporate existing and new nuclear plant in National Power. The markets gave nuclear power a resounding vote of no confidence just before the government's decision last November not to privatise existing nuclear stations and not to insist on a new nuclear building programme.

If there is any economic logic behind the review - and I am not necessarily saying that there is - it must be that government believes private capital and goods markets are incapable of placing a proper value on nuclear power. In principle, markets could attribute either too high or too low a value. In practice, the view taken by past governments has been that nuclear power has certain characteristics (external benefits) which are more valuable to society than they are to private decision-makers who cannot appropriate revenue from those benefits. Thus, it may be argued, government - acting as the agent for society as a whole - can improve welfare by a policy of promoting nuclear power.

What might these external benefits be? They have never been specified and discussed except in the vaguest of terms so we have to extract them for ourselves from various policy statements and then transform them into respectable economic arguments. There appear to be three broad categories of possible benefit (4).

4.1 Security of energy supply

"Security of supply" arguments have long been prominent in British government energy policy. They were used, for example, for many years to justify the policy of protecting

British coal which brought few, if any, benefits but imposed considerable costs on the community.

The Electricity Privatisation White Paper for England and Wales of February 1988 (5) followed in this tradition of producing ill-considered and vaguely expressed security of supply reasons for sheltering a particular energy source from competition. The White Paper links the case for supporting nuclear power closely to security of supply arguments; indeed, the link is so close that the relevant section of the White Paper is headed "Security of supply and the need for nuclear power" (6). The government claimed that, by setting a non-fossil-fuel obligation to be met principally by British nuclear power, it would promote diversity of fuel supply which would in turn enhance security. That view needs consideration because there will, no doubt, be claims in future that sheltering nuclear power from competition will be security-enhancing.

There appear to be two errors in the White Paper's claim. The first is that, though diversification of supply sources is a means of improving energy security, in practice forcing electricity distributors to take a substantial portion of their power from British nuclear stations is more likely to reduce than to increase diversity. Curiously, the government seems not to have followed the logic of its own privatisation policy. Privatisation and the freer choice of fuels which is likely to follow will, in the absence of further government action, increase diversity. Distributors, assuming they are responsible for security of supply, will in their own interests seek a variety of suppliers and a variety of fuels. Thus, there is likely to be more diversity and hence more security than under nationalisation when there was a single generator heavily influenced in its choice of fuels by government. Although it would have been better if the government had liberalised the electricity market much more than it proposes to do (7), nevertheless the supply system is likely to become more diverse in terms of fuels, supply sources and methods of generation than it was previously. But the distributors will be constrained in their efforts to diversify if they are coerced into dependence on a single nuclear generator using a particular technology. That kind of coercion would result in a partial restoration of the pre-privatisation monopoly and is inconsistent with a regime the professed aim of which is to increase the importance of the distributors and to reduce generator dominance.

The second error is that providing nuclear power with a protected corner of the market in the interests of security ignores the relative insecurity of nuclear fission power using present technology. One problem is the effect of accidents on public attitudes. The two most serious accidents of recent years (Three Mile Island and Chernobyl) provide evidence of the contagious effect of a nuclear accident. An accident anywhere affects nuclear power almost everywhere. Given the strength of public reaction to accidents and feared accidents - not only in reactors but in transportation, processing and waste disposal

- introducing more nuclear power into an electricity supply system may well reduce security. Although the primary fuel supply may appear secure and generating capacity may appear to be available, there is a constant danger that, because of events at home or abroad, future building might be deferred, some existing capacity might be shut down or derated and stricter regulation might lead to higher costs.

Apart from accidents, security problems can arise if nuclear plans are based on exaggerated claims which are not fulfilled (so that some plant is not built); if there are long building delays (so that plant is not commissioned when expected)); if there are operating problems (so that, after commissioning, less plant is available than anticipated); or if plant turns out more costly than predicted (adversely affecting the operator's financial state and possibly reducing output if operating costs are increased). The list will seem familiar to anyone who has followed the problems which have afflicted nuclear power in the past.

To summarise, from the viewpoint of energy security protecting nuclear power is more likely to impose an external cost than provide an external benefit. Such a policy is especially likely to reduce energy security if it involves building large scale plants, based on a single technology, clustered together, owned and operated by a single generator and inevitably rather vulnerable to industrial disputes.

4.2 Protecting against long run fossil fuel price increases

It is sometimes claimed that a reason for investing in nuclear plant is that it will protect against the impact of long run increases in the prices of imported fossil fuels. The hidden assumption usually is that fuel markets habitually under-predict prices: thus information about the future is imperfect and government action is needed to correct this failure. In such crude form, the case has little substance. There is no evidence that fuel markets do generally under-predict prices. Indeed past experience shows that, despite expectations of increasing prices, the trend of real fuel prices has been steady or falling over the long run. Except in the unlikely event that governments are better fuel price predictors than are fuel markets, it would seem preferable to leave private investors to judge when nuclear plant represents a profitable investment opportunity because of impending rises in fossil fuel prices.

A more respectable case can, in principle, be made along the lines that, though fuel prices are unforeseeable, society might be willing to protect indigenous fuels in case imported fossil fuel prices go very high in future. In other words, an insurance premium would be levied on consumers (who would pay more than necessary for fuel in the short run) against the eventuality that in the long run imported fuel prices might soar. To apply the principle would, however, involve heroic calculations - estimating the probability of occurrence of the feared high prices, the associated economic and social costs and evaluating society's attitude towards risk. Such calculations would have such wide error margins that they could be used to justify almost any protective action for indigenous fuels (not just nuclear power). Moreover, any action taken would involve forcing on to society now costs which otherwise might never be incurred or would not occur for many years.

4.3 Protecting the environment

As "green" issues have come to the fore, so the arguments for protecting nuclear power have focussed more and more on its supposed environmental benefits. It seems very likely that, in any future review of nuclear power policy, it will be claimed that investment in nuclear power is a means of mitigating the greenhouse effect.

One strictly practical and relevant issue is that, given the state of public opinion and the technical problems which seem to plague nuclear power, it is quite implausible to believe that in the foreseeable future there could be nuclear plant building programmes of sufficient size to make any appreciable impact on any tendency towards global warming.

Aside from the question of practicality, asessing the strength of the "green" claims made for nuclear power is not easy at present, principally because of the imperfections of scientific knowledge. It is unclear whether the most likely future climatic problem is global warming as is now generally believed, or global cooling as some still claim. Even if such issues could be resolved, it is not necessarily true that warming will reduce world welfare so that international action is required: it may be that whatever climatic effects occur they will have primarily redistributive consequences, making some people better off and some worse off (8).

Fortunately, it is not necessary to determine the answers to such awkward issues in order to address the question of whether investing in nuclear power is an appropriate means of trying to avoid the consequences of the greenhouse (if there is to be one). It may well be prudent to take out some insurance against the possibility of global warming. But, if one is to do so and wishes to minimise the premium, it seems clear that nuclear power is not the answer.

Abstracting for the moment from all the external costs associated with nuclear power, as a recent paper from Friends of the Earth (9) has pointed out there are more cost-effective means of mitigating the greenhouse effect than investing in nuclear stations. FoE's paper ranks means of reducing carbon dioxide emissions in order of cost-effectiveness, considering both demand-side measures (such as improving efficiency at the point of use) and supply-side measures (for example, utilising waste heat from power stations, replacing fossil with non-fossil energy sources and substituting for high carbon emitting sources such as coal lower emitting sources such as natural gas). Nuclear power comes very badly out of the analysis (fifteenth out of seventeen options).

I should make it clear that I am not necessarily supporting the means that FoE supporters would use to achieve what they believe to be the more cost-effective methods of reducing carbon dioxide emissions. I suspect that, like the nuclear enthusiasts, they want to use centralised decision-making to force on to people their preferred solutions. It is, however, in my view those centralised decision-making procedures which are one of the principal sources of our problems. Many of the more cost-effective measures FoE suggests would have come about naturally in a more cost-conscious market-orientated electricity supply industry.

5. THE EXTERNAL COSTS OF NUCLEAR POWER

I have tried to show how little substance there is in claims that nuclear power deserves a privileged position because of its supposed external benefits. But, even if external benefits could be demonstrated, in any proper analysis of costs and benefits they would still have to be set against the external costs of nuclear power. Some of those costs have been mentioned already. Many of them parallel those often attributed to fossil fuels. Very briefly, they fall into the following categories:

- insecurity costs if nuclear plant is not constructed to time or is shut down or derated after commissioning
- possible unanticipated long run cost increases because of technical problems and unforeseen safety and environmental requirements; for example, it may be more expensive to decommission plant, to transport and store waste than now expected
- health costs associated with "routine" releases of radiation from nuclear installations
- accident costs such as loss of life, damage to health and the sterilisation of large areas of countryside for many years (as at Chernobyl)

I would conclude that, on present evidence, it would be hard to make a case for granting special status to nuclear power (using present technology), protecting it from the competition of other fuels. In the privatised decentralised electricity supply industry, distributors, generators and large consumers should in general be able to make up their own minds which energy sources they will use. Indeed, if there is to be a genuine market in electricity it is very important that they should be encouraged to make their own decisions and to take responsibility for the consequences. They can assess for themselves the critical factors which determine fuel choice such as future relative price changes and changes in technology; some might, for example, at some time decide that new smaller scale forms of nuclear generation offer reasonable investment prospects in terms of both costs and safety.

There is an important role for government in promoting competition and intervening in cases where there clearly is "market failure". Possibly the market is failing in the case of nuclear power versus fossil fuels but it is not obvious that the direction of failure is the one assumed by enthusiasts for nuclear power. On the basis of the arguments I have presented and assuming present generation technology, I would find it easier to make the case that nuclear power imposes net costs on society than that it confers net benefits.

6. THE CONDUCT OF THE REVIEW

If and when a review takes place, it ought to be quite different from the reviews which have occurred in the past when nuclear decision-making has been shrouded in secrecy and all the information has come from nuclear enthusiasts. Some guidelines might be as follows.

It should, first of all, be recognised that in the new decentralised marketplace in electricity the government should only over-ride marketplace decisions if there is some very clear reason for it to do so. Second, the review should be open: if it takes place behind closed doors as a cosy discussion between the state nuclear companies and the Department of Energy the result is likely to be a repetition of the disastrous decisions of the past about nuclear policy. One particular problem with a review entirely within the state sector is that it would presumably use the relatively low public sector discount rate. To avoid a diversion of resources into nuclear power projects, they should be assessed at the same discount rate as other power station proposals.

As a first stage, a Green Paper would be useful, setting out the issues for discussion rather than reaching firm conclusions. Only after a reasonable period for public debate would it be time for a White Paper or other form of government statement to analyse and discuss the main points of the debate and to explain its conclusions. There should be no presumption that government should intervene. If it decided to do so, either to promote or to restrain the development of nuclear power, it should give a detailed explanation of why. Vague reasons such as "strategic", "security" or "environmental" should be ruled out. Otherwise the review will be a waste of time. It is because policy statements have taken refuge in such obfuscations that decisions about nuclear power have been so poor in the past.

The purpose of these stages in the review would be to bring decision-making about nuclear power into the open, placing the onus on Ministers to specify why and to what extent they wish to over-ride the market, if that is their intention. Instead of centralised decision-making about nuclear power, based on the preconception that it is an energy source which should be favoured by the state, policy would start from a more neutral base. There would be no presumption one way or the other that nuclear power should be promoted or restrained as compared with what a decentralised electricity market would decide. It would take its chance in the market like other energy sources for elctricity generation unless explicit reasons to the contrary could be provided.

Suggesting such an open review may appear a counsel of perfection. It is against the tradition of British government policy-making which does not encourage "outside" contributions and makes little attempt to explain the reasons why particular conclusions have been reached. But what is the alternative? If it is more political embarrassment, of the kind recently suffered by Ministers and civil servants who relied on information and opinions from nuclear enthusiasts, an open review might look quite appealing.

Note: Parts of this paper appeared in an earlier version in "Reviewing Nuclear Power", a paper given at a conference on 2nd April 1990 organised by the Consortium of Opposing Local Authorities

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THE FUTURE OF NUCLEAR POWER IN THE UNITED KINGDOM

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INTRODUCTION

Thirty-five years ago, when I entered the nuclear industry as a young and enthusiastic scientist, there was near global unanimity that nuclear power was a uniquely important technology, the exploitation of which offered the prospect of immense benefits to mankind. These benefits were expected to be partly economic in consequence of the high power density and low capital and fuel costs nuclear power appeared to offer, partly environmental through its substitution for polluting fossil fuel combustion, and partly resource conserving through the preservation and release of "scarce" carbonaceous fuels for high added value chemical synthesis.

Today, these expectations have been realised, but only in part and only in some countries. Unfortunately the complexities associated with meeting the demanding standards of radiation containment and safety, established by and for the industry, have meant that the costs of nuclear energy have been much higher than simple extrapolation might have led one to expect. At the same time fossil fuels have proved to be more abundant than was at one time thought and, despite two alarming excursions, their prices have not yet soared permanently to growth strangling levels as a consequence of resource depletion. Indeed, prices have fallen since the mid-1980s to levels that have removed much of the financial incentive to conserve fossil fuels, with adverse consequences for alternative technologies and the environment. Many analysts now see no reason for any major price increases until well into the next century (1,2), barring political disruption or imposed constraints.

Nuclear power now contributes 17% of world electricity supplies including 75%in France and 60% in Belgium (3) (Table 1). It is proving considerably cheaper than coal as a source of base load electricity in these countries, amongst others, and is expected to remain cheaper by the majority of OECD member countries, (4) (Table 2). It displaces over 550 million tonnes of coal (or equivalent fossil fuels) that would otherwise be burnt each year, and reduces carbon dioxide and acid gas emissions by over 1 billion tonnes and some 20 million tonnes pa respectively (Table 3). In its absence, premature deaths due to

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The views in this paper are those of the author and do not necessarily reflect those of AEA Technology.

TABLE 1 NUCLEAR SHARE OF ELECTRICITY (1989)

COUNTRY	PERCENT NUCLEAR
BELGIUM	60.7
CANADA	15.6
FINLAND	35.4
FRANCE	74.6
GERMAN FED. REP.	33.9
JAPAN	25.5
SPAIN	37.6
SWEDEN	45.3
SWITZERLAND	41.6
UNITED KINGDOM	20.8
UNITED STATES	17.8
BULGARIA	32.9
CZECHOSLAOVAKIA	27.6
HUNGARY	49.8
KOREAN REPUBLIC	50.2
TAIWAN	35.2
USSR	12.3
OECD TOTAL	21.6
WORLD TOTAL	17

Sources: Reference 3 for OECD and Nuclear News, June 1990, p.61

TABLE 2 COAL/NUCLEAR GENERATION COST RATIOS

COUNTRY	COST RATIO
BELGIUM	1.35
CANADA CENTRAL	1.41
EAST	1.15
FINLAND	1.21
FRANCE	1.32
GERMANY FED. REP.	1.24
ITALY	1.02 - 1.34
JAPAN	1.11 - 1.22
NETHERLANDS	0.99
SPAIN	0.97
UNITED KINGDOM	0.96
UNITED STATES	0.81 - 1.07

Source: Reference 4

Note : Ratios are based on countries' own groundrules and cost projections. Ranges reflect regional differences for USA or alternative coal price senarios.

TABLE 3 SAVINGS USING NUCLEAR POWER IN 1989

(Approx.)

COAL FUEL EQUIVALENT	>	550 Million tonnes
CARBON DIOXIDE EMISSIONS	>	1 Billion tonnes
ACID GAS EMISSIONS	>	20 Million tonnes
PREMATURE DEATHS (NET)	>	1000

Source: Reference 5

mining and transport accidents and to chest diseases would be increased by some 1000 per annum or more[5].

Despite these successes, nuclear power has lost rather than gained support over the years and it is still possible to question its future role and contribution to global energy supplies, as this seminar shows. From a United Kingdom standpoint, it is not a good time for a supporter of nuclear power to be debating nuclear futures. The nuclear privatisation debacle and the uncertainties raised in many people's minds by the Gardener Report on leukaemia incidence at Sellafield have added to the concerns that followed the accidents at Three Mile Island and Chernobyl.

These concerns, which are not confined to the United Kingdom, fanned by strident criticism of nuclear power and the nuclear industry by its opponents, have had political impacts that could affect the role allotted to nuclear power in the future, unless the public and politicians can be satisfied that the benefits that will flow from its use greatly exceed any consequential social costs that could arise.

Undoubtedly, criticism of some sections of the "nuclear industry" is fully justified, but blanket criticism based on generalised and, not infrequently, misleading assertions, is not the way to maximise the returns from what has been a major investment of scientific and technological skill.

In this paper, I shall examine briefly the significance of some of the criticisms to put them in perspective before returning to the question of the future role of nuclear power in an energy hungry world.

THE CRITICISMS

The criticisms can be broken down into three broad categories which I shall label the superficial, perfect hindsight and the specific.

1. The Superficial

It is a regrettable fact that "analysis" and comment in the mass media which is little more than arm-waving repetition of cliches is indistinguishable, so far as a majority of its audience is concerned, from that which is carefully researched and factual. Erroneous claims that are repeated loud and often may gain credence which is unaffected by un-newsworthy condensed rebuttals even if the latter are published. Popularised emotive and alarmist publications in the form of books or television documentaries can leave lasting impressions which no amount of detailed and unspectacular factual refutation can undo, even if it reached the same general audience, which, by-and-large, it does not.

This major problem facing modern society, for such it is, is not unique to nuclear power, although nuclear power has experienced more than its fair share.

One article from a national daily newspaper illustrates the point[6]. It is only singled out because its author's affiliation may have afforded it disproportionate credibility and because it was published shortly before this paper was drafted. Specific points made included:

(a) "Conservative manifesto commitments to privatise the ESI (electricity supply industry) and promote nuclear power were clearly irreconcilable". They were not inherently irreconcilable, but they were made so by the proposed structure and re-aligned responsibilities of the United Kingdom's ESI post-privatisation. A British Gas style privatisation could have accommodated both objectives. (I do not argue the merits of the alternatives, merely the accuracy of the blanket claims).

(b) "Phase out Magnox plants; their fuel costs are too high". The decision on Magnox futures ought to be based on marginal costs, not full costs. CEGB (and presumably Nuclear Electric) were committed to meeting the construction and decommissioning costs of the BNFL fuel plant so that the savings achievable by Magnox closure are much smaller than would be implied by inclusive fuel cost figures embracing unavoidable provisions for future commitments. In practice the marginal costs of running magnox plants are less than 1.5p/kWh, well below the marginal cost of gas or coal fired plants.

(c) "Give up struggle on the three second generation design AGRs". It is not clear what second generation design means in the singular. There were three basic designs in the first AGR programme of which Dungeness-B might be seen as the first, if all three are not taken as virtually concurrent. Second generation designs ought, if anything, to refer to the recently commissioned Torness and Heysham-B modifications of the most successful of the first generation AGRs, i.e. those at Hunterston and Hinkley. Decisions on Dungeness-B, Hartlepool and Heysham-B plants, which the author presumably meant, should also be related to avoidable costs which are comparable to those given for the Magnox plants at (b) above.

(d) "Any estimate of completing and operating Sizewell will be very high compared with abandonment costs". No justification was provided for this assertion and it is not factually correct. The avoidable costs associated with completing and running Sizewell are comparable to those of the gas fired plants currently favoured for most new investments, as made clear in recent statements by the Secretary of State for Energy.

(e) "Sizewell completion could only be useful as a demonstration that past industry failures have been remedied". What about Torness and Heysham? Have they not provided this demonstration?

(f) "(PWR) Design admitted by all sides to be hopelessly uneconomic". A sweeping generalisation not applicable to PWRs in all countries and only correct in the UK in situations where interest rates remain high (historically unprecedentedly high in real terms and unsustainably out of line with our main competitors in the long term) and with the uniquely risky supply arrangements initially envisaged for privatised generation companies in the UK.

Clearly such an article creates a series of misleading impressions in the reader's mind; and it is by no means an extreme example.

Misleading presentations of data are also not uncommon. A Guardian "Fact File" published on January 23rd 1990 listed electricity costs, said to be taken mainly from the 1987 study by the Watts *(sic)* Committee on Energy, as 2.26 p/kwh for wind power, 3.10 p/kwh for geothermal power, 3.17 p/kwh for wave power, 3.23 p/kwh (minimum) for tidal barrages. It contrasted these with claimed costs of CEGB electricity from coal, stated to be 3.5 p/kwh, and nuclear energy <u>not less</u> than 6.3 p/kwh. (My emphasis). As a coup-de-grace, it added that renewable costs are expected to decline.

Not only did the "Fact File" mix mid-1980s and 1989 money values, but it contrasted incremental generation <u>costs</u> at 5% rate of return for renewable and coal with indicative selling <u>prices</u> put forward by National Power in the context of privatisation, which had an implied 14% internal rate of return. The latter include overhead charges and extra contingency margins in addition to using the much higher rate of return. The Guardian was in fact asking it readers to compare apples and pears. An article on wave power in the same paper as recently as June 1st fell into precisely the same trap.

The question of comparative costs is, of course, a real one to which I will return later.

Superficial criticisms arise mainly from their authors' failure to ascertain (or understand) facts, or to think through clearly the arguments they choose to deploy. The same may be true of my second category, although some of its practitioners may be guilty of more conscious misdirection of a sort not uncommon in the political arena.

2. Lessons from Hindsight

There are few fields of human endeavour where it is not possible, with the benefit of hindsight, to point to errors of judgement or expectation. Indeed learning from mistakes is the very stuff of progress.

The electricity and nuclear industries have been no exception; a fact which a number of commentators, over the years, have been delighted to point out. Misdirection is introduced by subtly implying, or positively claiming, that because things could have been done better in the past (given perfect foresight), they should have been. Two considerations are almost invariably left unexplained; whether the retrospectively preferred decisions should have been obvious in the context of the time and what the implications of their adoption would have been in the real world.

The most recent offering of this sort is by Henney[7] on which I have commented elsewhere[8]. He follows others in criticising reactor choice, reactor performance, plant ordering decisions and overall nuclear economics in the U.K.

However, Britain's choice of the gas cooled graphite moderated reactor for plutonium production and for its post-war civil power programme was logical in its avoidance of costly enrichment plant and heavy water production. Equally, concerns about the medium and long term availability of fossil fuels and confidence in the economic potential of fission reactors were virtually universal.

The economically damaging substitution of mild steel for the core bolts in the Magnox reactors in place of the initially specified stainless steel was a misjudgment which forced downrating and reduced power output for which the nuclear industry and electricity user has paid dearly. The other major mistake was the ill-fated effort to introduce competition into manufacture and design through the creation of a plethora of consortia and the precipitate rush into ordering 3 prototype advanced gas reactor designs on a Buggins' turn basis.

None of these decisions invalidates the technology itself or the underlying rationale for the UK pursuit of gas reactor technology which had far greater development potential, higher thermal efficiency and inherently better safety characteristics for both workers and the public than the contemporary water cooled reactor designs. The concerns about manufacturing and siting PWRs with their demanding pressure vessel technology or BWRs with their two-phase cooling and (at the time) imponderable control problems were very real.

The dominant common factor to many of the problems that beset the nuclear industry in the UK was undoubtedly over-optimism about prospective economic growth and its translation into power plant requirements, both globally and domestically. This over-optimism permeated all aspects of industrial and energy policy under successive governments, not just the electricity supply industry.

It contributed to the view that an international market justifying the establishment of competing nuclear consortia would evolve. It contributed to the pace of ordering AGRs, whose belated commissioning did not, in the event, prove critical to power supplies. It also contributed to the timetable envisaged for fast reactor development and deployment.

The general concerns about the adequacy of energy supplies were not confined to the UK and they were exacerbated by perceived limitations in the global (and national) resource base for both fossil fuels and uranium, and, over time, by the effects of overseas political actions on the availability and price of individual fuels.

In both areas, we now have the benefit of hindsight and have experienced the global economic slowdown and resource expansion brought about by the oil price rises of the 1970s and 1980.

The question remains of what alternative choices could the UK have made and what would have been their consequences? Would we have built oil fired capacity and if so what impacts would that have had for British industry in 1973/74 and 1979/80 and the years thereafter? Would we have remained even more dependent on British coal supplies and how would this have affected coal prices over the past 30 years? If one wishes to compare the costs of nuclear electricity from Magnox plants with an alternative, one can not do so without relating it to the hypothesised alternative with all the problems that entails. Mr. Henney did not address this issue at all despite the fact that it has been recognised for a long time[9].

It is also unclear from his report whether he believes that the reactor choice was wrong or whether he is opposed to all nuclear power. Certainly there is no reason to suppose that early pursuit of the BWR or PWR would have been more successful in UK circumstances than the AGR turned out to be. Indeed, many of the problems that beset the US electricity industry with retrofitting, commissioning and multiple designs could well have led to additional problems for the UK. This objection would be less appropriate now that designs have absorbed the lessons of TMI, but not in the early 1970s.

The errors, as they turned out to be, in demand forecasts were not peculiar to the UK. Major internationally funded institutions like the International Institute for Systems Analysis together with the World Energy Conference and most countries' national forecasters favoured what was essentially a consensus view.

The presentation of the comparative economics of alternative electricity generation options has also been fertile ground for adverse comment in the past and Henney rehearses the familiar arguments. The weaknesses of conventional commercial accounting practices are well known yet they are still generally employed as performance guides by the private sector companies (and many electrical utilities) that Mr. Henney admires[10]. They are particularly misleading as guides for future investment in periods of rapid inflation but nevertheless are regarded as indicators of present performance arising from past decisions. Their use by CEGB was not calculated to deceive any more than the accounts of any other company using historical capital expenditure as a measure of its asset value. Nevertheless, because of the importance of true resource costs in displaying the impacts of past public sector investment decisions, CEGB and others have presented full cost constant money analyses incorporating future liabilities as well as past expenditures for many years[11] - [13].

It is not sufficient to compare such costs for different plant types without examining the overall impact of alternative past choices if one wishes to assess the true benefits or costs of those choices. This is far from easy and is subject to differences of judgement just as much as analysis of future investment options[14].

If failures of foresight are to be criticised, few are above criticism. The gas industry and governments have artificially restricted supplies believing, contrary to the currently accepted wisdom (which may itself prove wrong in retrospect), that gas was a scarce resource best reserved for premium uses; British governments, British industry and the city have failed, for whatever reason, to maintain the U.K's once dominant position in world trade; the majority of the 40 geothermal plants around Paris are reported to be losing money and unable to repay debts due to a combination of technical failings and low fossil fuel prices[36]; even God, according to Genesis, told Adam to go forth and multiply, and we can all see the problems that this unqualified instruction has caused and will continue to cause in the future!

Both Henney[7] and Colin Robinson, in his contribution to this Discussion Paper, attribute many of the problems the UK electricity and nuclear industries have experienced to the institutional structure and, in particular, to the public sector monopolies created in the post-war era. I share their view that institutional structures can and often do predetermine the way in which social, technical and industrial futures evolve. However, had we left the energy industries to the private sector would we still have maintained a high-cost coal industry like the FRG or switched rapidly to "cheap" but ill-fated oil? Would we have experienced the US free market's nuclear problems (or worse) or would nuclear development have languished as so many other advanced technologies have in the UK since World War II. In the absence of Government involvement my guess is that we would have become almost wholly dependent on imports for our fuels and much of our technology, as we have in so many other areas of manufacturing.

3. The Specific

There are several questions raised in connection with nuclear power which merit serious attention and it is to these that I now turn since they do affect the role and scale of the nuclear contribution in the future. These questions are, not necessarily in order of importance, the proliferation of nuclear weapons, nuclear safety matters, the contribution of nuclear power to fuel diversity and aspects of economics. Economics will be treated in a separate more detailed section of its own. The other points are covered briefly here.

3.1 Proliferation - No one would deny the prime need to ensure that the spread of nuclear weapons capability should be restricted to the greatest extent possible. Equally it is undeniable that the necessary science and technology are no longer beyond the reach of any reasonably affluent country with an industrial capability. It has long been recognised therefore that the only constraint on proliferation, apart from lack of desire in non-weapon countries, is the political and economic pressure that could be brought to bear by the major industrial nations, should world or regional stability be threatened by military nuclear programmes in other countries or groups(15).

Controls are maintained by the major powers on the transfer of sensitive nuclear and delivery vehicle technologies to other states and access to the benefits of civil nuclear power is provided under the aegis of the Non-Proliferation Treaty and the International Safeguards regime. This uses inspection and material accounting techniques designed to provide early warning of any attempts to divert nuclear materials from the civil fuel cycle, so that appropriate political responses can be stimulated.

Almost any country determined to have nuclear weapons and prepared to face the political and economic consequences could produce them without recourse to civil nuclear facilities. Limitations on the deployment of civil power reactors, where they could yield economic or environmental benefit, would therefore serve no useful purpose and would contribute to socio-economic problems that make international conflict more rather than less likely.

Those who are opposed to nuclear power because of a presumed risk of weapons proliferation are failing to face up to the realities. Certainly no one would gain if existing nuclear powers like the U.K. abandoned the technology on this score.

3.2 Safety - This remains a matter of concern in the minds of many. It has three facets; the risk of a major accident, the risks attached to routine industrial operations, and the safe handling and disposal of wastes.

The nuclear industry in the U.K. and internationally believes that the technical requirements are well understood and that all the industry's operations can be conducted in a fashion that puts the public and the workforce, both now and in the future, at no greater risk than other industrial activities. Indeed, on any meaningful comparison the nuclear industry should rationally be judged safer than the other energy industries on the basis of the assessments and quantitative analyses of risk the industry performs[16].

It has so far proved impossible to produce simple self-evident unequivocal demonstrations of the validity of these beliefs that will completely convince the layman, whose inherent scepticism has been heightened by the apparent fallibility of past statements on acceptable radiation dose levels and the remote probability of accidents.

This is an area where, in the foreseeable future, governments, backed by independent advisers, will have to weigh the arguments, establish the regulatory environment and make decisions on behalf of an inevitably less well informed public. This is neither an unusual nor a new circumstance, nor is it confined to nuclear power. Almost every industrial operation and form of transport, together with many non-industrial activities involve similar decisions, whether they be implicit or explicit. We, the public, are generally totally unaware of the inherent risks unless we are sensitised (or over-sensitised) by the media, or particular events force them on our attention.

3.3 Diversity - This topic is dealt with here since it became an issue in the U.K. following the publication of Government's privatisation plans for the electricity supply industry and their proposals to ensure the maintenance of a non-fossil fraction of generation capacity. The generalised policy objective of diversity was made the central plank of the CEGB's case for the Hinkley-C PWR at the official planning inquiry.

Inevitably opponents of the proposed plant, whose other lines of objection were blunted by the CEGB's chosen approach, attacked the vagueness of the diversity concept and questioned whether a single nuclear plant (or several) contributed as much as other approaches they themselves devised.

It was argued that similar (or greater) assurance of supply could be achieved by diversifying fuel suppliers (to imported coal or by splitting and privatising British Coal into competing companies); by diversifying the fuel base (to include gas, biomass, organic wastes or more oil); by maintaining stockpiles of fuel to cover periods of disruption; by using other non-fossil fuel sources (renewables): or by reducing demand through end-use efficiency measures (see Table 4).

It is clear that each of these courses would reduce, to a greater or lesser extent, exposure to risks of supply disruption arising from specific scenarios. For example, from strikes at fuel producers or in fuel transport companies or through externally imposed

TABLE 4 DIVERSITY CHART

	STOCKPILE	COAL SOURCING	MIXED FOSSIL	RENEWABLE	NUCLEAR	CONSER-VATION
MINERS' STRIKE	YES	YES	YES	YES	YES	NO
FOSSIL TRANSPORT	YES	NO	YES	YES	YES	NO
RESOURCE DEPLETION	NO	YES	NO	YES	YES	SOME
POLITICAL CONSTRAINT ST	YES	YES	NO	YES	YES	NO
POLITICAL CONSTRAINT LT	NO	YES	NO	YES	YES	NO
ENVIRONMENTAL	NO	NO	NO	YES	YES	SOME

ST = Short term
LT = Long term

political constraints. Conservation could only do this insofar as it reduced absolute dependence on fuels, but pro-rata interruption of supplies could still be as damaging to the economy overall at any level of energy consumption.

The two circumstances not guarded against are prolonged increases in fossil fuel costs (directly or through taxation) or restrictions on fossil fuel use for environmental reasons.

Both renewable sources and nuclear power are able to protect the economy against these eventualities, with nuclear power alone capable of doing so in the foreseeable future at levels comparable to existing fossil fuel use for electricity generation at costs comparable to current costs.

Over-reliance on nuclear power would carry its own risks since uranium supplies could be disrupted and unforeseen problems with similar nuclear plant anywhere in the world might impact on the use of U.K. plant. However uranium or fabricated nuclear fuel can be stockpiled more easily and cheaply than fossil fuels and the disaster at Chernobyl had little direct impact on nuclear plant operation outside the Eastern Block countries.

To claim, as some have done[17], that a privatised ESI would naturally lead to adequate long-term diversity is to fly in the face of facts. There is no longer any obligation on anyone in the UK to supply power and claims of force-majeure could be used to defend shortfalls arising from "external" factors. The current worldwide headlong rush into gas firing on grounds of short term costs and claimed environmental benefits could lead to as exposed a position as the economic reliance on oil in the early 1970s. The USSR's willingness to use energy supply as a weapon to restrain Lithuania must raise questions in those Western countries heavily reliant on Soviet gas. Also the major part of the world's known oil resources are still located in the middle-east where political stability remains a matter of widespread concern.

Coal is the only fuel whose external supply could be reasonably assured long-term on quantitative and geographical distribution grounds. Its transportation and price may be vulnerable however to short term disruptions and, on environmental grounds, it should be the fuel of last resort, had we not become so dependent on it.

To provide security through diversity a balanced mix of generating plant types would have to be established and maintained since construction lead times are long relative to the speed at which world economic/political events have their impact. The desirable balance has to depend on perceived vulnerability, realisable economic contribution, environmental impact constraints and, not least, comparative generating costs <u>within</u> the overall power system.

Perceptions of these factors have changed considerably over the past 20 years and are likely to continue to change in the future, though in which way is not necessarily clear.

To suggest that nuclear power is particularly susceptible to unforseen changes and therefore less fitted to providing diversity, also ignores facts. Problems with fossil fired plants have only just begun to be addressed with the belated and, by some, reluctant acceptance of their role in acid rain production, and their acknowledged contribution to the greenhouse effect. With the exception of hydropower most renewable technologies remain relatively untried and there is no experience of their plant lives and long term maintenance costs, although some ventures appear to have become expensive failures[36].

Leaving aside environmental and economic considerations, to which we turn later, it would be reasonable to seek protection against short term fossil fuel supply disruptions (measured in months) by using multi-fuelled plants and relying on stockpiles and fuel switching. As stated earlier however longer term changes whose onset is not anticipated could only be dealt with effectively by having an appropriate mix of operational plant in place. The existence of an unbuilt but proven 'option' is of no practical advantage. Thus, fast breeder reactors are capable of meeting all the U.K's electricity demand for centuries with no need for imported fuel[33] (existing accessible depleted uranium stockpiles are equivalent when used in fast reactors to all the UK's recoverable coal reserves), but they would need to be up and running to do any good in a situation where fresh uranium supplies for thermal reactors were unavailable or prohibitively expensive for protracted periods.

For this reason it seems to me sensible for the Government to seek to encourage the deployment of a mix of established technologies (including those becoming newly available, subject always to the costs of such a strategy being reasonable and its environmental and social consequences being acceptable.

THE ECONOMICS OF ELECTRICITY PRODUCTION AND USE

Because electricity can not yet be stored on a worthwhile scale its production has to match instantaneous demand and this creates an economic incentive to have supply networks in which a number of plants with different economic and technical characteristics are employed to provide a desired level of assurance of supply. The ongoing optimisation of the supply network is a complex task calling for long and short term demand forecasting, anticipation of future fuel price movements, knowledge of the technical availability of generating plant and an assessment of the potential variability of demand and supply due to weather, economic, regulatory or other factors.

For base load power generation coal has been the dominant fuel and it is therefore logical to use it as a yardstick against which to judge other options, both for economic and environmental assessment purposes.

There are two distinct economic issues that I wish to address, comparative generation costs and the costs of generation versus the cost of electricity conservation technologies.

1. Generation Costs

The costs of producing a unit of electricity (kWh) are made up of capital charges, fuel costs and other operations and maintenance costs. Conventionally companies comparing investment in alternative generation options look at incremental costs to the existing plant network omitting common company overheads, transmission charges etc., unless there are reasons for these differing significantly between options. It is important to ensure that all costs are covered, including those associated with delayed liabilities arising from plant operation. These are particularly significant for nuclear power where the processes of spent fuel management and plant decommissioning may involve costs long after power generation has ceased[12].

The question of investment cost appraisal is easy in principle but difficult in practice because it requires the estimation and/or prediction of construction costs, plant technical/economic lives, plant availability, the future movement of fuel prices (and, for imported fuels, exchange rates), and the costs of dealing with decommissioning and wastes. Judgements on any of these items can be and are questioned. A further problem is the appropriate discount rate (or return on capital) to employ in comparing options with radically different cash flow profiles[4].

I have dealt elsewhere with the question of calculation methods, the comprehensiveness of costs and the confusions that have surrounded nuclear costs and prices in the United Kingdom in the run-up to privatisation[10,18] (see Table 5). Any comparisons between generation options have to be made on a common basis because different calculation methods can and do yield widely different figures in absolute terms.

Based on CEGB evidence to the Hinkley inquiry, for the U.K. a new PWR is projected to produce electricity at a levelised cost equal to that projected for a new coalfired plant at an 8% discount rate (in real terms) with initial capital annuitised over the plants respective lifetimes (Table 6). At higher rates of return and with annuitisation over a shorter period the more capital intensive option becomes relatively dearer. The same is true for windpower, tidal barrages, etc.

In the U.K. situation a risk averse electricity utility with no long term assurance of a market for its product looked, in the process of being privatised, for higher returns from its investments and decided to depreciated its plants over a much shorter period. This together with some added contingency costs and the inclusion of central overheads was the basis for the high prices put forward by National Power as an opening salvo in

TABLE 5 COST AND PRICE RELATIONSHIPS

DECISION CRITERION FOR INVESTMENT = INCREMENTAL COST TO SYSTEM

TOTAL PRODUCER COST = INCREMENTAL COST PLUS SHARE OF COMMON OVERHEADS

TARGET SELLING PRICE = TOTAL PRODUCER COST PLUS PROFIT MARK UP PLUS CONTINGENCY CHARGES TO REDUCE RISK

Note: In practice the actual selling price may be higher or lower depending on the competitive position.

Note: In the UK case different money units were also introduced between the Hinkley-C decission criterion costs and the National Power estimates of target selling price.

TABLE 6 UNITED KINGDOM GENERATION COSTS

From Hinkley-C Inquiry figures in March 1987 p/kWh

DISCOUNT RATE	HINKLEY-C	COASTAL COAL	INLAND COAL
5%	2.24	2.50	2.62
8%	3.09	2.97	3.03
10%	3.80	3.35	3.36

Note: Incremental investment costs for existing network. Nuclear costs included waste management and decommissioning whilst coal plant allowed for desulphurisation of flue gases.

their contract negotiations. In a competitive position they would doubtless have to have adopted a more cost conscious position in due course (recently published estimates from Nuclear Electric confirm that this is indeed the case).

It is totally wrong, however, to suggest as many have done that the earlier comparative cost analyses were misleading or that the "true costs" have been "exposed" by the privatisation plans. It is true that if coal and nuclear generation costs from new plant for commissioning in the late 1990s are calculated for a situation in which high real rates of return are required and there is no assured market, nuclear electricity would be the dearer option though not by the margin implied by contrasting the negotiating price of 6.25p/kWh (1989 money) with a coal generation cost of 3.5p/kWh (1987 money) - new coal plant electricity prices would be nearer 5p/kWh (1989 money) on a comparable basis, tidal-barrage electricity 10p/kWh and wind-power 9p/kWh (Table 7). (This comparison carried forward the National Power calculations. On the basis considered appropriate by Nuclear Electric all the prices would be much closer to the cost data listed in Table 6).

Two factors make the present U.K. situation unique. We have the highest real rates of interest of the western developed countries. They are also very high by historic standards. It is hard to see how this situation can persist in the long term particularly since the Single European Market and the European Monetary System with free capital movement should bring interest rates into line. Secondly the U.K. is the only country trying to introduce unfettered competition into electricity supply. In most countries a degree of regional monopoly is granted to public or private utilities.

It is not surprising therefore to find that most OECD countries[4] look for more reasonable returns on capital invested in electricity supply (and elsewhere) and that 5% p.a. in real terms is fairly typical, based on market rates, with a few countries like France and Belgium looking for somewhat higher returns of 8% and 8.6% p.a. (Some smaller countries like Greece and Portugal seek 10% p.a.). The assumptions they use are listed in Table 8.

On the basis used by utilities in OECD countries, Table 8, including their own separate expectations concerning future coal prices and nuclear fuel prices, nuclear generation is expected to remain significantly cheaper than coal for base-load electricity in 7 out of 10 OECD countries providing data on both for a recent IEA/NEA study, with 3 others showing approximate break-even. (This excludes low cost coal regions of North America where coal-fired plant remains the cheaper). A similar result was obtained if the underlying assessment assumptions were harmonised.

This finding echoed the results of previous analyses by the NEA and by Unipede, the International Union of Electricity Producers, although the margin by which nuclear was cheaper than coal-power had declined since the earlier studies. Both fuels were

TABLE 7 PRICES OF OTHER GENERATION OPTIONS

Based on Hinkley-C Inquiry cost data and the Marshall conversion method as outlined to the British Nuclear Energy Society.

	PUBLIC SECTOR COST 8% ROR 1987 p/kWh	PRIVATE SECTOR PRICE "10%" ROR 1989 p/kWh	DEPRECIATION PERIOD YEARS	OVERHEAD AS % OF NUCLEAR
COASTAL COAL	2.97	4.5 - 5	20	50
NEW NUCLEAR	3.09	6.25	20	100
TIDAL BARRAGE	5.56	10	20	25
WIND PARKS	3.48	7.5 - 9	10	25

Notes: The public sector annuity periods were 40 years for coal and nuclear plant, indefinite for tidal and 25 years for wind.

The private sector price basis removed interest during construction but charged interest at 10% on undepreciated capital plus depreciation, equivalent to a 14% internal rate of return over 20 years.

The depreciation periods and overheads charges are assumptions introduced here to match the nuclear changes. The top end of the wind price range also takes an energy load factor of 30% to allow for risk, rather than the 38% given at Hinkley. The 9p/kWh corresponds to figures for wind prices recently given in the press.

TABLE 8 OECD COUNTRY COST RATIOS AND GROUNDRULES

	COAL/NUCLEAR COST RATIO	RATE OF RETURN % P.A.	CONSTRUCTION PERIOD MONTHS	LIFE* YEARS
BELGIUM	1.35	8.6	96	20
CANADA CENTRAL	1.41	4 - 5	72	25
FINLAND	1.21	5	72	25
FRANCE	1.32	8	72	25
FRG	1.24	4.5	72	20
ITALY	1.18	5	96	13
JAPAN	1.16	5	96	16
NETHERLANDS	0.99	4	84	20
SPAIN	0.97	5	108	25
UNITED KINGDOM	0.96	8	78	40
UNITED STATES (E)	1.07	5	84	30

Source: Reference 4

Note : * Life is amortisation period and is significantly less than the technical life anticipated for PWR plants.

showing expected cost reductions but the dramatic decline in fossil fuel prices since the mid-1980s had outweighed the improvements in nuclear costs and the extra costs associated with flue gas desulphurisation where these had not previously been included in fossil-fuelled generation costs.

There are of course question marks over projected coal and nuclear costs. What will happen to environmental regulations? Will these have an impact? Will carbon taxes be internationally adopted and if so what will this mean for electricity? Will fossil fuel prices rise or fall in real terms? If combined cycle gas plants are cheaper sources of base-load electricity than coal, as so many in the UK seem to think, will the present rush into gas burning force prices up to the point where it ceases to be attractive? (In the referenced IEA/NEA study[4][37] utilities providing data expected gas to be a dearer fuel than coal for base-load power).

The pessimistic "costs" for nuclear power given currency in the U.K. last year are so far out of line with most other western industrial nations that one has to conclude that either "we" or they have got it wrong. In fact a simple comparison shows that basic UK costs are not out of line with those of other countries[4] and that the adverse comparison in the UK arises from the financial ground rules employed by National Power[18] which deviate considerably from those adopted elsewhere. I can not subscribe to the view that everyone else is out of step and I feel that we have to conclude that nuclear generation will cost less than, or at worst break-even with, world traded coal in the 1990s and beyond. Ultimately, of course, if electricity markets dominate coal use and nuclear electricity were the cheaper, coal production would be cut back to a point where the two broke-even allowing for fuel transportation costs.

Should the general level of world interest rates increase then capital intensive options like nuclear power and renewable sources would be less competitive - just as coal-fired plants would lose ground against combined-cycle gas turbines. Such a situation could arise if globally concerted moves to protect the environment led to capital shortages.

2. Generation versus Conservation

There is no doubt that many potential energy saving measures are highly cost effective and that, despite the efforts of Governments and the self interest of energy users, many technical opportunities for improvement remain.

What is open to question is whether the pace of adoption of the cost-effective measures will reverse the growth of energy demand or merely reduce it and whether the efficiency improvements built into demand projections adequately reflect the savings likely to be achieved in a real world[2,19]. As Brookes and Greenhalgh point out[23][38] energy efficiency improvements are likely to lead to increases in energy consumption that will offset if not eliminate the initial gains.

There is equally no doubt that many potential energy saving measures are not cost-effective, and that their introduction would add to rather than reduce resource costs. (This may be acceptable if they yield other benefits through greater comfort, etc.).

However there are pitfalls in simplistic estimation of savings. Firstly there has to be a clear distinction between efficiency measures that pay for themselves in resource cost terms even if they are introduced before existing equipment/processes etc. have completed their useful life, and those that only pay for themselves if they are adopted at normal replacement cycles (when marginal costs are an appropriate basis for calculation).

Secondly the question has to be asked whether it is a true resource cost saving or whether it is merely a cash saving. Someone buying domestic electricity may effect personal savings by reducing his consumption but if a significant fraction of his saving arises from the fixed costs of the electricity supplier the gains may be at the expense of increases in prices of electricity for others.

These distinctions are important but are often brushed on one side in comparisons of savings versus supply, to the apparent detriment of the supply option(20). In practice it may be sensible to contrast the marginal costs of energy saving investment with investment in generation capacity where there is a real trade-off position. But in some instances apparently cost-effective conservation measures can be dearer than investment in and operation of new generation capacity(21,22).

Tables 9 and 10 illustrate the point. Based on Keepin and Kats'(20) data for fridge/freezers the levellised cost of saving a unit of electricity using a new high-efficiency machine would range from 6.9 US c/kWh for immediate replacement of a typical existing machine to 2.7c/kWh for replacement at the end of the normal life-cycle(21). Both courses appear to save a consumer paying 7.8 c/kWh(20) money but the marginal cost of units saved would be around 1.7c/kWh for nuclear or 1.5 to 2.5 c/kWh for coal-fired electricity (depending on the region and coal price), both in the USA(4). The effect of individual savings would be to transfer fixed costs to other consumers and raise the average price of electricity.

In the case of reduction of growing demand the marginal levelised savings costs (2.7 c/kWh) would be less than the 3 to 4 c/kWh levelised average cost of providing additional base load units from coal or nuclear sources in the USA.

In FRG the estimated costs of savings(22) through use of new equipment is significantly higher and exceeds the costs of incremental supply in several cases (Table 10).

TABLE 9 CONSERVATION AND SUPPLY COSTS

ITEM	LEVELLISED INCREMENTAL COST US cents/kWh
FRIDGE/FREEZER	
(a) Normal replacement	2.7 per kWh saved
(b) Immediate replacement	6.9 per kWh saved
NUCLEAR SUPPLY	
(a) Marginal units	1.6 per kWh saved or supplied
(b) New supply at full cost	3.5 per kWh supplied
(c) Net cost relative to coal	-0.3 to +0.7 per kWh coal-based electricity saved.

Note: All figures relate to USA.

TABLE 10 CONSERVATION VERSUS SUPPLY COSTS IN FRG IN PFENIGS/kWh

ITEM	INCREMENTAL COST PER kWh SAVED
HIGH EFFICIENCY LAMP	17.9
REFRIGERATOR	12.0
WASHING MACHINE	13.7
HEAT PUMP	31
	INCREMENTAL COST PER kWh SUPPLIED
NUCLEAR SUPPLY COST (FULL)	12.5
COAL FIRED SUPPLY (FULL)	16.8

Source: Reference 22. Coal prices relate to German hard coal.

Unfortunately there is great uncertainty about the realistically achievable energy savings in normal operation, great uncertainty about the costs of achieving them and uncertainty about the pace at which any worthwhile measures can or will be achieved. A lot of work remains to be done before confidence can be placed in projections of energy demand linked to high efficiency futures, particularly if the consequential effects of initial savings are to be incorporated(23)(38). There will also be major variations between countries depending on existing standards, the mix of equipment of socio-economic factors.

ENVIRONMENTAL BENEFITS OF NUCLEAR POWER

The erroneous disparity between electricity supply and conservation may be compounded if savings in pollution emissions are compared (eg carbon-dioxide) since in terms of costs per tonne of CO_2 avoided the marginal cost of nuclear or renewable plant relative to the fossil option would be the appropriate measure for essential supplies of electricity(21).

For most OECD countries the marginal cost of replacing or providing essential electricity from nuclear plant rather than coal plant is negative (nuclear is cheapest) and the carbon dioxide emissions can be avoided whilst saving money(4). This is not true of the end-use efficiency savings illustrated in Tables 9 and 10 although it would be true of some measures such as loft insulation.

In the circumstances peculiar to the United Kingdom at present, as indicated earlier the same claim would not be made.

Claims that nuclear power itself will contribute significantly to anthropogenic carbon-dioxide production are based on the fossil-fuel used in the extraction and fabrication of materials for the plant and its fuel(24) and rely on unrealistic nuclear installation scenarios, unrealistic figures for uranium resources(25) and adverse assumptions about the nuclear technologies used(26). For the UK using centrifuge enrichment plant nuclear power is comparable with renewable energy sources in its carbon-dioxide production (or better if the centrifuge plant is supplied solely with nuclear electricity). Indeed, for self-supplied pressurised water reactors (or fast reactors) the carbon-dioxide associated with a nuclear electrical output of 5TWh per year is comparable with that from the production of some of the better aids to energy efficiency on the basis of equivalent annual electricity savings(26).

The important point to note however is that all of the non-fossil options (and listed conservation options) have the ability to reduce carbon-dioxide emissions to 1% at less of those arising from coal combustion. Marginal efficiency improvements in coal combustion or its substitution by hydro-carbon fuels are nothing like as effective. Now that the anthropogenic contribution to greenhouse warming appears to be agreed to be a serious threat to planet[27] the stabilisation of emissions that might be brought about by fuel substitution and conservation in the short to medium term can only be seen as a first step towards the eventual reduction of emissions to sustainable levels equivalent to the natural net rate of removal from the atmosphere, which is put at around 2 GT p.a. (compared with some 5 GT p.a. of carbon-dioxide produced by fossil fuel combustion). Such a goal could not be contemplated even in the medium term in the developed countries, let alone the developing countries with their growing populations and legitimate aims of improving their per capita income[28].

PROSPECTS FOR NUCLEAR POWER

In the previous paragraphs I have spent some time examining the arguments that have been put forward in the UK to justify the contention by its opponents that nuclear power should not be seen as a safe, economic, strategically desirable and environmentally attractive energy source. In the confines of one short paper it is not possible to do more than indicate why I believe them to be wholly wrong. Clearly nuclear power has to be safe and to have at least one of the other listed characteristics if it is to feature in the future energy policies of UK Governments. To be worthwhile it also has to be capable of making a significant contribution to total energy supplies. Its ability to do the latter in the longer term is perhaps one point on which there can be no dispute. We do have 25000 tonnes of depleted uranium which is capable of providing some 15 Terrawatt-years of electricity.

Certainly there are a number of myths that gained some currency in the 1970s that continue to be used although they have no more foundation now than they had then. Thus, there is no inherent world shortage of energy although adjustment to a non-fossil fuelled world will take time and will involve considerable costs if it is attempted at a rapid pace. Energy use is not inherently a bad thing that has to be avoided at almost any cost. Energy has provided the means whereby the developed nations have reached the high living standards the majority of their populations now enjoy and without which prospects for those living in the less developed nations are pretty bleak.

Electricity production and use is no more 'wasteful' than any other process adding value to crude materials. That is not to say that economic efficiency should not be sought in the process but, provided the product commands a price justifying the conversion (allowing for externalities), criticisms on claims of energy wastefulness have no validity.

If we are able to provide abundant low-cost energy in an environmentally and ecologically benign way, I can see no grounds for not doing so. The present generation through the development of nuclear power has more than compensated for any of the world's physical resources it will consume and has opened up the possibility of leaving future generations far better off than they would have been without its development (not only in energy terms but also from the side benefits arising from the use of radiation and isotopes)[5].

Undoubtedly there will be growth of nuclear capacity on a world scale over the coming decade due to the construction plans already formulated[3]. The rate of commissioning new plants is slowing markedly however as the industry has reacted to the excess of capacity created by over-optimistic projections of economic growth and electricity demand in the 1970s. By the end of the decade this excess will have been assimilated everywhere and demand for new and replacement plant will be growing so that new generating plant orders can be expected to be on the increase.

The capital costs of new nuclear plants appear to have levelled out over the last five years[4] and their contribution to electricity production costs should be coming down, reflecting the marked improvements in operational availability being achieved in the majority of countries[30].

Nuclear fuel prices are at an all time low in real terms with uranium spot prices of $9 per lb U_3O_8 and separative work at around $50/kg SWU. Contract prices are higher than this but technological advances in enrichment plants will prevent a return to the high prices associated with the older diffusion plants. The expectation of price rises in the 1990s, as OECD countries' surplus mining and enrichment capacity was absorbed, seems likely to be confounded by the entry of hard-currency seeking East European and Soviet sources into Western markets[31].

In the longer term the adverse economics of some Eastern production and the likely balance between resources, production and demand in the East should leave the position in the old WOCA region (what were the non-centrally planned economies), for which projected uranium fuel supply and demand estimates have been published regularly[32] by the Nuclear Energy Agency and IAEA, relatively unchanged[33].

The costs of the back-end of the nuclear fuel cycle (spent fuel management) are likely to decline to some extent due to the contractual arrangements whereby the reprocessors have planned to recover their capital investment over the first portion of their plant's life. Waste management costs do not make a major contribution to PWR fuel costs[31,34] so that residual uncertainties are not likely to affect the medium term decreasing fuel price trend.

It is also to be expected that post-2000 the more stable environment for plant construction and ordering, plus industry consolidation, will permit the realisation of some of the benefits of learning and replication that have been so conspicuously absent in most countries other than France, Canada and, perhaps, Japan.

All-in-all the economic attractiveness of nuclear power, already established in many countries, should be showing further gains through the 1990s and into the next century.

However the fact that I believe nuclear power to be one of the most attractive of the package of policy options that we should be adopting for the future (the others being energy efficiency, fuel switching and development of renewable sources, where the latter can be made economic), does not mean that I am optimistic about its prospects in the UK in the short to medium term.

In the first place we now have a de facto moratorium on new post-Sizewell nuclear construction until 1994 so far as the government owned utilities are concerned. In practice this means that we are unlikely to see any post-Sizewell plants commissioned before 2000 at the earliest, assuming the government review takes place and decides in their favour. The politicisation of nuclear power in the UK could mean that the review is not held or is further deferred, depending on the manifestos of the political parties and the outcome of the general election to be held in or before 1992.

Nuclear electrical output should nevertheless increase as Sizewell-B is completed (this could also be subject to political developments) and the performance of Nuclear Electric's AGRs is improved. Almost certainly the company's remaining Magnox reactors will have their lives extended following the successful review by the Nuclear Installations Inspectorate of BNFL's Calder Hall and Chapel Cross stations.

There will also be strong pressures on the nuclear utilities in England and Wales and in Scotland to reduce their operational costs. I will also be surprised if on review, it is not possible to improve on decommissioning and waste management costs so as to reduce the levels of provision being made against future liabilities. (This is not a major factor for the PWR).

My expectation is that by the time of the 1994 review the UK's nuclear plant will be performing to significantly higher standards and Sizewell-B will have been completed without major time over-runs.

At the same time the structure and pricing arrangements for the wholly privatised ESI seem likely to result in temporary abandonment of plans for large generation plants, either coal or nuclear, in favour of smaller combined - cycle gas plants and joint venture combined heat and power plants involving the ESI and industrial enterprises in levy-free initiatives. These together with plant life extension, uprating and, possibly demothballing (with or without fuel conversion) of existing oil plants are likely to meet any growth in UK capacity requirements, at least up to the turn of the century.

If future governments persevere with privatisation and allow the industry and the market "free" rein, there will still be strong policy impacts arising from environmental and security of supply requirements. These could take the form of directives (e.g. on desulphurisation technology, fuel stockpiles, supply obligations, carbon-dioxide emissions limitations) or market influencing fiscal policies (pollution taxes and penalties for supply failure).

Such measures could radically alter the relative attractiveness of different generation options to the investor in the post-2000 period. Well before then the UK will have joined the EMS and the impact of this together with the Single European Market of 1992 with its open competition, rights of carriage, and market transparency, should result in the UK's interest rates and plant construction costs moving into line with those of its competitors. These changes should make nuclear power a more attractive option financially in the UK than it has seemed in the immediate past.

At the same time the prior commitment of the lowest cost North Sea gas supplies will be reducing the potential for its further economic deployment in power stations constructed in the post-2000 period. For these reasons there is every prospect that a privatised industry will be looking favourably at nuclear options for its post-2000 programme when, on a replacement basis alone, some 1.5 GWe of capacity per year will be needed on average. If the ESI structure remains unchanged the needs of individual distribution companies may be best met by commissioning smaller plants like the joint UK/US SIR design. Alternatively the UK utilities or joint venture companies, possibly involving overseas interests (Electricité de France?), could plan and construct large plants on the basis of multiple customer contracts.

If future UK governments decide that the 'free' market is not the best means of optimising the provision of energy and electricity supply and that for their policy reasons a more vigorous interventionist role is needed, the outcome will be dependent on the evolution of party policies. These will not necessarily adhere to current positions since there is a rapidly changing world situation to which all political parties will have to respond.

There already seems to be a greater realisation of the environmental attractions on nuclear power and even its most determined opponents now seem more willing to concede that it has a role to play. The intractable problem facing the Swedish and Italian governments as well as the major replacement programmes necessary in the USA in the post-2000 period will force decisions that I believe will come down in favour of new nuclear power programmes for environmental and economic reasons.

Even if individual countries seek other solutions the high costs that would be involved are likely to deter others from following suit. Swedish studies, suggest that the costs of going non-nuclear will have major adverse effects on their economy in terms of energy prices (electricity up 30 to 70%) and employment for example[29]. For this reason it seems probable to me that post-2000 UK interventionist governments would be likely to want the majority of replacement base-load plant to be nuclear subject to their being satisfied on safety matters

This should favour a return to large plant ordering by the utilities depending on how the comparative economics of large and small plants then appears. The trade-off between scale savings and replication with simplicity of design benefits for smaller nuclear plants has still to be resolved. Countries like France and Japan are satisfied with their existing large scale plant but some other countries see benefits from the adoption of smaller plants which fit better with their institutional structure and may be better matched to the markets that will exist in smaller and developing countries. Until some of the smaller plant designs are been approved, built and operated the comparative economics will remain a matter of speculation and debate[35].

From this it will be apparent that as well as being pessimistic about the short-term nuclear prospects in the UK, I am very uncertain about how things will evolve in the longer term. The political climate both globally and in the UK will have a considerable impact which I believe will favour nuclear programmes provided the industry maintains a good safety record.

Many of the current "uncertainties" will be resolved - waste management policies will have been determined, an operational "track-record" will have been established and the plants' ability to operate for the design life will have been sufficiently demonstrated.

Whether the UK environment will favour the construction of further Sizewell type plants at Hinkley or elsewhere may be academic in the early years of the next century unless technical alternatives can be designed and demonstrated in the intervening period. Work on such systems is in progress in the UK and elsewhere and the planned policy review in 1994 is likely to consider some of these alongside replicated large plants of UK or overseas design.

I can not see nuclear power becoming the dominant source of electricity in the UK as it has in France until well into the next century, but I remain convinced that the day will come and that the UK will, by the middle of the next century, be reaping the benefits of the fast reactor on a significant scale with its extra benefits in terms of independence from all fuel imports.

I also remain convinced that electricity will be the dominant energy vector of the future with direct fossil-fuel use limited to the few applications where it is unavoidable - but that is another matter.

In conclusion I should point our that these are my personal views and that they do not necessarily correspond with those of AEA Technology or any other sectors of the industry, Government or International Energy agencies with which I am associated.

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THE FUTURE FOR NUCLEAR POWER IN EUROPE

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I would like to split my presentation today into three parts or periods. The first part of my "trilogy" - like all such stories - will set the scene and introduce the main actors as they prepare themselves to meet the challenges the future will put in their way. We then will meet our central character again during the first decade of the next century, but rather than describe the path he takes we will consider what alternative ways he could follow. The future is not yet clearly defined. After another interval we come to the rousing finale when, after battling against great odds and triumphing over adversity, our hero looks forward to a long and happy life. The "hero" of this trilogy is nuclear power.

Book one - now and the next few years

I should add that, although the title of my talk is the future for nuclear power in Europe, the large majority of my comments will concern specifically the European Community. As you know there are many other countries in Europe with nuclear power programmes. For example, there is a substantial - and very successful - nuclear power programme in Sweden producing around 50% of the country's electricity. However, it would take a much braver man than me to forecast its future given the "Swedish dilemma" in the energy sector. Finland also produces about 35% of its electricity from nuclear power and here it is possible that a decision might be taken to extend the nuclear park in the near future.

Several of the countries in Central and Eastern Europe also have important nuclear programmes. There is a very large programme in the USSR (around 60 reactors producing 12% of the countries needs)and nuclear power produces 50% of the electricity in Hungary and around 30% in both Bulgaria and Czechoslovakia. With the exception of Hungary, all the countries have further plants under construction. Poland and Romania are also building nuclear plants. Finally East Germany produced over 10% of its electricity from nuclear power last year - but maybe I should, in future, deal with this as part of the Community.

The situation in Central and Eastern Europe is evolving very fast. It will be an area of vital importance for the future of nuclear power - and nuclear power will be of vital importance to the area. The Commission has a number of important responsibilities in the area and if I have a few moments at the end of my prepared speech I will give you a few personal impressions of the present situation there and what I think could happen in the future.

I will turn now to the European Community.

At the present time, nuclear power accounts for some 35% of electricity production in the European Community. It is the biggest primary energy source used for that purpose, ahead of hard coal (admittedly by a narrow margin). Hence its important role within the Community.

However the Community is made up of twelve Member States. Five Member States of the Community (Denmark, Greece, Ireland, Luxembourg and Portugal) have, in practice, decided from the start not to take up the nuclear option. These countries include nearly all the smaller Member States - a fact which could well have had some influence on their decisions. The electrical output of these States represents less than 6 percent of the output of the Community as a whole and some of them import significant quantities of nuclear electricity. The situation in the other Member States could be described briefly as follows:

In **Belgium** it is now clear that there will be no early decision in favour of building another nuclear station (N8). The utilities recent plan included the construction of an additional nuclear power plant, but the government requested additional economic studies and favors in principle development scenarios which do not call upon more nuclear energy. Natural gas appears to be the preferred option for domestically generated electricity, though importing electricity is an alternative solution. The existing nuclear power stations contributed 61% of the total electricity production in 1989.

In view of the present reserve margin available in **France**, the government has stretched its ordering schedule for nuclear plants. It will likely be stepped up again in a few years when the reserve margin disappears or it is justified by more long-term electricity export contracts. The 55 units coupled to the grid have a combined capacity of 53 GWe. In 1989, these units produced nearly 75% of France's electricity. A further 8 units are under construction (PWR-1300s and PWR-1450s).

In the **Federal Republic of Germany**, nuclear power produced 34% of the electricity in 1989. There are 21 plants in operation but none under construction (if we exclude the fast breeder reactor at Kalkar whose completion is delayed through licencing procedures). There is a general consensus that there will be no immediate follow-up to three nuclear units of the convoy currently entering commercial operation. No new nuclear capacity additions are expected during the next ten years. However, the Government of the Federal Republic has, on several recent occasions, reiterated its position in favour of the continued use of nuclear energy. Also there is the new East German factor to be added into the equation. In the GDR there are five reactors with six more under construction. These use Soviet technology. Two reactors have already been shut down and there are plans to "westernize" the designs of the rest. This is an area of intense activity. It is a very important one - especially given the great demands that will be placed on the energy supply system as the GDR starts to try to catch up the rest of Germany - and the much publizised needs to reduce its terrible pollution problems.

In **Italy**, after Chernobyl, nuclear energy became a hotly debated political issue. Following the referendum of November 1987, a policy calling for a halt of 5 years on nuclear power stations construction has been established. The existing nuclear power stations of Trino and Caorso are presently shut down and it is now planned to convert the plant under construction at Montalto to burn fossil fuels. (Meanwhile over 25 TWh of electricity will continue to be imported each year - mainly of nuclear origin. This represents around 15% of the country's needs. This dependance on imports may be contributing to the small signs of renewed interest in the nuclear option that we are just starting to detect).

In the **Netherlands** , the government and Parliament decided after Chernobyl that it was necessary to reconsider the use of nuclear energy and to carry out first a number of studies. The studies have now been published. The government has yet to formulate a standpoint on the construction of new nuclear power plants. In the meantime, rational use of energy is emphasised in electricity planning, imports of (nuclear) electricity will continue (3.6 TWh in 1987) and the use of natural gas will probably be increased.

In **Spain**, in spite of the fire at Vandellos last year, nuclear contributed over 50 TWh of electricity in 1989 -- representing 38% of all electricity generated. However, there are presently five nuclear station on which work was started but has since been halted. There appears to be little possibilty of work restarting on two of the stations (Lemoniz), though the two 975 MWe reactors at Valdecaballeros and the second plant at Trillo may be required to cover some of the 7-7.5 GWe capacity gap that could open between 1995 and the end of the century.

As far as the **United Kingdom** is concerned, I will note that nuclear power produced 21% of your electricity in 1989 and that Sizewell B is still under construction. Beyond that I would not like to comment other than to add that now that the Commission has authorized - under specified conditions - the "nuclear levy" the programme will continue and we shall watch closely for any new developments.

On the whole, the nuclear capacity in the Community will continue to grow over the next years from the current level of 100 GWe although at a reduced rate. A total of about 110 GWe can be expected for 2000.

In 1985, the Commission published its "Illustrative Nuclear Programme for the Community" in which it proposed industrial and strategic objectives for the development of nuclear energy and made a number of recommendations both to Member States and to companies involved in the nuclear industry. Work is already well underway on a new version of the PINC. In the meantime, the existing report continues to be the basis for the nuclear policy of the Commission.

The PINC - as it is known - set out two objectives, one concerning the nuclear share in electricity generation and the other relating to the fast reactor, and a number of recommendations and observations. For the moment we will leave aside the matter of the fast reactor - we will return to it later - and deal with the nuclear share and its implications.

In a section of the PINC covering the outlook to the year 2000, the report stated that **by 1990 nuclear energy "should account for about 35% of electricity production in the Community"** though it should have done better. The reasons for it not doing better were "uncertainties in the demand for energy and owing to difficulties of various origins, particularly the acceptability of nuclear energy to the public and the conflict between the powers of local authorities and national authorities. Moreover, in certain cases, priority was given to using domestic sources of fossil fuels".

It went on to say that "*In view of the existance of such difficulties, care must be taken not to set too optimistic objectives. It is for this reason that the Commission proposes the adoption of the following lines of development for nuclear energy:*

i) to produce about 40% of Community electricity in 1995, and

ii) subsequently to increase its share in electricity production to 50% around the turn of the century."

We have already achieved the target of 35%. However, when we did our calculations we expected that the Community (which was then 10 Member States) would require 120 GWe of nuclear capacity by 1995 to meet the objective for that year. Now, even with the addition of the nuclear reactors in Spain (following the enlargement of the Community to twelve Member States) we do not expect the installed nuclear capacity to exceed 110 GWe. The main reason for the difference between our latest and our earliest prediction results from the change in the Italian programme, where nearly 11 GWe had been planned by 1995. There have been other less significant changes (in Belgium and the Netherlands) also as a result of Chernobyl. As, at the same time, electricity demand is also growing quicker than we expected, it is likely that the share of nuclear energy in electricity production will tend to stabilize around its present level and may even decline slightly before the end of the century.

Does this then mean that we start our story with gloom and despondency over nuclear apparent failure to meet its objectives? We think not. Some people characterise the next years as "lean years" for nuclear power. To some extent this is true - especially if we compare it to the "years of plenty " of the past decade and more. An alternative view would be to look on them as growth in a different direction. As children grow older they increase most quickly in size in their earlier years. This growth often occurs in spurts and is followed by periods when very little upward growth occurs. However, just because their size is not increasing during these periods it certainly does not mean that they are not "growing up " . On the contrary, they are learning every day new skills, increasing in experience and maturity and becoming more and more integrated into society.

Over the next ten years while nuclear power's "upward growth " in the Community may be relatively slow it will be growing up in other ways. While we may not be bringing many new reactors on line, we will be opening other new nuclear facilities. At the front end of the fuel cycle Spain will increase its uranium production capability, several Member states have recently decided to increase their capacities for fabricating mixed-oxide (MOX) fuel, including the construction of the MELOX facility at Marcoule in France to produce 100 to 120 tonnes per year of MOX fuel by around 1993. URENCO expects to more than double its gas centrifuge enrichment capacity and there is continuing work on isotope enrichment using lasers (SILVA or AVLIS). At the back end of the fuel cycle there will be major expansions to reprocessing capacity in France and the UK as new plants come on stream in the early 1990s. By the end of the century, our reprocessing capacity for light water reactor fuel in the Community will be five times greater than what it is today.

One of the main concerns of the public over the use of nuclear power relates to the disposal of radioactive wastes. As our Member States plan to start disposing of high level radioactive wastes soon after the year 2000, a Community programme of research and development work on disposal concepts for different geological formations is underway. Site characterization - including, in some countries, in situ characterization - continues apace. There is no doubt that a demonstration that HLW can be disposed of safely will do much to relieve the public's concerns - however irrational - over this aspect of nuclear power. For this reason I must particularly regret that the French Governments has had to suspend, for one year, further studies on possible sites. (I mention this to point out the fact that even the French nuclear programme can be subject to negative political interference on occassions!). Finally, a great deal of experience will be gained in the field of decommissioning nuclear facilities as some of the older reactors in France, Germany and the UK are taken out of service.

So what about nuclear's 40% share in electricity generation? Must we shrug our shoulders and hope for better in the future? Maybe not!

Everybody will have heard of the completion of the single market - 1992 and all that! This process is now irreversible. One vital part of this major event is the opening up of the internal energy market. Through the completion of the internal energy market, electricity from nuclear stations could be more widely marketed throughout the Community. The existing reactors, many of which are not used to their full potential, could increase their "load factors" to a figure closer to their expected availability. Electricity production from the existing nuclear park could then increase to make it possible to get closer to - but not achieve - the 1995 objective.

What about the 50% objective for around the turn of the century? Increased utilization of existing plants and those under construction could help us on our way to this target but will not achieve it, especially if electricity demand continues to climb at its present rate. On the other hand, while we must rule out the possibility of any reactors not yet under construction having any impact on the nuclear capacity by 1995, I am not yet ready to do the same for the end of the century. Decisions can be taken and reactors built in less than 10 years. Though, to be realistic, the target is probably too far away for the time that we have left to reach it.

But whether or not we reach or approach 50% of our electricity by nuclear power by 2000 must not be seen as a major preoccupation for the energy sector. That would be like a runner in a 10 000 metres race - or the marathon - trying to break the record for the 1500 metres without thought to the remaining distance. A good start is important - but we already have that. We are not only up with the leaders but out in front. What is needed now is a calm reappraisal of the situation, planning for the future and finally, and most important, decisions.

For the Community we see decisions concerning the opening up of the Internal Market, the decisions to build new capacity or import from neighbours (these must be taken soon in many of our Member States), what fuel to use and, if nuclear is the choice, the standards to which the reactors should be built and the structure of the nuclear industry itself. There are many paths which our hero might take into the next century. Which one will he follow?

At the present time our net electricity production in the Community is around 1,700 TWh/year. We expect this to rise to between 2,000 and 2,400 TWh/year by the year 2000 and to between 2,000 and 2,700 TWh/year by 2010. We could be required to produce at least 50% more electricity in 2010 than we are now - or even more if our figures are under-estimates. How will we do this and what rôle will nuclear power play?

In trying to estimate this, we used a number of different scenarios. These ranged from a so-called "nuclear moratorium" to a "nuclear revival". These terms need a little explaination. The moratorium means different things to different countries so that while some Member States would continue not to build nuclear stations others, such as France, would construct fewer stations than in the past. It is, in fact, a continuation of the situation in which we now find ourself. The "revival" on the other hand does not necessarily mean that all countries would take up or accelerate the move to the nuclear option. The countries without nuclear power now could still be in that situation in 2010.

So what does this mean for nuclear? With a low electricity demand growth and a "moratorium" our forecasters estimated that we could only be producing a little more nuclear electricity in 2010 than we are now. At the other extreme, with "high" electricity demand growth and a nuclear revival we could be producing around twice as much. In other words, depending on the scenario chosen, the amount of electricity generated from nuclear stations may grow very little - or double - in the next twenty years! (Note: In terms of *installed capacities* the range for 2010 is from a low of 117 GWe to a high of 166 GWe).

It is an energy objective of the Community to reduce as much as possible the share of hydrocarbons in the production of electricity. The present objective is to reduce the proportion of electricity generated from hydrocarbons to less than 15% by 1995. This has, in fact, already been achieved. While no objectives have been agreed for the longer term there is no obvious reason to increase hydrocarbon's share, though a relaxing of the Directive limiting the use of natural gas in power stations could bring about some increase.

Given that the possibility of expanding the rôle of large scale hydropower is very limited in Europe and renewables are not likely to make a significant contribution in the time frame, the objective would appear to put the emphasis on solid fuels, in particular coal, and on nuclear power.

This would appear to be well in line with another of the Community's energy objectives - that of increasing the share of solid fuels in energy consumption. However, since the Energy Council agreed these objectives a new player has not only appeared on the sidelines but has been introduced into the game. I refer, of course, to the rapidly growing concern about the environment and, in particular, to the "greenhouse effect".

If we had to identify one single issue which we believe could influence our lives most over the next twenty years, many of us would say growing concern about the environment in which we live . It is something which affects every one of us as we cannot isolate ourselves from it. Not only that, the decisions we take now (and those we have already taken) will affect our children, grandchildren and great-grandchildren for many generations. We've got to get it right!

In our electricity study we estimated emission of SO_2, NO_x and CO_2. We are bringing SO_2 from power stations under control. We do not expect the same progress with NO_x though progress is technically possible. CO_2 is another problem altogether.

The Community presently produces about 2.8 billion tonnes of CO_2/year. Of this total the power generation sector accounts for about 860 million tonnes (30%). This is a smaller share than it was in the past. <u>For example, the quantities of carbon emitted during electricity production in the twelve Member States in 1987 was the same as it was in 1973 - in spite of a close to 50% increase in electricity production</u>. Assuming that we would have burnt coal in place of nuclear power our emissions now would have been over 70% higher than they now are. In the case of using gas in place of nuclear the emissions would have been 25% higher and 50% higher in the case of oil.

In the future, the emissions of CO_2 from power stations could then vary tremendously depending on the scenario followed. For example, we calculated that with a low electricity demand growth and a nuclear revival, the emissions from the power generation sector in 2010 could be around the same level as now. On the other hand, with a high demand growth and a nuclear "moratorium" the emissions from our power stations could rise to over 1.3 billion tonnes by 2010 - and our total emissions of CO_2 to nearly 3.5 billion tonnes each year.

I said earlier that the period 1990-2000 was one of major decisions. Before 2000 much of the capacity that will come on line in the first 10 years of 21st century will already have been planned and under construction. I can see some utilities and governments being drawn to gas, faster and cheaper than nuclear in the construction phase, partly because they are leaving - or have left - too late the decision to build new capacity. They will also be lulled by the soft market for hydrocarbons and the relative environmental benefits of gas. This "benefit" will only be realised if gas-fired capacity is built instead of coal (or oil). It will be a "debit" if it is built instead of nuclear.

Just as nuclear spectacular growth during the 1980s was a result of decisions in the 1970 - and the slower growth in the 1990s follow on from the events of this decade - the major influence on nuclear future in Europe will depend on what is decided in the next few years. Present low fossil fuel prices and lingering doubts in the minds of the public at large following Chernobyl will be balanced, in the decision makers mind, against the concerns over burning ever increasing amounts of fossil fuel and the continuing safe exploitation of a large nuclear park. At a conference in June 1989 I remarked that it would be interesting to see if CHELYABINSK has the same impact on natural gas as Chernobyl had on nuclear power! Even at that time - only days after that gas explosion which killed over 800 people in Russia - many people had not even retained the name. How many of you here think of "Chelyabinsk" when you think of natural gas?

I feel that nuclear may well be approaching a cross-roads in Europe. I also feel that while nuclear power may not double its present level of electricity generation by 2010 - though it still could - it will certainly increase substantially.

Book Three - The nuclear future.

Before I uncover my crystal ball and give you my thoughts on the longer term future, I must tell you something about one particular line of research which we believe will play possibly the major rôle in the long term future of nuclear power. I refer, of course, to the fast reactor.

While the uranium economy of the FBR is not disputed, the reactor type is often perceived as being less safe than water cooled reactors, producing more plutonium and being more expensive. This has led some people to suggest that its introduction, if ever, should at least be delayed until uranium becomes in short supply.

Reactors are only licenced in the Community if their safety is satisfactory. Therefore the FBR and the LWR are equivalent in that they are both safe reactor types. However, there are some differences between the features of the two reactor lines. With the FBR, for instance, of particular importance are the benefits from the point of view of safety of using liquid metal as a coolant. Another important advantage of the FBR is that it is even easier with this reactor to meet the emission limits for release of radioactive effluents to the environment and it also releases less heat. Furthermore, it actually produces less plutonium than an LWR of the same size and much less than a Magnox, an AGR or a heavy water reactor.

The present major drawback to the FBR is its initial capital cost. However, studies carried out with the support of the Commission have already shown that series construction could reduce the cost of building reactors identical to Superphenix by at least 45%. At this price the FBR would still be 50% more expensive than conventional light water reactors so the next step is to look at the actual design of the reactor itself.

Design work on a European Fast Reactor (EFR) started in the Spring of 1988 at the request of the European Fast Reactor Utilities Group (EFRUG) and the companies involved, after a two year conceptual design phase, have started on a three-year detailed design phase. Oganisations and companies from France, FRG and the UK together with organisations from Belgium, Italy and the

Netherlands are participating and both Spain and Switzerland are interested in joining the "club".

This is a major advance. We will now have one fast reactor design which will bring together the best features of the different national designs while reducing duplication of effort and saving on the costs. As you would expect, the Commission strongly supports the objective of a single design European Fast Reactor having advocated this for several years.

So my vision of the post-2010 period sees the fast reactor ready for commercial introduction if not already under construction. Will it have a rôle to play?

At the time of the first oil crisis in 1973, the World's annual primary energy consumption totalled well below 6 billion tonnes of oil equivalent (6 Btoe). The OECD region accounted for well over 60% of this. Consumption has now risen to over 8 Btoe with the OECD share falling to around one-half. By 2010 the World will probably be consuming well over 13 Btoe/year with the fastest growth in demand - by far - being in the lesser developed countries (LDCs). So in 20 years time the LDCs will account for about one-quarter of all energy demand. In the longer term this growth will continue as 95% of the World's increase in population will occur in the developing world over the next 50 years.

These changes are important to the Community, but also to many other countries, for two main reasons. The first is that being a major importer of fossil fuels - by 2010 we will be importing well over 50% of our gas and coal and over 80% of our oil - the Community can be very much affected on the world energy markets. With the rapidly growing demand for energy, we will see increasing competition in world markets for what must be a declining resource base. I am not preaching gloom and doom from the point of view of security of supply. Technically, the resources are such that demand could be covered for many years beyond 2010, but demand will be growing, fossil fuel resources are finite and it is possible that the number of important suppliers will be decreasing. It therefore seems very likely that our energy will - at least - become more expensive.

The second reason is concern about the environment. The large majority of the increasing energy demand will be met by carbon-based fossil fuels. Not only will this mean more CO2 going into the atmosphere but I wonder how many of the developing countries will be able to afford flue gas desulphurisation or selective catalytic reactors to remove SO2 and NOx? As the number of vehicles per capita increases in these countries, how many of the governments will introduce and monitor tight emission control standards? On top of this, there is the impact on global warming of deforestation which so far continues unabated.

We must not try to give the impression that nuclear power can solve the problem. It can't. We must, first of all, learn to produce and use our energy better - certainly more efficiently - to try to reduce the growth in our demand for fossil fuels and try to persuade the developing world to follow our example. However, we will reach a limit as to how far we can go before we start impacting on our economic growth and the lifestyle to which we have become accustomed and that to which many other nations aspire. Here then is the rôle for nuclear power.

While some of us may feel nostalgic about the steam engine and regret its passing, we must admit that the electrification of the railways has given us faster and more efficient transport and much cleaner stations. A candlelight supper for two (prepared on a wood burning stove?) may be very pleasant - but the electric light is much brighter and more convenient on most other occassions! We now take the tremendous benefits of electricity very much for granted - but there are many others who have not yet had this opportunity. It already does a lot for us - but it can and must do more if we are to reduce our dependence on fossil fuels. My vision is of a world increasingly dependent on electricity for its development. However, while we think of electricity as a clean energy source this is only in its use. In its production it can be one of the most polluting - unless we generate it with nuclear power.

So an increasingly "electric" world needs to be a nuclear one. If we expand our nuclear programmes we will need to be certain we can fuel them. Uranium resources - like those for the carbon-based fossil fuels - are finite, certainly at the prices we can afford to pay. However, we see no obvious reason for supply failing to meet any likely level of demand for at least forty or more years. Though, if I was to be responsible taking the decision to build a new reactor in 2010 - a time around which many such decisions will have to be taken if only to replace our existing park - and this reactor, once built, would have a life of 40 years, would I be as confident of my fuel supply? Remember, nuclear power may be expanding rapidly and those countries without fast reactor technology could be limited to using the conventional - inefficient from the point of view of uranium consumption - reactor lines.

The fast reactor may be needed to keep the demand for uranium at a level which could be met by supply for a much longer period of time - possibly hundreds of years. Without the fast reactor the nuclear star - the hero of our story - could burn very brightly but become extinct far too soon.

LOW IMPACT ELECTRICITY SERVICES - an environmentally sound policy for the future provision of electricity services

by Mark Barrett
Consultant with Earth Resources Research

INTRODUCTION

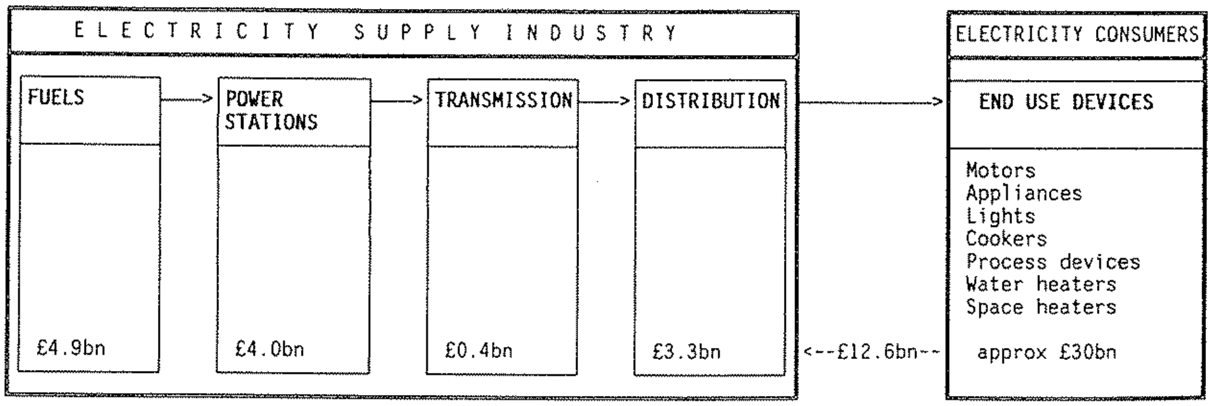
This paper summarises a piece of work in which economically and environmentally sound strategies for the provision of electricity services are constructed. This work was sponsored by Greenpeace and will be published shortly under the title **Green Light for the Future.**

ELECTRICITY SERVICES

Electricity itself is not useful and we have no need for it. Consumers have to put electricity through some end use device such as a refrigerator or a light in order to provide the service (food preservation or lighting) which they want or need. This combination of delivered electricity and end-use devices produces what can be called **electricity services.**

A complex and lengthy chain of technologies and resources is employed in the provision of these services. This is shown schematically in Figure 1 below. We see that in 1988 the total cost of delivering electricity was some £12.6 billion. This however was exceeded by the investment by consumers of some £30 billion made in electrical devices and equipment. Domestic consumers alone spent about £7 billion on white goods and other electrical equipment. Thus electricity supply accounted for only about 30% of the total cost of services.

Figure 1 The Electricity Service System



Note : Numbers are approximate investment in 1988 in £billion

CONSTRAINTS ON THE ELECTRICITY SERVICE SYSTEM

Security

Consumers wish to have their services provided with some level of security: the level of security that is acceptable depends on the consumer and the service. In current practice the most used security standard in the electricity service system relates to the technical matter of providing adequate generating capacity and reliability to meet uncertain demands. This level is currently known as the 9% security standard and ensures that electricity supplies are interrupted at winter peak in at most nine years in every hundred. Using the 9% standard, a planning margin of 19% is calculated. This planning margin takes account of three separate factors. These are: uncertainties in forecasting; winter peak availability of plant; and variability in weather forecasting.

Environmental constraints

The following environmental targets were set:

(1) **Acid emission abatement targets:**

- (a) sulphur dioxide emissions to be reduced by 90% of 1980 levels before the year 2000 and
- (b) nitrogen oxide (NO_x) emissions to be reduced by 75% of 1980 levels before the year 2000;

(2) **All nuclear power installations and nuclear power imports to be phased out within a 4 year timetable;**

(3) **Reduction in the emission of carbon dioxide** from UK sources by 30% of current (taken as 1988) levels by the year 2005.

Economic constraint

The strategies are such that the cost of meeting security and environmental constraints will not add more than 10% to the costs of electricity service. That is to say not more than 10% above what <u>the costs would otherwise be</u> in an 'orthodox' scenario in which environmental standards are lower.

A GENERAL APPROACH

The approach was to minimise the costs of service within the environmental and other constraints set. Five scenarios were constructed with the first being the 'orthodox' scenario. In the scenarios use was made of the following technical options:

i) Electricity conservation;
ii) Retrofit pollution control;
iii) Renewable electricity sources;
iv) Combined heat and power;
v) Natural gas generation.

PREVENTION OR CURE?

All energy supply technologies have their environmental impacts, and those supplying electricity are no exception. Nuclear stations produce long lived radioactive waste, fossil stations produce acid emissions and carbon dioxide, and renewable energy technologies have various direct physical and visual impacts. Technologies which increase the efficiency of use of electricity do not, if properly implemented, have significant adverse impacts.

The origin of the environmental impact of electricity supply is electricity demand. The less the demand the less the environmental impact at all stages upstream in the electricity service chain. Reducing demand diminishes the need to make invidious choices between acid and CO_2 emissions from fossil fuels, nuclear waste or the various impacts of renewable energy sources. We can use the example of an average domestic freezer to relate demand to its ultimate impact. During its life the freezer brings about the emission of 7 tonnes of CO_2, the formation of the equivalent of 150 kg of concentrated sulphuric acid and 40 kg of concentrated nitric acid, and the production of 0.8, 0.2 and 0.006 litres respectively of low,intermediate and high level radioactive waste.

Curative options, where they exist, often suppress a primary pollutant at the expense of creating different, albeit less damaging, impacts. For example, Flue Gas Desulphurisation removes acidic gases prior to emission to the atmosphere, but in so doing brings about other impacts such as limestone mining and the formation of chemical wastes such as gypsum sludge. For other pollutants, such as nuclear waste, there is no cure, only the isolation of these materials from the biosphere for (hopefully) very long time periods.

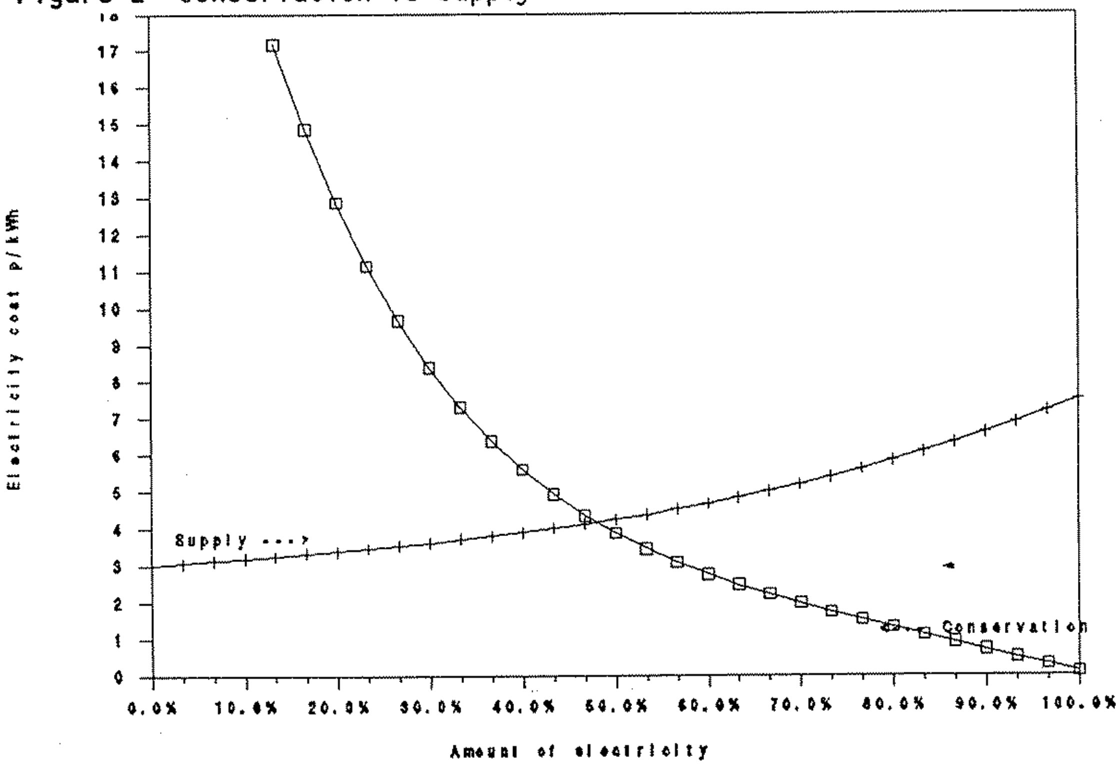
Demand management and reduction through cost-effective energy efficiency and conservation are therefore the key elements in an environmentally sound strategy for the provision of electricity services.

ECONOMIC METHODOLOGY

Investment is needed at all stages in the electricity service chain, and almost all of this investment comes ultimately from electricity consumers. They pay for the fuels, the power stations, the transmission and distribution network, and the end use devices from which they ultimately derive a useful service. The electricity service chain can usefully be divided into two parts. First there is supply, which is all links up to the point of delivery of electricity to the consumer (called the Electricity Supply Industry in the Figure above). Second there is demand, which is all links beyond the point of delivery and typically consists of a single device using electricity and providing a service.

A principal aim of consumers is to minimise the costs of the services they purchase. Schematic marginal cost curves for conservation and supply are shown in Figure 2.

Figure 2 Conservation vs Supply



At some point the marginal cost of conservation equals that of supply: this occurs at an electricity supply of about 50% (or 125 TWh for the UK) in the illustrative graph of Figure 2. This point represents the minimum cost of providing a given level of electricity service. The area between the two curves to the right of the crossover point represents the cost savings accrued through that optimum level of conservation.

SOME RESULTS

Figure 3 shows electricity demand for each of five cases. Zero cost energy efficiency (case B) brings about the stabilisation of demand at a level some 40 TWh less than base. In cases C,D and E electricity demand is reduced by 47%, 53% and 58% respectively by 2015.

Figure 3 Demand : Five Cases

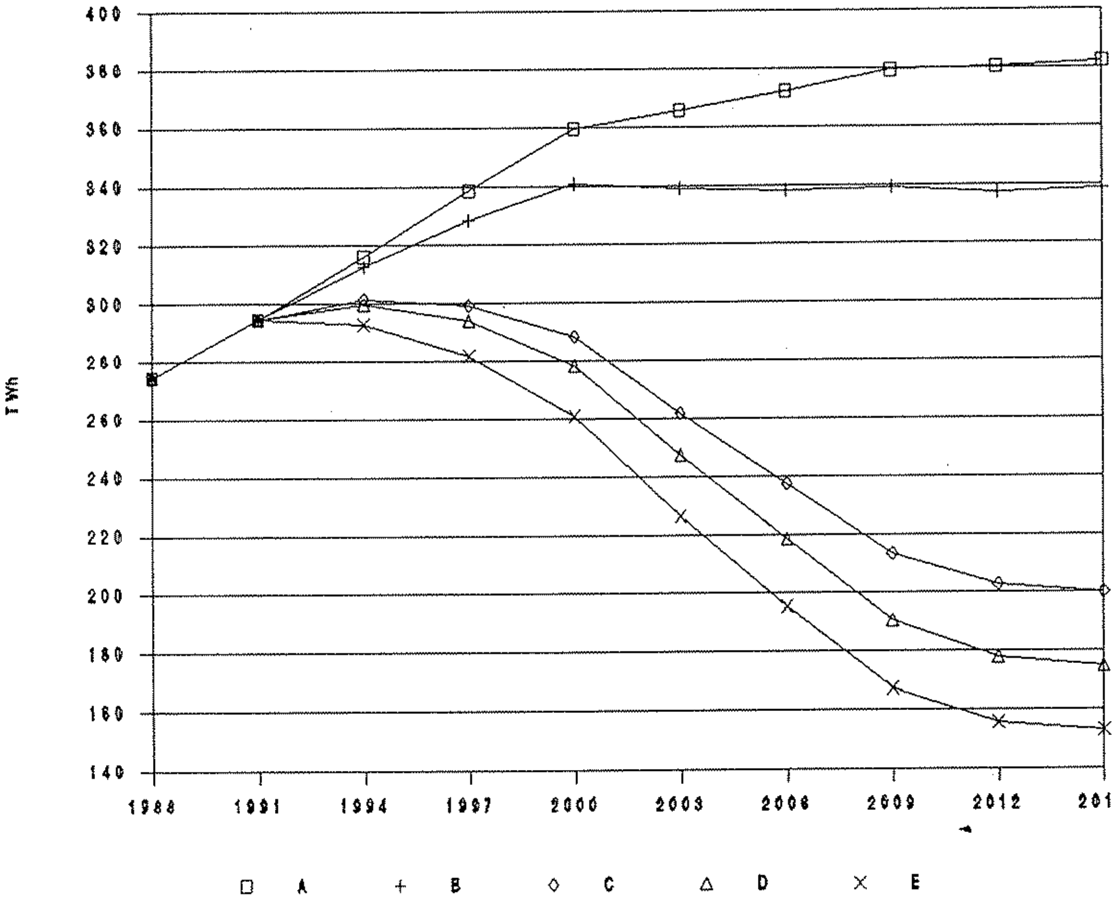
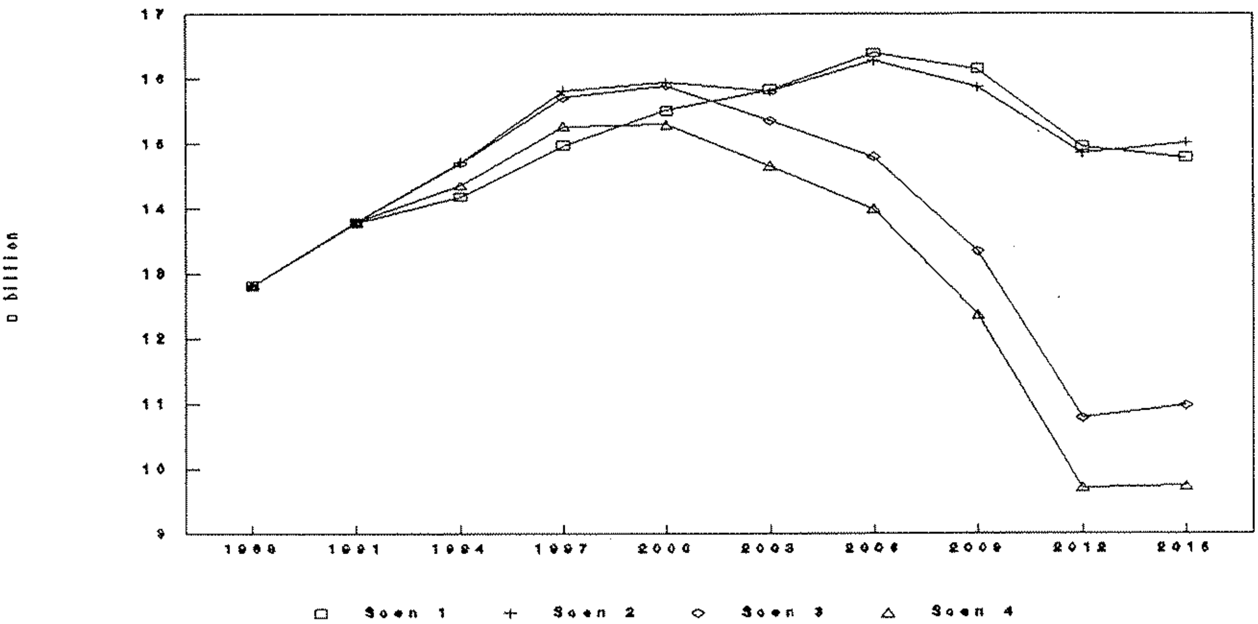


Figure 4 shows the total cost of service for four scenarios. In Scenario 1, the base case, we see total costs rising as demand increases and investments are made in new capacity. Total costs rise to nearly £16.5 billion in 2008 after which we see costs diminishing and levelling off at about £15 billion. This is due to a balance of various factors: the rate of demand growth is assumed to fall; much of the UK's ageing power station stock will have been replaced and the increasing thermal efficiency of new power stations limits fuel costs.

Figure 4 Electricity Service Costs (1988 - 2015)



It is evident from Figure 4 that the annuitised system costs for the environmentally constrained scenarios (2-4) are higher than those for the 'business as usual' scenario during the first ten years of the scenario period. This is largely due to the nuclear phase out which induces additional investment in new plant and earlier nuclear decommissioning. There is an additional cost burden due to investment in the new, cleaner technology required to meet the emission reduction targets. However, even in these early years, which are the most difficult from our perspective, we stay within our cost criterion (no more than 10% extra cost) set by Greenpeace.

In later years Scenario 2 has a service cost similar to Scenario 1. The extra costs in the early years are not balanced by later cost savings because the demand reduction defrays only a small part of extra capacity need.

Scenarios 3 and 4 demonstrate different cost trajectories over the later period of the scenarios. These scenarios diverge markedly from the orthodox scenarios as cheap energy efficiency measures displace capacity investments and fuel costs. In the early years, costs are higher than for Scenario 1, but by 2015 the total cost of service is some £4 and £5 billion less than the reference case for scenarios 3 and 4 respectively. This represents cost savings to consumers of some 30% of the total service cost calculated here.

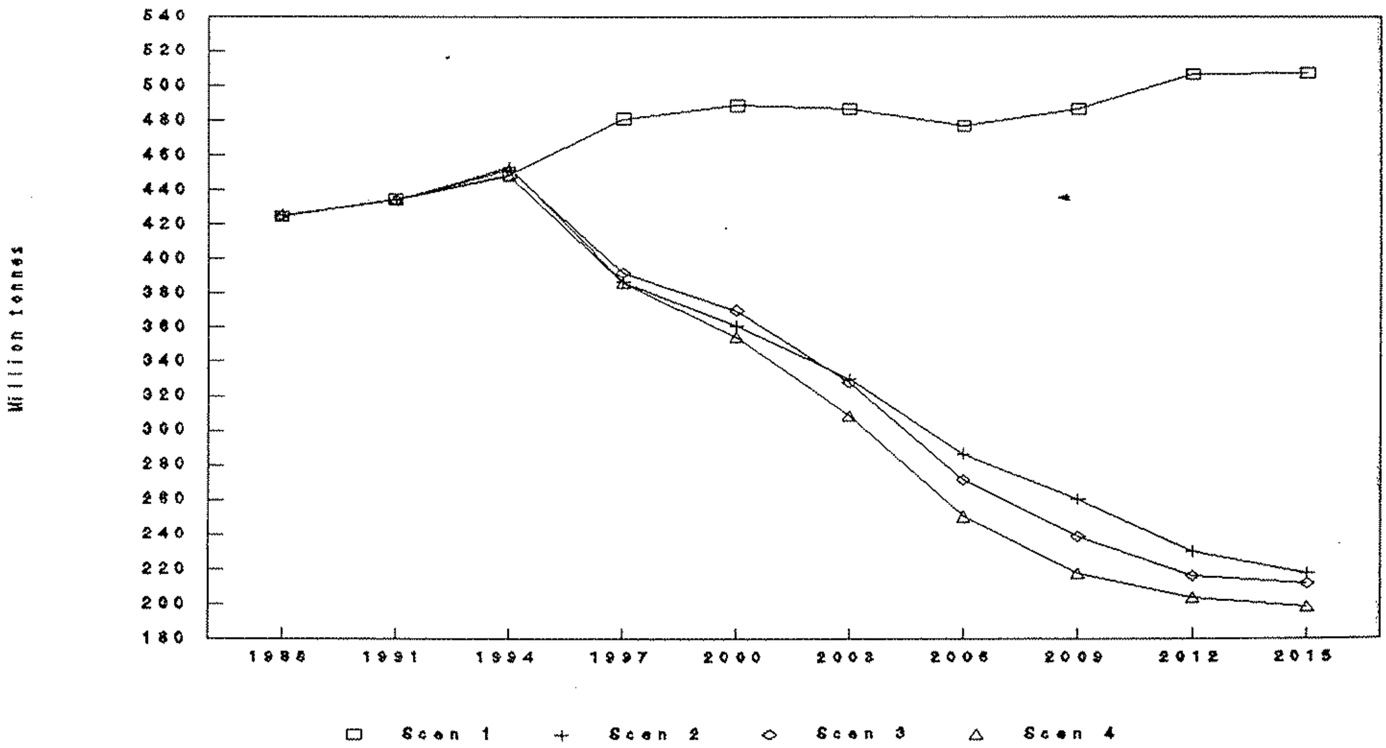
Towards 2015 the total cost of service increases in Scenarios 3 and 4 as the full potential for energy efficiency is realised. However, the difference in costs between these and the orthodox scenario remain.

Carbon dioxide emissions from the four scenarios are summarised in Figure 5. It is immediately apparent that there is a large difference between scenario 1, in which no demand reduction takes place in the electricity sector (although demand reductions are assumed within the non-electricity sectors) and supply side measures are more or less traditional, and the environmentally constrained scenarios.

If even lower targets for reduction are to be achieved over the next few years, some at least of the measures introduced in scenarios 2 to 4 are going to have to be adopted within the electricity sector.

It is not suggested that the levels achieved within the environmentally constrained scenarios represent limits to CO_2 savings in the energy sector. Indeed, the construction of gas, or possibly oil, fired combined heat and power plant in place of coal plant which are built during the last few years of the scenarios would reduce CO_2 emissions quite substantially on the levels achieved in this study. Of course such a strategy would depend not only on the availability of appropriate heat loads but also on the desirability of further decreasing the use of coal.

Figure 5 Carbon Dioxide Emissions (1998 - 2015) - excluding Transport



CONCLUSIONS

The scenarios show that large increases in the provision of electricity services can be accommodated whilst meeting tight economic and environmental constraints. The widespread use of cheap, simple and safe electricity conservation measures is the keystone to the strategies advanced here. These technologies considerably mitigate the need to choose between problematic alternatives such as CO_2 emitting fossil stations or nuclear power. It seems clear that the provision of electricity services can be economically maintained even with a four year phase out of nuclear power.

It is generally agreed that, for the foreseeable future, in narrow terms nuclear power is not economic against many other fossil and renewable electricity sources. The hope of the nuclear industry has been that environmental considerations, especially the greenhouse effect, would weigh in as an externality and alter the balance in favour of nuclear power. However, the study reported here shows in detail that within a comprehensive electricity service strategy, the economic role of nuclear power should be non-existent or small for the next few decades at least.