IN-SITU DECOMMISSIONING - YOU CAN TAKE IT OR LEAVE IT

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ABSTRACT

Faced with a very significant future liability for the cost of decommissioning its thirteen gas-cooled nuclear power stations Nuclear Electric has been reviewing its decommissioning strategy. This has hitherto been based on early partial dismantling with clearance to a green-field site after about 100 years. The main objective of the review has been to reduce the liability while still achieving the objectives of decommissioning. The review took into account all relevant factors including costs, safety and waste management and concludes that an alternative decommissioning strategy based on the deferral or even the avoidance of major dismantling looks very attractive to Nuclear Electric. This paper describes the background to the review, the review itself and the conclusions. It should be pointed out that the conclusions are specific to Nuclear Electric's gas-cooled power stations and do not necessarily apply to other nuclear plant on other sites.

INTRODUCTION

Decommissioning, in the context of nuclear power stations, is a word that is often misunderstood by many people. It is largely the nuclear industry's fault because we have used the word to mean different things at different times. It does not appear in most dictionaries and the nearest one can get to a definition is to assume that it means the opposite of commissioning - defined as "to prepare for active service" (in the naval sense) or "to bring into operation" (in the machine or equipment sense). Strictly speaking, decommissioning a nuclear power station should therefore mean taking out of operation. In that sense, many plants have already been decommissioned even though they may not have been dismantled. However, the nuclear industry has used the word decommissioning to include also the dismantling of the plant after taking it out of operation. That is, perhaps, unfortunate since, as this paper describes, there may well be alternative ways of achieving the objectives of decommissioning without totally dismantling a plant and leaving a green-field site.

Faced with a very significant future liability for the cost of decommissioning its thirteen gas-cooled nuclear power stations Nuclear Electric has been reviewing its decommissioning strategy. This has hitherto been based on early partial dismantling with clearance to a green-field site after about 100 years. The main objective of the review has been to reduce the liability while still achieving the objectives of decommissioning. The review took into account all relevant factors including costs, safety and waste management and concludes that an alternative decommissioning strategy based on the deferral or even the avoidance of major dismantling looks very attractive to Nuclear Electric. This paper describes the background to the review, the review itself and the conclusions. It should be pointed out that the conclusions are specific to Nuclear Electric's gas-cooled power stations and do not necessarily apply to other nuclear plant on other sites.

BACKGROUND

Decommissioning Objectives

The main objectives of decommissioning a nuclear plant, and, in particular, a nuclear power station can be stated as:

(i) to ensure the continued safety of the public, the workforce and the environment

(ii) to minimise the environmental and visual impact of he station

(iii) to release land for other use as appropriate and

(iv) consistent with the above, to minimise the expenditure of national resources on decommissioning.

The first of these objectives is, of course, obligatory for all times into the future. The remainder are, in comparison, of secondary importance. It could be argued, however, that insufficient attention has been given to the fourth objective and this has led to higher than necessary decommissioning cost estimates in some cases.

Reference Decommissioning Strategy

The Nuclear Electric Reference Decommissioning Strategy has been developed over the last decade and is a three stage strategy culminating in clearance of the site 100 years or so after station shutdown. Stage 1 commences at shutdown and essentially involves only defuelling of the reactors and dispatch of the fuel from the site for reprocessing. This may take up to 5 years to complete and removes 99.9% of the radioactivity from the site. Almost all of the remaining activity is in the form of activated steel and graphite and is thus physically and chemically stable and immobile. The station in this stage thus presents an extremely low potential risk to the public.

Stage 2 then commences and involves the dismantling of all active and non-active plant and buildings on the site outwith the biological shields of the reactors. During this stage all active wastes are packaged and disposed of offsite provided a disposal facility is available at that time. The reactors are sealed within their biological shields. This stage takes about 5 years to complete and releases the rest of the site for re-use.

There then follows a period of surveillance and security of the reactor blocks and this could extend to about 100 years after shutdown of the power station.

Stage 3 then follows in which, over about 10 years, the site is cleared to "green-field" status, the reactors having been dismantled completely and all radioactive material having been disposed of offsite. The justification for Stage 3 being deferred for about 100 years is well established being based on the decay of the radioactivity in the reactors and the consequential ability to safely gain man access which eases the dismantling of the reactors.

Cost/Liability

In 1989 the detailed cost estimates for decommissioning a typical Magnox station were as follows:

	£ million	($US million)
Stage 1	60	(120)
Stage 2	110	(220)
Surveillance (90 years)	60	(120)
Stage 3	370	(740)
Total	600	(1200)

It should be noted that the above costs are undiscounted and in 1989 money. Discounting at a net rate of 2% per annum back to the date of station shutdown reduces the total to about £250 million ($US 500 million) and it is on this basis that decommissioning provisions are set aside in the Company accounts. These figures include about 25% contingencies and risk margins. The estimated cost for AGR decommissioning is similar to that for Magnox stations and for 8 Magnox and 5 AGRs the total discounted liability amounted at the end of 1989 to some £3000 million ($US 6 billion). In 1990 money this is about £3200 million ($US 6.4 billion)but still only represents less than 5% of the generating cost of electricity at these stations. Nevertheless, this is a considerable liability and there is a significant incentive to reduce it. Hence the comprehensive strategy review initiated by Nuclear Electric in 1990.

STRATEGY REVIEW

A breakdown of the £3000 million ($US 6 billion) liability shows that £1800 million ($US 3.6 billion) is attributable to Magnox stations and £1200 million ($US 2.4 billion) to AGRs. Figure 1 illustrates the contribution from the different stages of decommissioning and it is by reference to this that the scope for cost reductions can be identified.

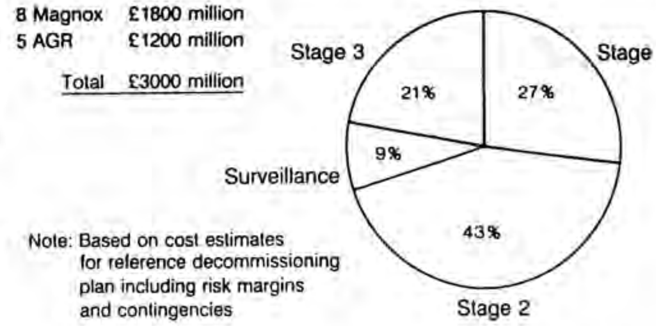

Fig. 1. Nuclear Electric decommissioning liabilities discounted to shutdown of each station (1989 mv).

Stage 1 accounts for 27% of the total and is essentially the cost of manpower on the stations during defuelling which is assumed to take 5 years. Although the necessary site specific work has not yet been done it is likely that significant savings could be made by shortening the defuelling time, e.g. to 3 years.

Stage 2 accounts for 43% of the total and is mostly the cost of contracted manpower for dismantling operations. The reference strategy assumes this Stage, and hence the spend, commences 5 years after shutdown. However, there is no overriding reason why this Stage should not be deferred provided safety is maintained. This would have the advantage of reducing the discounted cost (the liability) provided the net return from discounting exceeds the annual cost of maintaining the site, etc. Figure 2 illustrates the

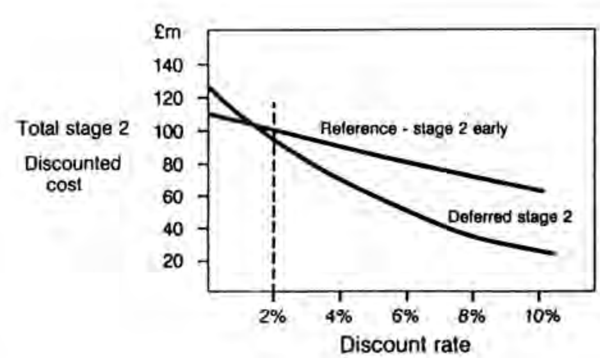

Fig. 2. Effect on costs of deferring stage 2 decommissioning by 30 years.

effect for a Magnox station and shows that, at discount rates above about 1.5% there is financial benefit in deferring Stage 2. It is considered that the most appropriate annual discount rate to apply in Nuclear Electric's particular circumstances is 4% for the next 30 years, 3% for the following 30 years and 2% thereafter. It should be stressed that these rates are used solely for the purpose of the strategy study and not for determining provisions, for which a more prudent rate of 2% is used. Deferral of Stage 2 is thus an option included in the review.

Whenever Stage 2 is carried out, similar deferral advantages apply to Stage 3 which, in the Reference Strategy, is carried out at 100 years following shutdown. There are, in fact, good technical reasons for carrying out Stage 3 after 135 years based on radiological considerations. This is illustrated in Figs. 3 and 4 which are self-explanatory.

In addition to the scope for reducing costs as noted above there was also scope for reducing the contingencies and risk margins by carrying out more detailed engineering studies and reducing the uncertainties. This was therefore included in the review.

The above considerations represent, essentially, optimisation of the Reference Strategy with only limited scope for reducing the decommissioning liability. It was therefore decided to examine all possible approaches to achieving the objectives of decommissioning. From the many, sometimes quite radical, approaches examined, two came forward as being worthy of inclusion in the review alongside the dismantling strategies mentioned earlier. The first is an alternative to Stage 2 dismantling and is essentially the cocoonment or containment of the active plant and buildings on the site in such a way that they can then be left,

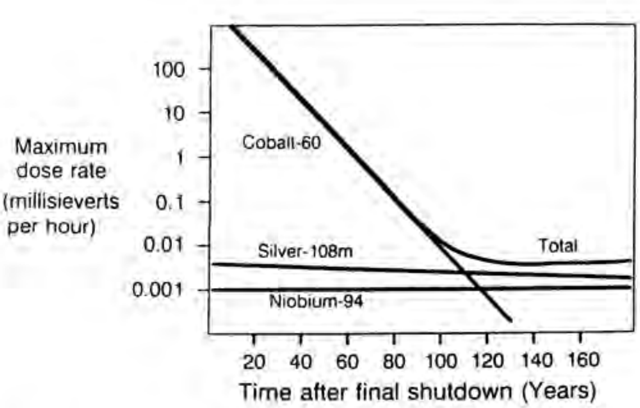

Fig. 3. Reduction of dose-rate with time inside a typical Magnox reactor.

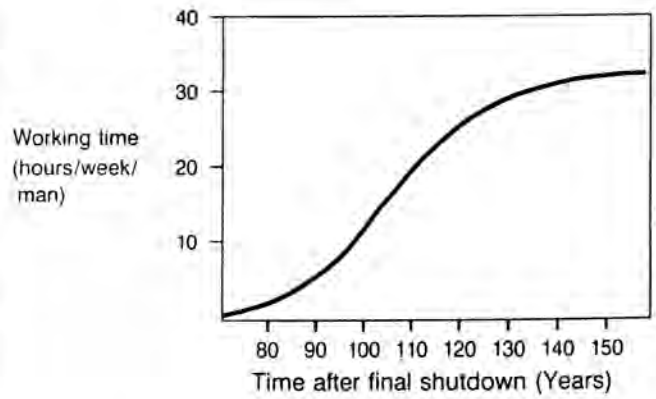

Fig. 4. Working time inside a Magnox reactor for dismantling based on an annual exposure of 5 mSv.

maintenance free, for a period of about 100 years before dismantling. This approach is referred to as the "Safestore" and, as with Stage 2, could be carried out early or deferred.

The second alternative approach we refer to as "In-situ" decommissioning. This involves engineering a stable mound over the buildings and, in effect, burying them albeit above ground. This could be carried out as an alternative to Stage 3 or as an alternative to Stages 2 and 3. Of course, the safety case for such a proposal must address all possible pathways for public exposure into the far future since it is essentially a surface radioactive waste repository. Although it is probable that such a safety case could be made for some Nuclear Electric stations it may not be possible for certain others. All voids would be filled during construction of the mound which would largely be formed by pumping sand from the local seabed or river. Although the cost of In-situ decommissioning would not be low it would be only a fraction of the cost of dismantling and hence is worth serious consideration in the strategy review.

All the above options and combinations of options have therefore been studied in our review by carrying out a detailed "Best Practicable Environmental Option" analysis using standard decision analysis techniques. The model and the results are summarised in the following Sections.

DECISION ANALYSIS

Model

The decision analysis methodology employed was based on amulti-attribute utility analysis using the HIVIEW program. This methodology is a useful tool for imposing

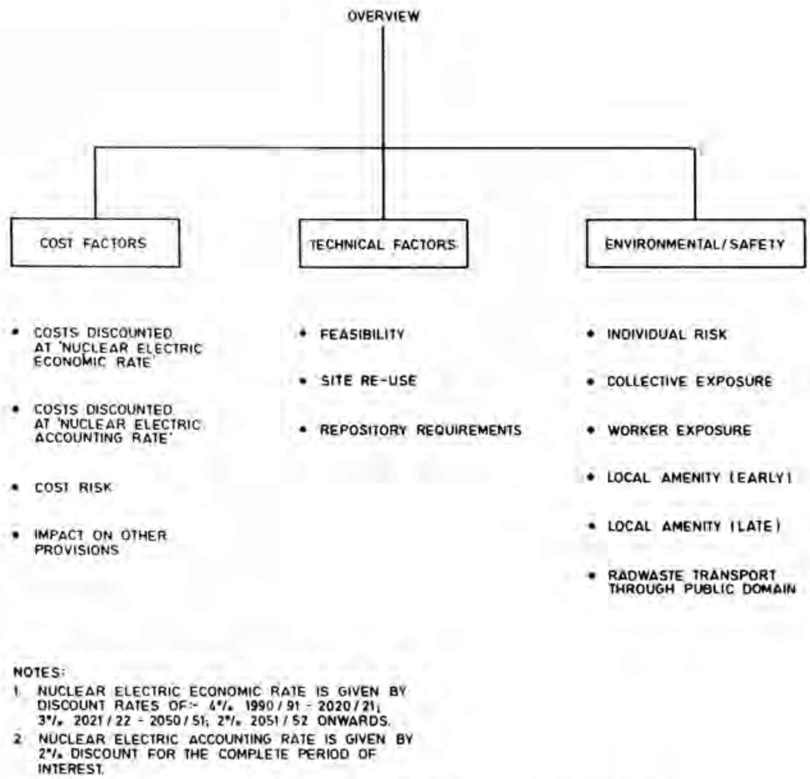

Fig. 5. Multivariate decision analysis model.

discipline and dictating a reasoned choice between the advantages and disadvantages of the various options; it was regarded as a tool rather than the final arbiter of choice. The analysis model is shown in Fig. 5. The impact parameters chosen were regarded as the key factors upon which a choice of strategy should be made and fall into three groups - cost, technical and environmental/safety factors.

Cost Factors

The most important cost factor is the discounted cost of each of the options. As mentioned earlier, discount rates of 4%, 3% and 2% over the periods up to 2020, on to 2050 and beyond that respectively are considered appropriate for determining the best overall strategy from an economic appraisal point of view. However, the discount rate to be used in determining provisions must necessarily be prudent and is assumed to be 2% per annum at all times and so the discounted cost of each option on this basis was also included as a parameter. Other cost factors were included to reflect the degree of financial risk and the impact on other provisions that are associated with each option.

Technical Factors

The important parameters included were the technical feasibility, the impact on the future re-use of the sites and the degree to which each option relied on a waste disposal facility being available.

Environmental/Safety Factors

Environmental parameters included the local amenity (e.g. visual impact and heavy transport requirements) and the requirements for radioactive transport through the public domain. These parameters were considered for times in the near future and in the distant future. Safety factors included individual risk, collective public exposure and exposure of the workforce. The individual risk was derived taking into account all possible public exposure pathways including groundwater transport, intrusion and other dispersion processes followed by direct radiation or inhalation or ingestion of radioactive material.

Input Data

Input data were generated on costs and radiological safety for four specific power stations representative of all the gas-cooled stations. These were broken down in such a way that the discounted costs and safety impacts of nine discreet alternative decommissioning strategies for each station could be derived. These nine strategies covered the range from the original Reference Strategy to In-situ Decommissioning at 35 years. Intermediate strategies included early and deferred Stage 2 dismantling, or early and deferred Safestore, each combined with Stage 3 dismantling or In-situ Decommissioning at 135 years. Qualitative values were ascribed for the other input parameters and weightings derived for all parameters using a range of expertise in a "decision conference" before the outcome scores for each of the nine strategies could be evaluated. Sensitivity analyses were also carried out in order to determine the robustness of the analysis. These included varying such things as the input costs, the discount rates and the weightings ascribed to the different parameters.

RESULTS

The clear outcome of the analysis and the sensitivity studies was that Safestore followed at 135 years by dismantling is an attractive strategy for Nuclear Electric power station decommissioning. The timing of construction of the Safestore did not appear to be critical between doing it early or at 35 years. However, cash flow considerations lead to a strong preference for deferring it to 35 years after station shutdown. Such a strategy also leaves open the option to build the Safestore or change to another strategy at any time up to 35 years. The In-situ strategy options did not score higher than the dismantling one because of the uncertainty of being able to make the detailed safety case at this time - a factor that may change in the future when more studies have been carried out. For this reason, and because, if the safety case can be made, the In-situ option becomes by far the most attractive one, it is considered highly desirable to retain this option as well as eventual dismantling. Thus the alternative decommissioning strategy for Nuclear Electric stations would be as follows:

	Time (year)
Reactor shutdown	0
Stage 1 (defuelling)	0 - 5
Prepare for surveillance period	5 - 6
Surveillance period	6 - 35
Construct Safestore	35 - 36
Second surveillance period	36 - 135
Stage 3 dismantling/site clearance OR In-situ decommissioning	about 135

In view of the uncertainty about whether In-situ decommissioning could eventually be carried out it would clearly be prudent to make financial provisions for the more expensive option of eventual dismantling. This would mean that, if a decision is made in the future to adopt In-situ decommissioning, significant provisions could be released for other purposes.

As a result of the review, the estimated cost and liability associated with decommissioning the thirteen power stations could be significantly reduced. If this alternative strategy is adopted as Company policy for all stations the £3200 million ($US 6.4 billion) liability would reduce to about £2000 million ($US 4 billion). This means that annual provisions could also be significantly reduced to the benefit of the profit/loss accounts of the Company and hence to the electricity consumers. As mentioned earlier, the avoidance of the major expenditure on early Stage 2 dismantling would also be of significant benefit in cash flow terms.

A further advantage of the alternative strategy over the Reference strategy is that it would avoid the generation of significant volumes of decommissioning radioactive waste which, instead, would be stored on the power station sites in the plant where significant radioactive decay would take place prior to eventual dismantling (or In-situ decommissioning).

CONCLUSIONS

An extensive review of the Nuclear Electric decommissioning strategy has been carried out with a view to reducing the financial liability for the Company's thirteen gas-cooled nuclear power stations in England and Wales. It is concluded that the existing Reference Strategy based on early partial dismantling and eventual clearance of the site at 100 years after shtudown is not the optimum strategy. Significant financial benefits can be gained by adopting instead a strategy based on constructing Safestores to contain active plant and buildings at 35 years after shutdown and eventual site clearance at 135 years. Further significant financial benefit could be gained in the future by adopting In-situ Decommissioning instead of dismantling provided the safety case for such an option can be made. Although this may be possible at some sites it may not be at others and further work will be needed to establish this. This change in decommissioning strategy to the Deferred Safestore Strategy is currently under consideration by Nuclear Electric.