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Regulatory Trends and Practices Related to Nuclear Reactor Decommissioning

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1. OVERVIEW

In the next several decades, the electric utility industry will be faced with the retirement of 50,000 megawatts (mW) of nuclear capacity. Responsibility for the financial and technical burdens this activity entails has been delegated to the utilities operating the reactors. However, the operators will have to perform the tasks of reactor decommissioning[1] within the regulatory environment dictated by federal, state and local regulations. The purpose of this paper is to highlight some of the current and likely[2] trends in regulations and regulatory practices that will significantly affect the costs, technical alternatives and financing schemes encountered by the electric utilities and their customers.

There are three characteristics of reactor decommissioning that make it an important regulatory issue. The first, and most obvious, is the public health and safety considerations that result from the decontamination, dismantlement and disposal of retired power reactors. In addition to satisfying the NRC, the operator may have to accommodate state and local regulations[3] that address the control of activities which involve radioactive materials.

The second characteristic is it potentially involves more than one generation of ratepayers. Since several generations will benefit from the plant, some scheme must be devised to distribute the cost such that fairness is preserved across customers. The length of time before the site is restored to a status of unrestricted use is dependent upon which technical alternative is selected. In addition, the local community will forego the benefits derived from some alternative use of the site.

Third, uncertainty is prevalent in many of the significant aspects of reactor decommissioning. Since appropriate insurance mechanisms do not exist at this time, and may not become available, regulation is one way of obtaining a strategy to follow under uncertainty. Although the expected useful life of the reactor may be known with some confidence, there remains the possibility that the decommissioning will be required much sooner than expected. Three Mile Island unit 2 is a case in point. A second area of uncertainty is the fund's earning over time. A third factor is the cost uncertainty of the decommissioning estimate. And finally, the sum of the payments to the fund or collection of the total cost at one time is uncertain due to demand uncertainty.

A major premise of this research is that the regulations, practices, and public reactions that develop from concern over the decommissioning activity will be the significant determinants of the ultimate decommissioning costs experienced by the utilities. The rationale of prior approaches is that decommissioning costs can be adequately predicted from technical or engineering relationships.

In the next section, the decommissioning problem is discussed in terms of the two major decisions it presents for utilities and their regulators. The third section discusses the approach used in the research. Trends are presented in the fourth section, where actual decommissioning cost estimates are also presented to indicate current expectations. A numerical example is provided in the last section to illustrate the financial implications of some of the identified trends.

2. THE DECOMMISSIONING PROBLEM

An economic analysis of the decommissioning problem requires that at a minimum, two interdependent issues are addressed. These are: (1) the choice of the appropriate technical mode and (2) the choice of the appropriate financing arrangement. The financial and regulatory consequences of the decommissioning activity are ultimately tied to how these issues are resolved. General criteria are used to assess an option's ability to meet the regulatory concerns generated by either the technical or financing problems.[4]

2.1 The Technical Decision

In the Draft Environmental Impact Statement (DGEIS) prepared by the NRC (U.S. NRC 1981), three objectives are stressed which directly affect the desirability of technical alternatives. They are: timeliness, planning, and residual radioactivity levels.

Timeliness is a preferred characteristic since it avoids the problems associated with the accumulation of unproductive nuclear sites. However, the NRC recognizes that delaying the completion of decommissioning may be beneficial if occupational radiation doses and nuclear waste are reduced over time. The report recommends that the maximum delay for a power reactor, even for the special circumstances of phased decommissioning at a multi-unit site, not exceed thirty years.

Planning is important because it provides a means of reducing future adverse effects on health and safety. Planning also allows the operator to recognize site-specific factors and make decisions accordingly. More importantly, an active decommissioning planning process is seen as being more adaptable to changes in technological and cost parameters. Options which are well defined in terms of their technical and financial requirements are easier to incorporate into current operating and planning decisions since they involve less uncertainty.

The residual radioactivity level resulting from a decommissioning option, as well as the interim occupational exposure during the process, is an obvious consideration in the technical decision. Residual levels required to release the property for unrestricted use are currently being evaluated by the Environmental Protection Agency (EPA) and the NRC.

Four general options encompass the majority of currently viable technical options. These are: safe storage, entombment, prompt dismantlement, and conversion to a new nuclear or fossil fuel system.5

Safe storage means that the facility is taken out of service but the structures of the site are left intact. Safe storage entails three activities: preparation, continuing care, and deferred dismantling. Different methods of safe storage are distinguished by their requirements for preparation, which is to some degree a substitute for the continuing care functions, that is, surveillance and maintenance.

An in-place entombment technique requires that the property is encased and maintained in a structural material such as concrete. The structure must be of adequate durability to provide assurance that the entombed radioactive materials can decay without being disturbed. In many respects, entombment necessitates activities similar to safe storage, however, the annual continuing-care costs tend to be much lower while preparation costs are estimated to be about 33% higher.

The removal of radioactive components and dismantling of the facility shortly after cessation of operations is termed prompt dismantlement. All radioactive materials above the level permitted for unrestricted use of the site are removed. Dismantling of the facility will require the decontamination, removal, packaging, shipping, and burial of the radioactive components.

Conversion to a new nuclear or fossil fuel system is an option mentioned in Regulatory Guide 1.86, however, it does not appear as an alternative in the DGEIS. One approach using this method employs the existing turbine system with a new steam supply system. Thus, the original nuclear steam supply system is decommissioned, and the site is re-employed. Another approach refurbishes the original facility to extend its operating life beyond that contracted for in the operating license. Either conversion approach is, however, very uncertain since the NRC has not established regulatory standards to outline the requirements of this alternative.

2.2 The Financing Decision

In general, there are four criteria which are used to evaluate different financing arrangements and their effectiveness in demonstrating the capability of the operator to obtain adequate funding. These are: assurance of funds, cost, equity, and flexibility.

There are three aspects which are relevant to the assurance of funds. First, the funds should be sufficient to cover the actual costs of decommissioning. Second, the financing arrangement should reflect and be prepared to handle the possibility of a premature decommissioning. Finally, it should be highly probable that the funds collected for decommissioning are reserved for those activities and not used for other purposes. This implies that the arrangement should account for the possibility of bankruptcy or default of the operator.

The cost of the financing arrangement is defined to include the direct costs expended on the decommissioning, the costs incurred to administer the fund, and any additional public costs generated by the alternative. An important consideration for the assessment of the costs is the tax treatment of the fund. Thus, net-of-tax returns and payments into the fund are the relevant measures in the evaluation.

A third criterion is achievement of an equitable distribution of the decommissioning costs. In the decommissioning literature, an equitable distribution has been defined as one that apportions the decommissioning costs to the beneficiaries of the nuclear plant in proportion to the benefits received. The prescribed application of this definition is to assume equal yearly benefits and to charge customers equal annual constant dollar amounts. Alternative concepts of equity would suggest different payment schemes. Decommissioning uncertainties imply that any payment scheme may prove to be inequitable ex post.

The arrangement should be flexible with respect to changes in the important parameters. For example, inflation, interest rates, and taxes will affect the value of the fund; and changes in technology, input costs, and regulations will alter the amount necessary to pay for decommissioning.

Four arrangements may be considered in the financing decision. Three are plant-specific: funding at commissioning, funding over the plant's useful life, and funding at decommissioning. The fourth option is based on the pooling of risks among plants, and is primarily considered as supplemental to the other three. Surety bonds and insurance pools would fall under this category.

Funding at commissioning, that is, prepayment, entails the commitment of cash or liquid assets at the time the reactor is commissioned. Funding over the plant's useful life is designed to collect the total estimated decommissioning cost over the operating life of the plant. This is commonly known as a sinking fund. In general, these arrangements are separated from other utility assets until decommissioning.

Funding at decommissioning accumulates the necessary funds over the life of the plant by a series of annual charges to customers. A major difference between this approach and those above is that it relies on an unfunded or unsegregated reserve method to pay for the decommissioning. Thus, the annual collections over the life of the plant represent an additional source of internal funds for the utility. Decommissioning costs are treated as a negative net salvage value when the plant is retired. At the end of the plant's life, the collected depreciation charges exceed the investment costs by an amount equal to the decommissioning expenses. During the life of the plant, the accumulating fund can offset an equivalent amount of current utility borrowing needs. If the cost of this option is not adjusted for risk, it will appear to be the least expensive (in discounted revenue requirements) of the plant-specific options. This is due to the fact that the fund is implicitly earning the utility's cost of capital which generally exceeds the net-of-tax return paid on a low-risk investment. However, if regulators desire to ensure that the financial risk of this option is comparable to the others, then a risk premium should be added to the annual payments, thus, increasing the total cost of the option. How much should be added depends on the risk of the utility's income stream and its expected financial state at the time of decommissioning.

3. THE APPROACH

To identify significant trends and practices among regulatory bodies and utilities, a review of these factors was undertaken at various levels in the regulatory hierarchy. The technical policies were examined in reference to their treatment of allowed technical modes, restoration of the plant site including any specific recognition of the residual radioactivity levels, and planning requirements. The financial policies were examined for specification of acceptable financing arrangements, mechanisms which adjust for changes in the important parameters used to establish the fund, tax and rate-base treatments of the payments to and earnings on the fund, and whether or not escalation and/or discounting were considered in the estimates of decommissioning costs.6

At the federal level, policies of the NRC, Federal Energy Regulatory Commission (FERC), Internal Revenue Service (IRS), and the Nuclear Waste Policy Act of 1982 were examined in the framework above. Next, state resolutions and legislation, both enacted and introduced since 1979, were examined. In the sample, there were 16 cases of legislation pertaining specifically to decommissioning, 21 cases of legislation affecting the transportation of radioactive wastes, and 26 cases of legislation on emergency preparedness and/or reactor accidents. The latter two categories were important not only for the costs of removing radioactive materials from a reactor site, but also for identifying preferences about the allocation of risks arising from nuclear plant operations.

Finally, state public service commission (PSC) regulations and practices were reviewed as well as the decommissioning plans of individual utilities. Nineteen of 24 representative PSC's expressed preferences about technical and/or financial policies.

4. TRENDS AND EXPECTATIONS OF DECOMMISSIONING COSTS

The regulatory information was used to highlight more general trends in the treatment of nuclear reactor decommissioning. Four major classifications of policy trends were identified: technical, financial, exercise of the state's authority over nuclear-related activities, and the allocation of risks.

4.1 Technical Trends

Prompt dismantlement appears to be the most favored technical option. There were two observed reasons for this conclusion. First, at the state level, the timeliness criterion is seen as very important. Second, nearly all of the cost evaluations reflect cost escalation but ignore discounting. Thus, prompt dismantlement appears to be the least expensive option in some constant year's dollars, however, this is rarely true in discounted dollars. In light of this practice, little support was found for the other three technical options.

Two trends regarding the residual radioactivity levels that will be considered acceptable after decommissioning can be observed. The first reflects the NRC's preference for a limitation established by the EPA that reflects the as low as reasonably achievable (ALARA) principles. In contrast to this, there was the preference expressed at the state level that the site be restored to the pre-construction status. If these two criteria do not coincide, a potential conflict may arise between the states and the NRC.

4.2 Financial Trends

There are several significant financial trends that can be identified from the regulatory information. First, the assurance of funds appears to be an important criterion at both the federal and state levels. Correspondingly, there is a tendency to favor financing options which provide higher levels of assurance such as the prepayment or sinking fund option. Additional measures to regulate the assurance of funds include the creation of decommissioning committees which are responsible for the management, review and adjustments to the fund. Another trend that may be captured by the preferences for external committees, is the desire to avoid additional taxation on the earnings of the decommissioning fund.

4.3 Trends Reflecting Changes in the States' Authority

On a broarder level, the policies reviewed signal trends regarding the degree and scope of the states' regulatory authority over nuclear-related activities. This is significant given the historical position of nuclear power as primarily a federal regulatory responsibility.

Areas where the scope may be changing can be detected from programs which increase the level of technical expertise within the state. Examples of these programs include the creation of select committees to study decommissioning in particular, or nuclear planning and regulation in general. This trend is most prevalent in emergency preparedness and transportation of hazardous wastes, but it is also evident in the decommissioning legislation which requires state review and approval of the technical plans submitted by the operator(s). In a few cases, the states have requested information on safety studies and plant accidents that previously was only reported to the NRC. Another area of increased authority is the assessment of penalties for violations of radiation protection laws (especially with respect to transportation) or legal action taken against plant operators for negligence in these tasks.

4.4 Trends Reflecting the Regulation of Risks

More than any other consideration, it is probably uncertainty that makes decommissioning a significant regulatory problem. Thus, regulators' attitudes toward the assumption and allocation of risks is a factor that is likely to bear on decommissioning policies. One of the strongest preferences expressed at the state level was for the prevention of a state bail-out for utilities unable to fulfill their decommissioning responsibility. In addition, states appeared to oppose national risk-sharing for nuclear accident clean-up costs, with the exceptions of New Jersey and Pennsylvania. The tendency is to allocate these risks away from the ratepayer and impose them on the owners of the utility. While the aversion to national risk-sharing is perhaps justifiable given the moral hazard problem, it is less understandable that decommissioning risk-spreading mechanisms are not found at the state or utility levels.

4.5 Current Cost Expectations

Data on nuclear plant decommissioning with respect to technical options and cost and chronological estimates illustrate common beliefs among utilities. A partial listing of the plants is given in table 1. If the chronological estimates are correct, we may expect a large number of decommissionings over the 2000-2015 time period possibly resulting in shortage problems.7

In general, there seems to be little difference in the cost estimates with respect to the type of plant. The most striking difference occurs across the state jurisdictions, for example, the constant 1983 dollar cost for a 800 MWe PWR falls in the range, $120-34/kilowatt (kW). However, cost estimates for similar size plants within a single jurisdiction are more consistent, suggesting that the practices used to produce the estimate may affect its magnitude. Both across and within jurisdictions, there is evidence of

Table 1. Plant Data

STATE OF JURISDICTION	PLANT NAME	UNIT #	TYPE OF REACTOR	ESTIMATED DATE OF DECOMMISSIONING	ESTIMATED 1983$ COST PER KILOWATT	TYPE OF TECHNICAL MODE ASSUMED[a]
Alabama	Farley	1	PWR	2012	49.41	A
	"	2	PWR	2012	48.28	A
Arkansas	Ark Nuc One	1	PWR	2009-2014	34.62	A
	"	2	PWR	2011-2016	29.65	A
California	San Onofre	1	PWR	1997	252.86	A
	"	2	PWR	2015	109.99	A
		3	PWR	2015	124.57	A
	Diablo Canyon	1 and 2	PWR	2015	95.72	A
	Humboldt Bay	3	BWR	1984-2014[b]	802.24	B
Florida	Turkey Point	3	PWR	2007	115.85	A
	"	4	PWR	2007	84.52	A
	St. Lucie	1	PWR	2010	108.01	A
	"	2	PWR	2023	92.00	A
	Crystal River	3	PWR	2008	102.35	A
Maryland	Calvert Cliffs	1	PWR	2009	55.48	A
	"	2	PWR	2009		
Michigan	Enrico Fermi	1	FBR	c.	203.91 and 14.88/yr	B
	Fermi	2	BWR	c.	111.02 20.24 and .15/yr and 93.26	A C

					6.45 and .37/yr and 104.27	B
New York	Ginna	1	PWR	c.	112.60	A
	Indian Point	2	PWR	c.	86.31	A
	Nine Mile Point	1	BWR	c.	112.28	A
South Carolina	Oconee	1,2 and 3	PWR	2003	67.72	A
	Robinson	2	PWR	1997	76.61	C
	V.C. Summer	1	PWR	2013	55.96	A
Wisconsin	Kewaunee	1	PWR	2008	133.37	A
	Point Beach	1	PWR	2007	105.56	A
	"	2	PWR	2008	105.56	A
TVA	Browns Ferry	1,2,3	BWR	2004-2007	53.52	A
	Sequoyah	1,2	PWR	2011-2012	44.43	A

NOTES: a. A implies prompt dismantlement.
B implies safe storage with dismantlement.
C implies entombment with dismantlement.
D implies conversion of the site.

b. Safe storage to begin in 1984, dismantlement in 2014.

c. Not available.

expected economies of scale. A few of the estimates for multi-unit plants indicate that costs are expected to be less for the second unit, which is consistent with either the assumption of joint costs or the assumption of learning externalities.

5. AN EXAMPLE OF THE FINANCIAL IMPLICATIONS

This paper has argued that we can identify current regulatory trends and practices that give some indication of the technical and financial preferences of the different groups involved in the decommissioning problem. We now present an example to illustrate that estimates of the discounted revenue requirements to pay for decommissioning must reflect these influences.

Consider two scenarios. In the first, the regulators are risk averse and have full authority over the decommissioning choices. Thus, they select the prompt dismantlement option, and use the prepayment financing arrangement to establish the decommissioning fund, where the earnings on the fund are taxable. In the second scenario, regulators are risk neutral because they have guaranteed the payments to the decommissioning fund. The utility uses the funding at decommissioning option and selects the thirty-year safe-storage technical alternative. Using a 4% escalation rate, a 10% discount rate, and an $85/kW 1983 dollar decommissioning cost, the discounted revenue requirements to decommission 50,000 mW over the next thirty years for the first scenario is $3,500 million, while the requirement for the second scenario is $500 million. This example, although a rough approximation, demonstrates that the regulatory environment can significantly affect the cost of decommissioning.

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1. Decommissioning refers to the safe removal of the facility from service and disposal of the radioactive residue.

2. Likely regulations and practices refer to those which seem to be favored by different regulatory bodies, but have not been formally instituted at the time of this writing.

3. Although they are not quantitatively assessed in this paper, regulations affecting the transport of radioactive materials from the nuclear facility to disposal sites will also bear on the final costs of decommissioning.

4. This discussion is primarily based on NRC publications, but supplemented with viewpoints expressed at both the state and utility levels.

5. Only a brief description will be given here, the interested reader is referred to the bibliography for more detailed discussions.

6. While it is not possible to present all of the information and cost estimates obtained from the review in the space allowed, it is contained in Cantor 1984.

7. See Office Of Technology Assessment 1984, p.121, for a discussion of the shortages with respect to the construction of the plants.

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