Final Report on

FUNDING NUCLEAR POWER PLANT DECOMMISSIONING

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The DECON cost (present value) estimates for a pressurized water reactor vary from $35.6 million to $122 million, depending on plant capacity, with a mean of $65.3 million, while the estimated cost of DECON for a boiling water facility varies from $35.2 million to $145.8 million, with a mean of $77.3 million. The cost estimates for SAFSTOR for a pressurized water reactor range from $3.5 million to $14.2 million, with a mean of $6.9 million, while the estimated SAFSTOR cost of a boiling water facility ranges from $4.2 million to $23.9 million, with a mean of $11.1 million. The estimated costs for ENTOMB range from $7.8 to $49 million for pressurized water reactors and from $13 to $45.5 million for boiling water reactors, with means of $17.2 million and $28.5 million, respectively. Various plant sizes can be accounted for in cost estimates by use of a scaling factor. But even after accounting for capacity variations, cost estimates still show wide variation because of other differences in the cost estimation procedures.

After decommissioning costs have been estimated, financial arrangements for funding decommissioning can be identified and assessed. The financial arrangements for funding decommissioning can provide for funding either prior to reactor start-up, over the plant's useful life, or at the time of decommissioning. Funding over the plant's useful life can take the form of either an external sinking fund or an internal sinking fund held by the utility but segregated from the rest of its assets. Alternatively, the fund held by the utility may not be segregated from the rest of its assets if the decommissioning cost is collected from consumers over the plant's useful life through a depreciation entry that accounts for this cost as a negative salvage addition to the plant's capital cost. In addition, each of these methods of funding decommissioning could be supplemented by a surety bond, insurance, or government assurances in order to reduce the risk of inadequate financing.

There are many regulatory treatments of decommissioning funds that result in possibly different costs to the utility's customers. These include treatment of how the fund is raised, how it is recoverd from the utility's customers, the rate base treatment of the unrecovered amount, and the handling of the tax expenses. The change in the revenue requirement when decommissioning is prepaid by the utility can be determined for each of the potential regulatory treatments.

Because the nuclear decommissioning costs occur in the future, three separate types of risks must be taken into account in assessing the various arrangements for funding decommissioning and their associated regulatory treatments. These are the risks associated with (1) the cost itself, (2) the revenues which are gathered to recover the cost, and (3) the earnings on any decommissioning fund--the last of which can be termed portfolio management risk.

It is particularly important to distinguish between cost and revenue risk. Most previous financial studies of decommissioning implicitly have used the utility's cost of capital, which reflects revenue risk, to discount future cost. The result is an inadequate annual decommissioning revenue requirement that increases the risk of inadequate funding at the time of decommissioning. All the funding arrangements can be adjusted so that the risk-free value of the decommissioning fund is equal to the risk-free value of the cost. With the proper risk adjustment, the consumers' cost of decommissioning may be higher than has been reported previously.

Whether control of the fund rests internally or in the hands of an external trustee raises the issue of portfolio management risk. Investing any decommissioning monies in a well diversified portfolio would yield the highest return for the overall market value of risk. An internal reinvestment program solely in the utility itself is not an efficient portfolio and is one that would be avoided by any risk-averse, individual investor. The remaining differences between internal and external control that have been discussed previously are substantially reduced if not eliminated if their revenue and cost risks are made the same.

It has been asserted by several studies in the literature that there are numerous factors that affect the annual decommissioning revenue requirement. Three of these factors in particular are whether or not the fund is prepaid by an issuance of utility securities, whether the fund is internal or external, and whether an ordinary type of sinking fund or rate base treatment is used to compute the revenue requirement. In fact, however, if each funding arrangement is adjusted to have the same risk, none of the three factors just listed changes the present value of the annual revenue requirements. Factors that do affect the annual revenue required for decommissioning include the tax rate on the fund's earnings and the risk due to revenue and cost uncertainty. All of these serve to increase the cost to consumers.

Economic efficiency is promoted if the fund's earnings are not taxed. State regulators may wish to investigate the possibility of federal legislative relief in this matter.

The risk of inadequate financing in the event of a premature decommissioning can be reduced by insurance. Such insurance is not yet available, however. If it were available, it could be used to fill any gap between the fund and actual cost if the monies are needed early. Importantly, the gap is not smaller if the fund is prepaid, as some have suggested. The critical issue is not the prepayment but whether state regulators will require future consumers to pay for decommissioning after the premature shutdown. If future revenue is disallowed and the fund was prepaid, then the utility will suffer financially in paying off previously issued decommissioning securities. If that revenue is allowed and the fund was not prepaid, revenue backed securities can be issued at the time of the premature shutdown, and no additional need for insurance can be traced to the lack of the prepayment.

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CHAPTER 1

INTRODUCTION

This report is intended to provide state public utility commissioners and their staffs with sufficient information in one report so that they will have a thorough background for examining the financial means of funding nuclear power plant decommissioning. Commissions may either choose to raise the issue themselves or be asked to rule on a utility's proposed solution.

At the time of this writing (October 1982), the Nuclear Regulatory Commission (NRC) is moving toward promulgating comprehensive new regulations governing decommissioning of nuclear power plants. These new regulations are likely to attempt to strike a balance between the legitimate health and safety concerns of the Nuclear Regulatory Commission (and other federal agencies) and the ratemaking concerns of state commissions. The Nuclear Regulatory Commission is presently scheduled to receive for its consideration the NRC staff's proposed changes to the present rules in February 1983.[1] An ancillary purpose of this report is to provide state utility commissions with the necessary background for expressing their concerns before the NRC.

According to the NRC, decommissioning of any nuclear facility means "to safely remove contaminant radioactive material down to residual levels considered acceptable for permitting unrestricted use of a facility and its site."[2] The regulation of activities related to decommissioning of a nuclear power plant has traditionally been within the purview of the NRC.

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[1]Statements of Mr. Robert Wood of the Nuclear Regulatory Commission presented to the NARUC Ad Hoc Committee on NRC-State Liaison at its meeting held in Washington, D.C. on May 14, 1982.

[2]U.S. Nuclear Regulatory Commission, Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, NUREG-0586 (Washington, D.C.: 1981), p. vii.

However, the actual funding for decommissioning of nuclear power plants is provided by the utilities that own the reactor. These utilities collect the funds to decommission a reactor from ratepayers through electricity rates. The actual collection of decommissioning funds by a regulated utility is accomplished through a financial arrangement explicitly or implicitly approved by a regulatory utility commission.

The cost of decommissioning is a part of the total cost of electricity from nuclear power. Indeed, the cost of decommissioning is a liability that the utility incurs, which must be considered in financial statements, according to current accounting standards.[3] Traditionally, accounting principles have prescribed that net salvage value, positive or negative, be considered in depreciation rates. The costs of removal, such as the cost of decommissioning nuclear reactors, have been a part of the calculation of net salvage value. In the past, therefore, decommissioning costs often have been implicitly considered in rate cases as a part of the depreciation expense. More recently, other more explicit methods of funding decommissioning costs have come under consideration.

The cost of removal usually exceeds the salvage value of nuclear reactors, resulting in a negative net salvage value. The cost of removal is also beginning to exceed the salvage value of coal-fired plants.[4] Many of the same issues raised throughout this report concerning funding a future expense, nuclear decommissioning costs, might also be raised concerning the proper way of funding the future expenses associated with dismantlement of coal-fired plants.

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[3]Fakos and Dickson, "Nuclear Power Plant Decommissioning As a Cost of Service," The Public Utilities Fortnightly, November 19, 1981, pp. 31-34. This article contains a summary of how current accounting standards apply to decommissioning.

[4]Federal Energy Regulatory Commission's Office of Chief Accountant, Electric Utility Depreciation Practices, FERC-0058 (Washington, D.C.: 1980), p. 49.

Because many nuclear power plants are approaching the end of their useful lives, the NRC began to reexamine and reevaluate its present policies on decommissioning in 1975. A detailed NRC plan for evaluating decommissioning was developed in 1978.[5] One portion of the NRC reevaluation concerns the options for decommissioning. The NRC is in the process of changing the basic terminology used to describe decommissioning options. The NRC is also reassessing which options of decommissioning are acceptable to the NRC. Such a reassessment could affect the cost of decommissioning, and thus affect the amount of funds to be collected from the ratepayer.

The NRC, as a part of its efforts to achieve its primary objective of protecting the health and safety of the public, is also reassessing its regulations concerning the assurance of funding to cover the cost of decommissioning. It is possible that the NRC will issue new regulations that emphasize assurance of funding more than current regulations. Promulgation of such regulations would require that the state public utility commissions renew their attention concerning the various methods of funding decommissioning costs.

Organization of the Report

The report is organized according to the steps that one might go through when analyzing funding of decommissioning costs. The first step in analyzing decommissioning costs might be to review the present regulatory framework within which decommissioning cost decisions must be made. Chapter 2 contains a description of the present NRC regulations that address the decommissioning of a nuclear power plant. Chapter 2 also contains a description of recent state public utility commission activities concerning funding the costs of decommissioning. Possible future trends in NRC regulation are also discussed within chapter 2.

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[5]U.S. Nuclear Regulatory Commission, Plan for Reevaluation of NRC Policy on Decommissioning of Nuclear Facilities, NUREG-0436, Revision 1, December 1978, and Supplement 1, July 1980, and Supplement 2, March 1981.

Next, the report deals with the estimation of decommissioning costs. The material presented in chapters 3 and 4 is intended to assist the reader in making some judgment about the reasonableness of decommissioning cost estimates. The first step is to determine which of the various decommissioning options is to be used. Chapter 3 contains a description of each of the possible decommissioning options. The options of decommissioning include immediate dismantlement, various types of safe storage, and entombment. Chapter 3 is not intended to be an engineering analysis for selecting a decommissioning option; rather, it is intended as an introduction for the reader of the various options of decommissioning a nuclear power plant for purposes of following the cost estimation discussion.

Chapter 4 contains a discussion of cost estimations for each decommissioning option for nuclear units containing pressurized water reactors and boiling water reactors. Included in this chapter is an explanation as to why cost estimates done by different consulting and engineering firms vary, including an explanation of how the engineering and cost assumptions that were used in the cost studies vary.

Chapter 5 contains a description of the various methods of collecting funds for decommissioning as well as a discussion of their possible regulatory treatment. These methods of funding decommissioning are categorized in the chapter according to the timing of the creation of the fund. The funding arrangements discussed include prepayment, internal sinking funds, external sinking funds, and unfunded reserves, including the use of negative net salvage value depreciation reserves. The chapter also includes a discussion of how variations in the cost of decommissioning can be due to the manner in which the fund is structured and the regulatory treatment of the decommissioning costs collected by the alternative methods of funding.

In chapter 6, the funding methods are evaluated using five criteria. Each criterion relates to the degree to which a method achieves an objective. The first objective is that the present value of the future revenues collected by the funding arrangement be equal to the present value of the estimated future cost of decommissioning. The second objective is that the funding arrangement ensures that the funds collected from ratepayers be adequate in the case of a premature shutdown of the reactor. The third objective is that the funding arrangement be equitable and impose the decommissioning costs on those ratepayers who receive the benefits from the nuclear plant.[6] The fourth objective is that the cost of the risk differential between external control of the funds and internal utility control be considered when deciding whether the fund be internal or external. The fifth objective is that the tax treatment of the funding mechanism spread the tax payments and the benefits of the deductible expense of decommissioning costs across those who paid for and received the benefit of the plant.

Material within chapters 5 and 6 provides the reader with background information that might assist state utility commissioners or their staffs in choosing or evaluating one of the financial mechanisms for covering decommissioning costs.

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[6]This objective corresponds roughly with the concept of intergenerational equity. Another way of defining intergenerational equity is to state that those generations of ratepayers who receive a benefit ought to pay for the benefit, and that costs should not be shifted between generations of ratepayers.

CHAPTER 2

THE PRESENT REGULATORY FRAMEWORK

Until changes are made to the present NRC rules, any decommissioning of nuclear reactors that occurs will be governed by the present regulatory framework, as summarized below. As mentioned, however, certain changes are likely in 1983. In the first section of this chapter, the present NRC regulations concerning decommissioning of nuclear power plants are discussed. In the second section, the various ways that the state public utilities commissions and state legislatures treat decommissioning costs are presented. The third section is a discussion of possible NRC decommissioning regulations of the near future.

The Present NRC Regulations and Guidelines

The present NRC regulatory framework concerning the decommissioning of a nuclear power plant is composed of federal NRC regulations and regulatory guidelines. Compliance with NRC regulations is legally mandatory. While compliance with NRC regulatory guidelines is not mandatory, they do describe decommissioning procedures acceptable to the NRC staff. Thus, NRC guidelines set forth a "safe harbor" standard of behavior that will assure NRC staff approval and expedite NRC approval for a course of action.

NRC Regulations

Title 10 of the Code of Federal Regulations (CFR) contains two major references to decommissioning: environmental impact statements and applications for termination of licenses. Until recently, the NRC regulations addressed financial qualifications in construction and operating licensing. Specifically, Title 10 CFR Section 50.33(f) required all applicants for an operating license to provide information that

> show(s) that the applicant possesses or has reasonable assurance of obtaining the funds necessary to cover... the estimated costs of permanently shutting the facility down and maintaining it in a safe condition.

Recently, however, this requirement has been dropped. The amendments to the NRC regulations concerning elimination of financial review requirements became effective on March 30, 1982.[1] The NRC dropped the requirement because it did not find a demonstrable link between public health and safety and a utility's financial qualifications. Instead, the NRC now requires that an applicant for an operating license obtain on-site property damage insurance or an equivalent amount of surety protection from the time the NRC first issues an operating license for the reactor. The amendments requiring on-site property damage insurance became effective on June 28, 1982.[2]

One major reference to decommissioning in Title 10 of the CFR is Title 10 CFR Section 51.5. Title 10 CFR Section 51.5(b) specifies actions that may or may not require preparation of an environmental impact statement depending upon the circumstances.[3] These actions include license amendments or orders authorizing the dismantling or decommissioning of nuclear power reactors.[4] Thus, the determination of the need for an environmental impact statement would take place immediately prior to any order authorizing decommissioning. If it is determined that an environmental impact statement is unnecessary, then Title 10 CFR Section 51.5(c)(1) provides that

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[1]Federal Register, March 30, 1982. Also see NARUC Bulletin No. 15-1982, page 2.

[2]Ibid.

[3]10 CFR 51.5(b)

[4]10 CFR 51.5(b)(7)

> a negative declaration and environmental impact appraisal will, unless otherwise determined by the [NRC], be prepared in accordance [with NRC regulations.][5]

The NRC also can determine that decommissioning is "a major [NRC] action significantly affecting the quality of the human environment," and therefore require an environmental impact statement before allowing decommissioning. However, a generic environmental impact statement, addressing those forms of decommissioning that are acceptable to the NRC, might qualify as an environmental impact statement for those subsequent decommissioning actions addressed in the environmental impact statement.

Recently, the NRC has issued a Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities[6] because the regulatory changes that might result from the NRC's regulation of decommissioning policy that is presently taking place may be a major NRC action affecting the quality of the human environment. Whether environmental impact statements will be required with individual decommissioning orders in the future or whether a generic environmental impact statement will suffice is yet untested.

The second major reference to decommissioning in Title 10 of the CFR is Title 10 CFR Section 50.82. This section is entitled "applications for termination of licenses." The section authorizes the NRC to set termination procedures, including providing notice to interested parties, requiring information on planned decommissioning procedures, and specifying the operational steps of acceptable decommissioning that are necessary to assure public health and safety. The section also explicitly extends the generic safety standards in Title 10 CFR to decommissioning activities.

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[5]10 CFR 51.5(c)(1)

[6]U.S. Nuclear Regulatory Commission, Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, NUREG-0586 (Washington, D.C.: 1981).

The principal document applicable to nuclear power plant decommissioning is NRC Regulatory Guide 1.86, which interprets Title 10 CFR 50.82. While not mandatory, Guide 1.86 "describes methods and procedures considered acceptable by the [NRC] regulatory staff for the termination of operating licenses for nuclear reactors."[7] The next subsection describes Guide 1.86.

NRC Regulatory Guide 1.86

Regulatory Guide 1.86 contains a discussion of the procedures associated with amending an operating license to a possession-only license. A possession-only license is a preliminary step to be taken when a licensee decides to terminate his nuclear reactor operating license. A possession-only licensee must retain authorization for special nuclear material, by-product material, and radioactive source material until the fuel, radioactive components, and radioactive sources are removed from the reactor facility. A possession-only license does have the advantage of reduced surveillance requirements when the reactor is not operating.[8]

Regulatory Guide 1.86 requires a degree of surveillance based on the potential hazards and the integrity of the physical barriers. The variables to be considered in evaluating potential hazards include the amount and type of remaining contamination, the degree of confinement of the remaining radioactive materials, the physical security provided by the confinement, the susceptibility to release of radiation as a result of natural phenomena, and the duration of required surveillance.[9]

Regulatory Guide 1.86 also covers in outlines the decommissioning procedures that the NRC staff finds acceptable. One note of caution, the terminology used in Regulatory Guide 1.86 to describe decommissioning

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[7]NRC Regulatory Guide, 1.86, Part A.

[8]NRC Regulatory Guide, 1.86, Part B.

[9]Ibid.

options does not match the terminology used elsewhere in this report. Terminology that is more precisely defined and better reflects the current trend of NRC staff views on decommissioning can be found in chapter 3 of this report.[10] The four acceptable procedures described in Regulatory Guide 1.86 are mothballing, in-place entombment, removal of radioactive components and dismantling, and conversion to a new nuclear system or fossil fuel system.

The mothballing option requires the applicant to make an application for a possession-only license and continuous surveillance and security. Mothballing would, at a minimum, involve removal of fuel assemblies and radioactive fluids and waste from the site.

The entombment option also requires an application for a possession-only license. The entombment option requires the submittal of a dismantlement plan at the time of possession-only application, in spite of the absence of complete dismantlement. The entombment option requires continuous surveillance and security. At a minimum, entombment involves removal of fuel assemblies, selected components, and radioactive fluids and waste from the reactor site, as well as the sealing of all remaining highly radioactive or contaminated components within a structure integral with the biological shield. Presumably, the dismantlement plan need only address those portions of the power plant that are removed.

The dismantlement option requires an application for a possession-only license as well as submittal of a decommissioning plan at reactor shutdown. Dismantlement also requires a comprehensive radiation survey prior to release of the reactor site for unrestricted use. The dismantlement option results in a termination of the operating license.

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[10] The terminology used in chapter 3 is based on terminology used in a report, entitled Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station. See R.I. Smith, G.J. Konzek, and W.E. Kennedy, Jr., Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Station, NUREG/CR-0130 (Battelle Pacific Northwest Laboratory: 1978).

The conversion option requires an application for a possession-only license and submittal of a dismantlement plan. It involves conversion to a new system after removal of spent fuel assemblies, and radioactive fluids and wastes from the site. If the conversion involves a new fossil fuel system, then all radioactive materials that are above unrestricted use radiation limits must be removed from the site and the operating license must be terminated.[11]

The next section is about the current regulation of decommissioning costs by state public utility commissions and the Federal Energy Regulatory Commission. State regulation often, in the past, chose a method for financing decommissioning costs implicitly. Currently, increasing attention is being given to choosing explicitly a means for financing decommissioning costs.

Regulation by State Public Utility Commissions and State Legislatures

The state public utility commissions have traditionally been responsible for overseeing utilities' finances, particularly in their determination of the revenue requirement. In order to oversee the funds set aside for nuclear reactor decommissioning, commissions must first analyze whether the decommissioning cost estimate is reasonable. Second, commissions must approve (or choose) a financial vehicle for setting aside these decommissioning costs. In the past, many state commissions implicitly considered the financing of nuclear decommission costs in each rate case. Until recently, many commissions accepted the utility's estimate of the decommissioning costs and allowed recovery through a negative salvage value depreciation reserve.[12] Beginning in 1978, commissions began to examine more closely other alternatives for financing decommissioning costs.

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[11]NRC Regulatory Guide, 1.86 Part C.

[12]With the negative salvage method, the expenses of decommissioning give nuclear power plants a net salvage value that is negative. This negative salvage value is included in the depreciable basis of the plant but not in the rate base.

State Legislation

Some state legislatures have passed statutes that place requirements on the financing of decommissioning. Appendix A sets forth a summary of state legislative activity related to power plant decommissioning, received from the NRC, covering the period of January 1975 to January 1982. For example, one of these bills, enacted by the New Hampshire legislature (Decommissioning Bill H-1), establishes a committee to ensure that safe decommissioning and subsequent surveillance of sites will be provided. This bill also provides that the committee will administer monies in a nuclear decommissioning financing fund. The monies are to be paid by the utility to the state treasurer.

In April 1982, after the appendix A summary was complied, Maine enacted a comprehensive bill (LD-2124) to ensure funding for the eventual decommissioning of nuclear power plants.[13] It is worth examining in detail as an illustration of the scope of state legislative authority. The bill requires that funds collected to finance decommissioning be placed in a separate external, segregated trust fund for each plant and be invested by a trustee until they are needed for decommissioning. The trustee is to be a bank or trust company, which is qualified to act as a fiduciary and chosen by a decommissioning fund committee. The decommissioning fund committee is responsible for the prudent management of each trust fund.

Existing and future licensees are to submit, for each nuclear plant, a decommissioning financial plan to the Maine Public Utilities Commission (MPUC) for its approval. The plan must include an estimate of the time of closing of the nuclear power plant, an estimate of the cost of decommissioning the plant expressed in dollars current in the year the plan is prepared, the share of the estimated decommissioning expenses attributed to each electric company to which the plant supplies power, plans for periodically reviewing and updating its decommissioning plan, plans for establishing a decommissioning trust fund adequate to pay the estimated decommissioning costs, plans and options for insuring against or otherwise

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[13] 35 MRSA c. 269 Sub-c.III §§3351-3359.

financing any shortfall in the fund resulting from a premature closing of the plant, reasonable assurance of responsibility in the event that the assets of the decommissioning trust fund (and, if necessary, the assets of the licensee) are insufficient to pay the cost of decommissioning, a general description of the decommissioning option that is intended at a level of detail necessary to support the cost estimates, a fully executed decommissioning financing agreement between the licensee and each owner, and any other information related to the financing of decommissioning that the MPUC requests. The bill provides that for purposes of cost estimates that the decommissioning option used shall be immediate dismantlement, unless the NRC requires another method.

The decommissioning financial plan must also include, if the licensee plans to establish its own decommissioning fund committee, a statement of intent to set up a decommissioning fund committee together with its proposed membership, a copy of the proposed decommissioning trust instrument, and its plan for implementing the trust and establishing the committee. In the event that either the licensee elects not to establish its own decommissioning fund committee, the MPUC fails to approve a decommissioning funding committee proposed by the licensee, or the MPUC elects to terminate a committee for good cause, a public decommissioning fund committee will be established. The duties of a decommissioning fund committee include appointing a trustee, approving the selection of any other financial managers by the trustee, establishing investment policy, evaluating investment policy and trustee performance, establishing procedures for expenditures from the trust fund for decommissioning and administrative expenses, and such other duties as it finds necessary to carry out its responsibilities.

Any funds that are collected by the licensee for decommissioning are to be immediately segregated from the company's assets and amounts not subject to refund or required to pay tax liabilities are to be transferred to the trustee for placement in the decommissioning trust fund. Amounts subject to refund or required to pay tax liabilities are to be deposited in a separate escrow account. The bill provides that, until a definitive determination has been made by the federal government that the income of the fund is tax exempt, the assets in the fund may be invested only in securities exempt from federal income taxation. The assets in the fund may not be invested in the securities of the owner of any nuclear power plant.

If there are assets in the fund after decommissioning has been completed, the assets are to be returned to the owners and any other persons who made payments to the licensee, in proportion to their payments. No portion of the remaining assets in the fund may accrue to the benefit of the licensee. Any electric utility in Maine which receives these assets must distribute them equitably, under the guidance of the MPUC, to its customers.

State Generic Hearings

A few states have recently initiated generic hearings on methods of financing decommissioning costs. For instance, the California Public Utilities Commission initiated an investigation into the present and alternative methods of financing decommissioning costs.[14] The methods being investigated include prepayment, sinking fund, depreciation reserve, surety bond, premature decommissioning insurance, and expensing. At the time of this writing, no final order has been issued in the California generic hearing. The California staff's Engineering Analysis group filed testimony recommending that the Commission adopt the following as policy:

1. the straight-line remaining life depreciation methodology should be used to determine the recovery of decommissioning costs.
2. federal legislation, which would allow funds set aside for decommissioning to be allowed as deductions for income tax purposes, should be supported.

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[14]California Public Utilities Commission, Order Initiating Investigation No. 86, January 21, 1981.

3. this proceeding should be referred to docket OII-24, the Commission's investigation into the method to be utilized in establishing the proper level of income tax expense for rate making purposes.

4. the recovery of decommissioning costs should be regularly reviewed pending adoption of federal legislation and regulations related to decommissioning.[15]

Another state commission that has initiated a generic hearing on the various financial means of funding nuclear decommissioning is the Michigan Public Service Commission.[16] The generic hearing considers which methods of funding decommissioning are the most equitable and the least expensive for ratepayers, the implications for the various funding methods, and the legal requirements necessary to ensure the availability of funds collected at the time of decommissioning. At the time of this writing, a proposal for decision had been issued by the Administrative Law Judge (ALJ). The ALJ concluded that an external trust fund with required revenues partially skewed for inflation is the funding mechanism that best meets the criteria set forth above. The ALJ also concluded that normalization accounting should be followed with respect to federal income taxes.

The Florida Public Service Commission has concluded a generic hearing on the appropriate accounting and ratemaking treatment of nuclear power plant decommissioning cost.[17] The commission concluded that an internally funded reserve is the appropriate method to account for decommissioning costs. The internally funded reserve would invest the money received from

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[15]California Public Utilities Commission's Revenue Requirements Division of the Engineering Analysis Group, "Study of Recovery of Decommissioning Costs," Docket OOI-86, San Francisco, 1981.

[16]In the Matter of the Establishment and Treatment of Nuclear Plant Decommissioning Funds, Michigan Public Service Commission, Proposal for Decision, Case No. U-6150.

[17]In re: Investigation of the appropriate accounting and ratemaking treatment of decommissioning costs of nuclear-powered generators, Florida Public Service Commission, Order No. 10987, Docket No. 810800-EU(CI), July 15, 1982.

customers to pay for decommissioning in a segregated fund. The fund would be invested and would not be available for any other use than decommissioning. The commission also ordered that the docket remain open pending a staff recommendation on affecting any revenue requirement changes pertaining to the recovery of decommissioning costs.

Case by Case Treatment

Recently, some state commissions have explicitly addressed the financing question in rate cases, also. An example is a recent Connecticut case in which the Department of Public Utility Control increased the depreciation expenses to provide for decommissioning based on the latest decommissioning study performed by Northeast Utilities.[18] The new decommissioning cost estimates are based on the immediate dismantlement option. Another example of a recent decision explicitly mentioning decommissioning costs is a recent case before the Virginia State Corporation Commission.[19]

Trends

As noted above, the NRC plans to issue proposed rule changes concerning decommissioning in February 1983. The rulemaking is likely to change the types of decommissioning options that the NRC finds acceptable from those presently described in NRC Regulatory Guide 1.86. The best indication of the options that the NRC is likely to find acceptable is

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[18] Application of the Connecticut Light and Power Company and the Hartford Electric Company to Increase their Rates and Charges to All Classes of Customers, Connecticut Department of Public Utility Control, Docket No. 810602 & 810604, Decision & Notice of Supplemental Hearing (December 2, 1981).

[19] Virginia Electric and Power Company--Final Order in Company's Application for an Increase in Electric Rates, Virginia State Corporation Commission, Case No. PUE 8100025, 1981.

found in the Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities.[20] These options are discussed in chapter 3.

The NRC regulations will also reexamine the extent to which the NRC's regulations and policies assure that adequate funds will be available to decommission a nuclear facility. It is likely that the new NRC regulations will set forth minimal standards of assurance that state commissions must meet. Mr. Robert S. Wood of the NRC in a presentation to the NARUC Ad Hoc Committee on NRC-State Liaison suggested that funds for decommissioning should be assured by some funding or reserve method. Mr. Wood also indicated that while the NRC staff would "prefer to see an external fund established for decommissioning, given the recent requirement for on-site insurance for decontamination, the major long-term risk to a utility's financial solvency is covered. Thus, [the NRC] would probably accept an internal reserve or fund when accompanied by adequate insurance."[21]

Given the current emphasis of the NRC on assurance of funding, it is likely that accounting for decommissioning costs will be a topic that must be addressed by public utility commissions (and perhaps state legislatures) in the near future. Commissions may wish to participate in the formation of the NRC's final regulations on decommissioning of nuclear power plants.

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[20] U.S. Nuclear Regulatory Commission, Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, op. cit.

[21] Wood, op. cit.

CHAPTER 3

OPTIONS FOR DECOMMISSIONING

While the government must act as decommissioning agent of last resort, the primary responsibility for the decommissioning of a nuclear facility rests with its owners. This chapter sets forth the major options for the decommissioning of commercial nuclear power stations. The main decommissioning options can be divided into three categories: immediate dismantlement and decontamination (DECON), safe storage (SAFSTOR), and entombment (ENTOMB). Immediate dismantlement and decontamination begins soon after the reactor ceases operation and involves the disassembly of the reactor and other contaminated systems and the removal of all hazardous radioactive materials from the site. Safe storage involves the long term storage of the closed facility followed by eventual dismantlement and decontamination to remove the long-lived radioactive materials which have not decayed during the storage period. Entombment typically requires that soon after the reactor ceases operation the reactor vessel is disassembled and all long-lived radioactive material is confined (i.e., "entombed") within the buildings at the reactor site using concrete or other barriers. This remaining radioactive material is left at the site to decay to safe levels within the remaining life of the enclosing structures.

The pseudoacronyms DECON, SAFSTOR and ENTOMB have been recently introduced by the NRC in the hope of clarifying the terminology used in referring to specific decommissioning options,[1] since in the past different terms have been used to refer to the same decommissioning option, and a single term (such as "entombment") was used for quite different courses of action. The nomenclature chosen for this report has been selected so as to be both descriptive and compatible with the NRC terms.

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[1]U.S. Nuclear Regulatory Commission, Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities NUREG-0586 (Washington, D.C.: 1981), pp. II-4.

During the period from 1969 to mid-1976, sixty-five licensed nuclear reactors were decommissioned.[2] Of these reactors only nine were in nuclear power plants; the remainder consisted of 6 test reactors, 28 research reactors, and 22 critical facilities. Of the nine nuclear power plants decommissioned during the period from 1969 to mid-1976, one was dismantled, five were placed in safe storage, and three were entombed. In addition to this limited experience, many studies have been conducted in recent years to estimate the cost of decommissioning commercial nuclear power stations. This chapter describes in detail the three main options for decommissioning, while chapter four examines the costs associated with these nuclear plant decommissioning options.

Immediate Dismantlement and Decontamination (DECON)

DECON means immediate dismantlement and decontamination. This decommissioning option requires the complete decontamination of the nuclear facility site such that residual levels of radioactivity at the site are sufficiently low to allow the NRC to release the facility for unrestricted use.[3] The immediate dismantlement option is the only decommissioning option that leads to the release of the site for unrestricted use shortly after the plant is retired from service.

Preparation activities for immediate dismantlement include the development of an environmental impact report, submitting a dismantlement plan to the NRC, and preparing detailed work plans and schedules for dismantlement activities. Special tools such as the plasma arc torch must be acquired and tested. In some cases, specialized equipment must be designed to meet the needs of a specific dismantlement project.

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[2]G. Lear and P.B. Erickson, "Decommissioning and Decontamination of Licensed Reactor Facilities and Demonstration Nuclear Power Plants." Proceedings of the First Conference on Decontamination and Decommissioning (D&D) of ERDA Facilities, CONF-750827 (Idaho Falls, ID; August 1975) pp. 31-45.

[3]Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, op. cit., p. II-5.

Preparations will also include the selection of a staff and specialty contractors such as explosives specialists for the project. The planning and preparation for an immediate dismantlement project are expected to take two years. Hence, these preparation activities would commence two years prior to the reactor's expected shutdown date.[4]

After the final cessation of power generation, the decontamination of equipment and buildings would begin. The disassembly and decontamination of the reactor itself may be delayed to allow time for fuel cooling. The objective of the initial decontamination effort is to reduce the occupational exposure of the decommissioning personnel and to prepare any salvageable material for unrestricted use. Occupational exposure during decontamination and decommissioning is required to be as low as reasonably achievable. The decontamination of water pipes and storage tanks may permit their reuse or sale as scrap and at the same time reduce the quantity of contaminated material that must be disposed of. Surface contamination would be removed using chemical or physical means (e.g., water-jet decontamination). The concrete surfaces of walls and floors, which have been activated or contaminated,[5] would be stripped away using explosives, jackhammers, or scrapers, allowing the rubble to be packaged and shipped to a licensed disposal site.

The next step in an immediate dismantlement project would be the disassembly of equipment in the containment and auxiliary buildings. The sequence in which equipment would be removed is designed to minimize the expected exposure of personnel to radiation. The structures causing the greatest exposure will be removed first, or, if they are inaccessible, shielding will be provided. Process systems will be unbolted or cut into

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[4]R.I. Smith, G.J. Konzek and W.E. Kennedy, Jr., Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station, Report of the U.S. Nuclear Regulatory Commission by Battelle Pacific Northwest Laboratory, NUREG/CR-0130, June 1978, pp. IX-1 to 4.

[5]Activation refers to the development of radioactive isotopes in formerly nonradioactive material which has been subjected to neutron bombardment. Contamination is simply the absorption of radioactive substances by formerly nonradioactive materials.

shapes that would be accommodated by standard waste disposal boxes. Trucking companies that specialize in the transportation of hazardous materials would be employed to ship the materials to a suitable disposal site.

Once the nuclear facility has been fully decontaminated with residual radioactivity brought to levels allowing unrestricted use of the property, the nuclear license is terminated, and the NRC's regulatory interest ends. NRC regulations do not require that the facility be demolished and the site restored to its former condition.[6]

Of the nine nuclear power plants decommissioned during the period from 1969 to mid-1976, only the Elk River Reactor in Elk River, Minnesota was dismantled.[7] This 58 megawatt (thermal)[8] boiling water reactor was decommissioned in 1974 after three years of work at a cost of $6.15 million.[9] In contrast, most of the research reactors and critical facilities decommissioned in the period from 1969 to mid-1976 were totally dismantled at the end of their useful lives.

There are several arguments both in favor of and against immediate dismantlement (DECON). The advantages of the immediate dismantlement and decontamination option include the rapid release of the site for another power plant or alternate use, the reduction of uncertainty regarding the magnitude of actual decommissioning expense, since these costs are incurred immediately rather than postponed, and the sure removal of a potential hazard. The disadvantages of immediate dismantlement include higher occupational exposure to radioactivity levels of a recently closed facility

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[6]R.I. Smith, G.J. Konzek and W.E. Kennedy, Jr., op. cit., p. IX-8.

[7]G. Lear and B. Erickson, op. cit., pp. 31-45.

[8]The term, megawatt (thermal), indicates the heat output of the facility in operation. This quantity is typically about three times greater than the generation facility's output of electrical power, which is indicated by the megawatt (MW) electric capacity of the plant.

[9]Final Elk River Reactor Program Report. COU-651-93, Revised, United Power Association, Elk River, MT, November 1974.

during the dismantlement process and the potentially higher present-value cost of immediate over deferred dismantlement.

Safe Storage (SAFSTOR)

Under the decommissioning option SAFSTOR, the nuclear facility is closed down without great changes, placed in storage, and maintained with some continuing care so that the safety risk during storage is within acceptable bounds. At some time in the future the facility will be dismantled and decontaminated to a degree permitting unrestricted use of the site.[10] The storage period may last any length of time up to about 100 years, since beyond 100 years the integrity of the concrete structure would begin to be in doubt and most of the remaining radioactive materials would be very long-lived.

There are three types of safe storage: custodial safe storage, passive safe storage and hardened safe storage.[11] These types differ in the extent of continuing care necessary for the facility after preparations for safe storage are completed. The facility held in custodial safe storage requires the most continuing care, while a reactor in hardened safe storage requires the least continuing care.

Custodial safe storage,[12] or layaway, requires minimal initial decontamination. The active protection system (i.e., the ventilation and air filtration system) is maintained in operation during the continuing care period. Radiation monitoring is continuous to provide for the safety of on-site personnel. Such personnel inspect and maintain the ventilation equipment and the structure on an ongoing basis. Security personnel at the site guard against accidental or intentional unauthorized entry. At the end of the continuing care period, the nuclear facility is dismantled and

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[10] Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, op. cit., p. II-7.

[11] Ibid.

[12] Ibid.

fully decontaminated in a manner similar to that of immediate dismantlement.

Passive safe storage, also called mothballing, relies on a more thorough immediate decontamination effort to permit the shutdown of the active protection (i.e., ventilation) system. Electronic surveillance is used to detect fires, changes in radiation levels, and intruders. Off-site security personnel such as those of a private security agency would be used to monitor the alarm systems at the plant. Passive safe storage requires periodic inspection and repairs to maintain the structure in a stable condition.

Hardened safe storage[13] is also known as temporary entombment. It requires the construction of physical barriers around areas with high concentrations of radioactivity. The use of concrete and other barriers to seal off access to the facility is intended to eliminate the potential for accidental intrusion and to make a deliberate break-in quite difficult. Electronic surveillance is used to detect any disturbance of the entombment barriers. Infrequent inspections of the site are made to detect any change in radiation levels within the facility and to monitor the structural integrity of the facility. At the end of the storage period the nuclear facility is dismantled and the remaining long-lived radioactive materials are disposed of.

Passive safe storage has been by far the most commonly tried of the three safe storage choices.[14] Power reactors that have been decommissioned using passive safe storage are the Carolina-Virginia Tube Reactor, South Carolina; Pathfinder, South Dakota; Peach Bottom 1, Pennsylvania; and Vallecitos Boiling Water Reactor, California. Custodial safe storage is reported to have been used at the Hanford Production Reactors at Richland, Washington.[15]

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[13]Ibid.

[14]R.I. Smith, G.J. Konzek, and W.E. Kennedy, Jr., op cit. pp. III-3 to 5.

[15]Ibid.

The chief advantage of safe storage is that during the continuing care period the radioactive isotopes with short half-lives[16] will largely cease to be a problem. The radioactive isotope cobalt-60 has a half-life of 5.27 years, and within one hundred years the remaining radioactivity from this material could be indistinguishable from normal background levels of radiation.[17] In fact, cobalt-60, a major source of radioactivity in a light water reactor, will lose nine-tenths of its radioactivity after a period of 17 1/2 years. Hence, a deferring of dismantlement into the future will result in reductions in the costs associated with the control of occupational exposure during dismantlement.

A disadvantage of safe storage is that the postponement of final dismantlement makes its costs more uncertain. In addition, the continuing care costs and the "cost" associated with the loss of the site for alternative uses during the storage period are additional costs that would be incurred while final dismantlement is deferred.

Entombment (ENTOMB)

The decommissioning option ENTOMB, "means to encase and maintain property in a strong and structurally, long-lived material (e.g., concrete) to assure retention until radioactivity drops to a level acceptable for releasing the facility for unrestricted use."[18] Given the requirement that the remaining radioactivity decay to acceptable levels within the life of the entombed structure, entombment usually requires an initial disassembly of the reactor vessel to allow the removal of all long-lived

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[16] A half-life is the time period required for one half of the atoms of a radioactive isotope to decay. For example, given a sample of a radioactive material with a half life of five years, after five years the sample will emit only half of the radiation that it did originally. After another five years only half of this latter amount of radiation, or 1/4, will be emitted.

[17] R.I. Smith, G.J. Konzek and W.E. Kennedy, Jr., op cit. p. IV-5.

[18] Draft Generic Environmental Impact Study on Decommissioning of Nuclear Facilities, p. II-9.

radioactive materials from the site. The remaining radioactive materials must be of a short-lived type so that they will decay to harmless levels within the remaining life of the structure. The short half-life of the entombed materials and the limited lifetime of concrete structures suggest that 100 years might be a reasonable upper limit for the period of entombment.

In the past, entombment referred to the use of concrete or other such materials to encase the nuclear facility in a protective physical shell. Such temporary entombment is no different than hardened safe storage in that it requires the eventual disassembly of the reactor to allow the final disposal of long lived radioactive materials. Because several radioactive isotopes in nuclear reactors have extremely long half-lives, a temporary entombment no longer meets the NRC staff's definition of entombment, since radioactivity will not decline to acceptable levels within the lifetime of any man-made structure. The radioactive materials nickel-59 and niobium-94, which accumulate in the reactor vessel over its useful life have half-lives of 80,000 and 90,000 years, respectively. Thus, initially removing these long-lived radioactive materials is needed to make the entombment of the remaining radioactivity a viable option.

There are at least two cases in which entombment is a feasible approach to decommissioning. Since the nuclides niobium-94 and nickel-59 build up gradually over the reactor's useful life, a premature reactor shutdown early in the reactor's expected life means that very little contamination of a long-lived variety has time to accumulate. Hence, an unexpectedly short plant operating life may make entombment a viable option. Entombment also becomes feasible, when the reactor vessel internals are removed from the site, since these components contain the radioactive isotopes with long half-lives. The remaining radioactive contamination present at the site can be entombed and will decay to levels permitting unrestricted use of the site within a reasonable entombment period (i.e., one hundred years or less).

There are three entombed reactors under U.S. jurisdiction. These government-owned sites are all former nuclear power demonstration plants.

The three entombed facilities are Hallam, Nebraska; the Piqua Nuclear Power Facility, Ohio; and the Boiling Water Nuclear Superheater Power Station in Ricon, Puerto Rico. The entombment preparations for the Hallam and Piqua reactors took approximately three years to complete. All three reactors have had their entrances welded shut and have a concrete cover to secure the radioactive equipment.[19]

The primary advantage of the entombment option over passive safe storage is that an entombed reactor will require no delayed dismantlement and decontamination, since only those radioactive elements are entombed which will decay to safe levels within the entombment period. In addition, the use of physical barriers to restrict access to the facility allows a reduction in continuing care costs associated with monitoring the facility. Entombment and safe storage both suffer from the drawback that they do not allow alternative uses of the site for a very long period of time. The cost of this lost opportunity depends upon the value of the site in its best alternative use. Immediate dismantlement, of course, does not share this drawback, but it requires greater expenditures to control the level of occupational exposure to radioactivity and to gather, package, and dispose of materials contaminated by short-lived isotopes.

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[19] R.I. Smith, G.J. Konzek, and W.E. Kennedy, Jr., op cit., p. III-3 to 5.

CHAPTER 4

ESTIMATING THE COST OF DECOMMISSIONING

Estimating the cost of decommissioning, which can take place anywhere from thirty to one hundred forty years after a nuclear power plant begins operation, is a difficult task. The objective of this chapter is to report and examine the work that has been done in estimating the cost of decommissioning commercial nuclear power stations.

An excellent and detailed examination of the cost of decommissioning has been conducted by the Pacific Northwest Laboratories of the Battelle Memorial Institute in two reports for the Nuclear Regulatory Commission. The first report, which was published in 1978, contains estimates of the cost of immediate dismantlement and the cost of passive safe storage for a large (i.e., 1,175 MW) pressurized water reactor.[1] The second report, published in 1980, contains estimates of the costs of decommissioning a boiling water reactor.[2] Both reports have appendices that provide extensive documentation of the assumptions and procedures for estimating decommissioning costs. This chapter contains the findings of these and other studies on the cost of the major decommissioning options.

Estimating the cost of decommissioning consists of two separate steps. First, the actual cost of a decommissioning procedure is estimated as though it were to occur today. Second, one must take into account the effect that the passage of time may have on the costs. To deal with the uncertainties that arise in estimating the costs of decommissioning, every decommissioning cost study makes crucial assumptions about such factors as

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[1]R. I. Smith, et al., Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station, Report of U.S. Nuclear Regulatory Commission by Battelle Pacific Northwest Laboratory, NUREG/CR-0130, June 1978.

[2]H. D. Oak, G. M. Holter, W. E. Kennedy, Jr., G. J. Konzek, Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station, Prepared for U.S. Nuclear Regulatory Commission by Battelle Pacific Northwest Laboratories, NUREG/CR-0672 vol. 1, June, 1980.

the permissible levels of occupational exposure to radiation, the type of waste materials disposal, and the discounting of future costs based on expected interest rates.

In this chapter, the estimated costs of decommissioning by immediate dismantlement, safe storage, and entombment are examined. The key assumptions made by the authors of these studies are analyzed, and their part in producing the considerable variation in decommissioning cost estimates is explained. A scaling factor is presented that can be used to adjust cost estimates to reflect different plant sizes. Lastly, the potential for the refurbishment of commercial nuclear power plants is explored.

Immediate Dismantlement (DECON) Cost Estimates

The primary cost components of decommissioning by immediate dismantlement are staff labor; the packaging, shipment, and disposal of radioactive materials; demolition; tools and supplies; and power. Table 4-1 presents a breakdown of the total estimated costs for the immediate dismantlement of a reference 1,155 MW boiling water reactor and a reference 1,175 MW pressurized water reactor. These cost estimates, originally made by Battelle,[3] have been updated to January 1, 1982 dollars in a study by personnel affiliated with the Stone and Webster Engineering Corporation.[4]

Immediate dismantlement is an extremely labor intensive undertaking. The entire dismantlement process for a 1,175 MW pressurized water reactor is expected to require 301.5 man-years to complete.[5] The two years of planning and preparation prior to the reactor shutdown are expected to

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[3]R.I. Smith, et al., op cit.

[4]D.F. Greenwood, R.K. Westfahl and J.W. Rymsha, "Analysis of Decommissioning Costs for Nuclear Power Reactors," a paper presented before the Nuclear Engineering Division of the American Society of Mechanical Engineers, in Portland, Oregon, 82-NE-20 July 1982.

[5]R.I. Smith, et al., op cit., p. IX-19.

require 24.6 man-years of labor time.[6] The year immediately following the reactor's shutdown will require 103.5 man-years of labor.[7] Labor requirements in the second year after shutdown are 95.5 man-years, and in the third and fourth years labor needs are 63.9 and 4 man-years, respectively.[8]

The estimated amount of labor time necessary to complete the immediate dismantlement is very sensitive to the assumed permissible level of occupational exposure to radioactivity. According to table 4-1, almost twice as much labor expense is required to complete the immediate dismantlement of a large boiling water reactor than for the dismantlement of a pressurized water reactor of a similar size. These higher labor costs are due not only to the greater degree of labor associated with decommissioning a boiling water reactor but also to different assumptions in the two studies regarding the permissible level of occupational exposure.

Boiling water reactors are typically more expensive to decommission. The estimated level of occupational exposure to radiation is higher for the boiling water reactor dismantlement (i.e., 1,845 man-rems[9] versus 1,200 man-rems for the pressurized water reactor), because they require more elaborate decontamination and the removal of the radioactive portions of their condensate system.[10] However, the difference in the labor costs in these two studies is too great to be completely explained by technological differences between the two types of reactors.

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[6]Ibid.

[7]Ibid.

[8]Ibid.

[9]A man-rem is a measure of human exposure to radioactivity. A rem is a dosage of radiation with a biological effect in humans of about one roentgen of X-ray exposure. Five rems per year is considered the maximum occupational exposure for long-time radiation workers. The exposure of a group of workers, expressed in man-rems, is the sum of the exposures of the individuals, expressed in rems.

[10]D.F. Greenwood, R.K. Westfahl and J.W. Rymsha, op cit.

Much of the difference in labor requirements is due to different assumptions made in the two studies regarding the permissible levels of occupational exposure. In the pressurized water reactor study, it is

TABLE 4-1

A COST BREAKDOWN FOR THE IMMEDIATE DISMANTLEMENT (DECON) OPTION

Cost Components	Boiling Water Reactor DECON Costs (millions of 1982 dollars)	Boiling Water Reactor DECON Costs (% of cost)	Pressurized Water Reactor DECON Costs (millions of 1982 dollars)	Pressurized Water Reactor DECON Costs (% of cost)
Radioactive Materials Disposal*	12.15	18.0	15.50	32.8
Labor	24.60	36.5	12.59	26.7
Electrical Power	4.93	7.3	4.91	10.4
Tools, Equipment and Supplies	5.43	8.1	3.34	7.1
Specialized Contractor Services	0.50	0.8	0.75	1.6
Insurance and License Fees	1.20	1.8	1.13	2.4
Demolition	18.54	27.5	8.98	19.0
Total	67.35	100.0	47.20	100.0

Source: D.F. Greenwood, R.K. Westfahl and J.W. Rymsha, "Analysis of Decommissioning Costs for Nuclear Power Reactors," a paper presented before the American Society of Mechanical Engineers, in Portland, Oregon, 82-NE-20 July 1982.

*The pressurized water reactor's radioactive materials disposal costs include 3.46 million dollars for the shipment of spent fuel. The boiling water reactor's radioactive materials disposal costs do not include the cost of shipping spent fuel in the figures presented here. Of course, in fact these costs will be experienced for both reactor types.

assumed that all decommissioning workers would safely receive radiation doses of up to 3 rems per quarter.[11] While in the boiling water reactor study, the assumption is made that long-term radiation workers, such as supervisors, health physics technicians, etc., should not receive more than 5 rems per year.[12] Only those workers with little previous radiation exposure would be permitted to receive the three rems per quarter maximum exposure. Reducing occupational exposure per man to this level requires the employment of a much larger work force. The labor cost of the immediate dismantlement of the boiling water reactor would be reduced by 9.8 million 1982 dollars if all workers were allowed to receive a radiation exposure of up to 3 rems per quarter.[13] Hence, the labor cost required for immediate dismantlement is highly sensitive to the study's assumptions regarding permissible occupational exposure limits and the mix of short-term and long-term workers exposed to radiation.

Demolition costs in these studies include the cost of demolishing all reactor buildings and structures and restoring the site to approximately its original condition. The reasonableness of including these costs as a part of the legitimate decommissioning cost is open to question. The NRC does not currently require the demolition of nuclear reactor buildings upon completion of their decontamination.[14] The Battelle study of decommissioning costs for boiling water reactors presents this cost separately, since it cannot be clearly identified as belonging to immediate dismantlement.[15]

In a competitive industry, a cost which is not required for the production of an item will not influence its per unit cost or price. A firm which includes such costs in its product pricing would be driven out

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[11]H.D. Oak, et al., op cit. p. XII-11.

[12]Ibid., p. XII-12

[13]Ibid.

[14]R.I. Smith, et al., op cit. p. IX-8.

[15]H.D. Oak, et al., op cit. p. X-7.

of business by competitors who refused to bear such costs. Hence, unless mandated by law, demolition and site restoration expenditures are part of the cost of preparing the site for its new use and are not normally considered part of the cost of decommissioning. However, decommissioning cost studies include various such costs. This accounts, in part, for variations in the estimated costs of decommissioning.

Another major component of immediate dismantling cost is waste materials disposal expense. One major uncertainty affecting the cost of immediate dismantlement is the amount of material that will require final disposal. It is anticipated that chemical and mechanical decontamination techniques may make much of the more valuable materials (e.g., stainless steel) salvageable. Decontamination of materials to levels permitting unrestricted use not only produces salvage revenue but also eliminates the packaging, shipping, and disposal costs associated with this material if it were not decontaminated. One crucial problem in estimating the potential for salvaging material is that safety standards for the unrestricted release of decontaminated material have not been firmly established.[16] Hence, the studies on which table 4-1 is based contain the conservative assumption that no decontaminated material is sold for salvage and that all such material is disposed of as radioactive waste.

While the total cost of decommissioning by immediate dismantlement is relatively insensitive to an increase in the charges for waste disposal, the cost of immediate dismantlement is highly sensitive to the mix of final waste disposal options employed. In the boiling water reactor study, it was assumed that only 89 cubic meters of highly activated radioactive waste would require deep geologic emplacement. The remaining 18,787 cubic meters of waste would be disposed of using a much less costly burial ground site.[17] According to a sensitivity analysis of burial ground charges, a

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[16] Ibid., p. IX-6

[17] Ibid., p. XIV-5

doubling of burial ground charges will increase the cost of immediate dismantlement by nine percent or less.[18] A tripling of the charges for deep geologic emplacement would raise total immediate dismantlement costs by approximately 6%.[19] In contrast, if all radioactive wastes were required to be placed in a deep geologic repository, the additional disposal cost would more than quintuple the total cost of immediate dismantlement. Hence, the estimation of future immediate dismantlement costs is very sensitive to assumptions about the regulatory environment at the time of dismantlement. More stringent radioactive waste disposal regulations have the potential to increase dramatically the cost of waste disposal for immediate dismantlement.

The assumptions regarding the type of contractual agreements used by the utility to facilitate decommissioning can significantly alter the estimated cost of decommissioning. According to Battelle's study of the decommissioning costs for boiling water reactors, the cost of immediate dismantlement (excluding demolition and spent fuel disposal) is higher under the likely arrangement that the utility will retain some overview and control functions while subcontracting most of the decommissioning effort.

The cost of dismantling and decontaminating a commercial nuclear power station has been the subject of numerous studies in recent years. Table 4-2 summarizes the total cost estimates for immediate dismantlement made by a number of independently conducted studies. Although the total cost estimates in the table have been adjusted to January 1, 1982 constant dollars and the contingency costs have been removed,[20] the estimates

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[18]Ibid.

[19]Ibid.

[20]Contingency costs are those unanticipated costs that arise during the course of the project. Most studies raise the final cost estimate by a fixed percentage in order to attempt to account for these costs. Different assumptions regarding the appropriate magnitude of this adjustment for contingencies can produce wide variation in cost estimates. See D.F. Greenwood, et al., op. cit., p. 3.

TABLE 4-2

COST ESTIMATES FOR DECOMMISSIONING BY IMMEDIATE DISMANTLEMENT (DECON)

Study	Decommissioning Cost For a Pressurized Water Reactor (millions of 1982 dollars)	Decommissioning Cost For a Boiling Water Reactor (millions of 1982 dollars)
Battelle Pacific Northwest Laboratories	47.2	67.4
National Environmental Studies Project	46.2	53.6
Nuklear-Ingenieur Services	120.1	145.8
New York State Electric & Gas Co.	70.3	-
Department of Energy	35.6	-
Arkansas Nuclear No. 1	28.4	-
Prairie Island No. 1	54.0	-
Maine Yankee	60.2	-
Three Mile Island No. 1	122.0	-
San Onofre No. 1	80.5	-
Millstone No. 2	67.3	-
Palisades	68.1	-
Davis-Besse No. 1	48.8	-
Monticello	-	56.7
Oyster Creek	-	115.5
Millstone No. 1	-	66.9
Big Rock Point	-	35.2
Average of the Cost Estimates	65.3	77.3

Source: D. F. Greenwood, R. K. Westfahl and J. W. Rymsha, p. 7-10 display considerable variation. The immediate dismantlement cost estimates for pressurized water reactors vary from 122 million to 35.6 million dollars with a mean of 65.3, while the estimated cost of immediate dismantlement for a boiling water facility varies from 145.8 million to 35.2 million dollars with an average estimated cost of 77.3 million. The considerable variation in these cost estimates is related to the many crucial assumptions regarding such factors as permissible occupational exposure levels and disposal methods.

Safe Storage (SAFSTOR) Cost Estimates

The cost of decommissioning by safe storage consists of three temporally distinct expenditures: the cost of preparing the facility for safe storage, the cost of continuing care throughout the dormancy period, and the cost of final dismantlement and decontamination at the end of the dormancy period.

A breakdown of the costs of preparing a boiling water reactor and a pressurized water reactor for passive safe storage is presented in table 4-3. This estimated cost information is based on the Battelle studies[21] of reactor decommissioning that was adjusted and converted to 1982 dollars by the Stone and Webster analysts.[22] The much higher labor expense for the boiling water reactor relative to the pressurized water reactor reflects in large measure the assumption of a lower permissible occupational exposure in the boiling water reactor study.

Decontamination under passive safe storage is minimal, consisting primarily of a chemical decontamination of the reactor coolant system and other equipment with readily accessible contamination. Easily removable radioactive wastes are then shipped to an off-site burial facility. Very high levels of radioactivity will remain in the reactor building.

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[21] R.I. Smith, et al., op cit. and H.D. Oak, et al., op cit.

[22] D.F. Greenwood, et al., op cit.

TABLE 4-3

THE COST COMPONENTS IN PREPARING A COMMERCIAL NUCLEAR FACILITY FOR PASSIVE SAFE STORAGE

Cost Components	Boiling Water Reactor SAFSTOR Costs (millions of 1982 dollars)	(% of cost)	Pressurized Water Reactor SAFSTOR Costs (millions of 1982 dollars)	(% of cost)
Radioactive Materials Disposal	1.71	7.2	4.21*	29.7
Labor	15.75	66.0	5.11	36.1
Electrical Power	2.97	12.4	2.60	18.3
Tools, Equipment and Supplies	2.39	10.0	1.41	9.9
Specialized Contractor Services	0.28	1.2	0.42	3.0
Insurance and License Fees	0.77	3.2	0.42	3.0
Total	23.87	100.0	14.17	100.0

Source: D. F. Greenwood, R. K. Westfahl and J. W. Rymsha, pp.5-8

*Includes 3.46 million dollars for the shipment of spent fuel.

A summary of the estimated costs of passive safe storage from a number of different studies is presented in table 4-4. The average estimated preparation cost for the passive safe storage of a pressurized water reactor is 6.9 million dollars with a range of estimates from 3.5 million to 14.2 million. The estimated cost of safe storage preparations for a boiling water reactor ranges from a high of 23.9 million to a low 4.2 million with a mean of 11.1 million dollars.

The estimated annual security costs in the dormancy period are not included in table 4-4. These costs range from $108,000 to $192,000 per year for those studies that specify these costs. The type of security

TABLE 4-4

COST ESTIMATES FOR DECOMMISSIONING BY
PASSIVE SAFE STORAGE (SAFSTOR)

Study	Decommissioning Cost For a Pressurized Water Reactor (millions of 1982 dollars)	Decommissioning Cost For a Boiling Water Reactor (millions of 1982 dollars)
Battelle Pacific Northwest Laboratories	14.2	23.9
National Environmental Studies Project	4.0	4.2
Nuklear-Ingenieur Services	7.1	-
New York State Electric and Gas Co.	4.0	-
Maine Yankee	5.4	-
Arkansas Nuclear No. 1	3.5	-
Palisades	10.7	-
Three Mile Island No. 1	6.6	-
Davis-Besse No. 1	6.6	-
Oyster Creek	-	9.3
Average of the Cost Estimates	6.9	11.1

Source: D. F. Greenwood R. K. Westfahl and J. W. Rymsha, pp.5-8

force and its size are matters of disagreement. In general, it is expected that electronic surveillance and off-site private security personnel will be used in the case of passive safe storage.

Considerable savings in the annual expenditures for security are possible when more than one reactor is located on the same site. Security can be inexpensively provided by personnel stationed at the adjunct facility. Savings can also be realized by placing a facility in safe storage and later dismantling more than one facility at the same time.

Since many radioactive isotopes with very long half-lives will remain after the shutdown of a commercial nuclear facility which has operated for over thirty years, a final dismantlement and decontamination must be completed at the end of the dormancy period. The reduction in the radioactivity from short-lived isotopes will allow the dismantlement and decontamination process to be conducted with much less of an occupational exposure to radiation. After thirty years of safe storage, the cost of dismantlement for a boiling water reactor power station will equal about 82% of the cost of immediate dismantlement with no adjustment to reflect the time value of money.[23] After fifty to one hundred years of safe storage, the cost of dismantling and decontaminating the facility should fall to about 60% of the cost of immediate dismantlement.[24]

However, if the time value of money is taken into consideration, the present value cost of a deferred dismantlement and decontamination can be much less. Assuming a real rate of interest of three percent[25] yields discount factors of 74.4% in 10 years, 41.2% in thirty years, 22.8% in fifty years, and 5.2% in one-hundred years. Thus, a dollar spent one hundred years from now is worth 5.2 cents today, assuming that a real return of 3 percent can be earned over the period. Thus, if the dismantling and decontamination process can be delayed for many years, it is possible that its present value cost may be substantially reduced.

A problem in estimating the present value of a future expenditure is that the particular set of services involved in decommissioning a power

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[23]H.D. Oak, et al., op. cit. p. II-14.

[24]Ibid.

[25]The real rate of interest is the annual return on an investment after removing the effects of inflation.

plant may increase in cost faster than the general rate of inflation, swamping the real return on funds held for decommissioning purposes. Hence, if dismantlement costs were to increase at a sufficiently rapid rate, the present value cost of deferred dismantlement could end up higher than the cost of an immediate dismantlement. Since the future rate of inflation and the rate of increase or decrease in decommissioning costs are difficult to forecast, the actual present value cost of a deferred decommissioning is subject to considerably more uncertainty than the cost of immediate dismantlement at the end of the plant's useful life. The discounted cost of immediate dismantlement need only be forecast for the thirty to forty years in advance of the power station's shutdown. But, when final dismantlement is deferred for up to one hundred years after the facilities close, the forecasting error problem is magnified, since dismantlement costs must be forecast into the very distant future.

Deferring the final clean up into the distant future subjects society to uncertainty regarding this clean up effort. The societal cost of the uncertainty involved in delaying the final removal of a potentially serious health hazard may be worth the added cost of an immediate over a delayed dismantlement.

Entombment (ENTOMB) Cost Estimates

The entombment of a large commercial nuclear reactor which has been in operation for many years consists of the initial removal and disposal of the reactor vessel's internal components containing the long-lived radioactive isotopes which will not decay during the entombment period, and the sealing off of the remaining radioactivity from the outside world using concrete or other barriers. A breakdown of these entombment preparation costs for a boiling water reactor is presented in table 4-5.

The preparation for entombment is rather costly. However, according to tables 4-1 and 4-5, entombment preparation costs are about 67.6% of the cost of immediate dismantlement. The reduction in cost is due to the fact that the entombment process allows short-lived radioactive materials to remain at the site until they decay to harmless levels. This avoids a

TABLE 4-5

A BREAKDOWN OF THE ESTIMATED COST OF PREPARING
A COMMERCIAL BOILING WATER REACTOR FOR ENTOMBMENT

Cost Components	Cost In Millions of Jan. 1, 1982 Dollars	Cost As A Percentage of Total Cost
Radioactive Materials Disposal	8.00	17.6
Labor	25.35	55.7
Electrical Power	5.29	11.6
Tools, Equipment and Supplies	5.45	12.0
Specialized Contractor Services	0.24	0.5
Insurance and License Fees	1.19	2.6
Total	45.52	100.0

Source: D. F. Greenwood, R. K. Westfahl and J. W. Rymsha, p.9.

significant amount of the decontamination and disposal costs which would otherwise be incurred.

One important cost which is highly relevant to both entombment and passive safe storage is the lost income from the site during the entombment or storage period. The value of this property in its best alternative use will be different for each nuclear facility studied. Also, the value of such real estate is difficult to forecast with accuracy. Given the estimation difficulties, most studies of decommissioning do not include the potential rental value of the site on which the closed nuclear facility is located as part of the dormancy period's annual cost. For a nuclear facility that occupies a very choice industrial location, the lost income from the site may make entombment unattractive. The potential for lost income from the site should be judgmentally incorporated in the final choice of a decommissioning option, especially given the potential future scarcity of good power plant sites.

The cost estimates made by a number of studies of entombment are reported in table 4-6. Some of these cost estimates include annual future costs such as surveillance. The estimates of these annual costs range from \$69,000 to \$145,000 per year.[26] The estimated total entombment costs range from 7.8 to 49 million dollars for pressurized water reactors with a mean of 17.2 million. The estimated entombment costs for a boiling water reactor range from 13 to 45.5 million dollars with an average of 28.5 million.

Adjusting Decommissioning Cost Estimates to Reflect Plant Size

One important factor in estimating the decommissioning cost of a nuclear power station is the size of the facility. Nuclear plant size is typically measured in megawatts of thermal power MW(t).[27] Larger nuclear plants will, of course, require a greater decommissioning expenditure. However, there are economies of scale involved in decommissioning such that the decommissioning of a plant that is twice as large will not be twice as expensive.

A scaling factor has been estimated which allows Battelle's estimate of the decommissioning costs for a boiling water reactor (BWR) to be adjusted to reflect different plant sizes.[28] The original decommissioning study was based on a reference boiling water reactor of 3,320 MW(t). The scaling factor was derived by examining the main component parts of six

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[26]D. F. Greenwood, et al., op cit. p. 3.

[27]Thermal Megawatts, MW(t), indicate the heat output of the facility in operation. The portion of this heat energy that is transformed into electrical energy is the Megawatt, MW(e), capacity of the plant.

[28]H.D. Oak, et al., op cit., pp. XIV-1 to 3.

TABLE 4-6

COST ESTIMATES FOR DECOMMISSIONING
BY ENTOMBMENT (ENTOMB)

Study	Decommissioning Cost For a Pressurized Water Reactor (millions of 1982 dollars)	Decommissioning Cost For a Boiling Water Reactor (millions of 1982 dollars)
National Environmental Studies Project	12.7	13.0
Department of Energy	7.8	-
New York State Electric & Gas Co.	16.1	-
Arkansas Nuclear No. 1	7.9	-
Prairie Island No. 1	14.7	-
Maine Yankee	13.8	-
Three Mile Island No. 1	49.0	-
Davis-Besse No. 1	15.3	-
Battelle Pacific Northwest Laboratories	-	45.5
Monticello	-	15.1
Oyster Creek	-	40.4
Average of the Cost Estimates	17.2	28.5

Source: D. F. Greenwood, R. K. Westfahl and J. W. Rymsha, pp. 6-9.

smaller boiling water nuclear facilities[29] (i.e., Vermont Yankee, 1,593 MWt; Oyster Creek, 1,600 MWt; Monticello, 1,670 MWt; Cooper, 2,381 MWt; Dresden 2, 2,527 MWt; and Peach Bottom 2, 3,293 MWt). Scaling factors for each major cost component are developed and then used to produce a composite cost estimate for each of these facilities. Fitting an equation to the composite cost estimates for each of the seven reference plants, including the original facility, yields the following cost scaling factor, CSF.

$$CSF = 0.324 + (.0002035 \times MWt) \qquad [1500 < MWt < 3400]$$

The term MWt is the thermal megawatt capacity of the power station. A plant with a thermal megawatt capacity of 1,800 would have a cost scaling factor of 0.6903 (i.e., 0.324 + 0.0002035 x 1,800). The estimated immediate dismantlement cost for an 1,800 MWt boiling water reactor is found by applying this cost scaling factor to Battelle's estimated cost for immediate dismantlement. Hence, the cost of immediate dismantlement for a 1,800 MWt boiling water reactor is 46.5 million dollars, which is the Battelle's cost estimate for a large reactor (3,320 MWt) of $67.35 million[30] times the cost scaling factor of 0.6903. This cost scaling factor can also be used to rescale estimates of the preparations cost for safe storage and entombment and the cost of deferred dismantlement.

This cost scaling factor should only be used for nuclear plants within the size range from 1,500 MWt to 3,400 MWt. Since the cost scaling factor was developed based on boiling water reactors within this size range, application of this cost factor to plants of a much larger or smaller size is inappropriate. Also this scaling factor ought to be used for the scaling of Battelle's decommissioning cost estimates for which it

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[29]Ibid., p. XIV-1.

[30]Costs are adjusted to 1982 dollars.

was designed. Using this scaling factor to adjust the decommissioning cost estimates of other studies could lead to a considerable distortion of their estimates.

The scaling factor from Battelle's boiling water study does not apply to pressurized water reactors, though it does yield a rough estimate of the cost of decommissioning pressurized water facilities. Using the boiling water scaling factor on a pressurized water plant would overestimate the cost of decommissioning a pressurized water reactor, since boiling water reactors are typically more expensive to dismantle and decontaminate than pressurized water reactors. Note that the CSF formula implies fixed costs of 21.8 million dollars (i.e., 67.35 million times 0.324) for an immediate dismantlement of any plant size or type.

Factors Producing Variation in Estimates of Decommissioning Costs

The decommissioning cost studies mentioned in this chapter contain cost estimates that vary substantially. Many factors contribute to this wide variation in the estimated costs of the various types of decommissioning.

The size of the nuclear facility being decommissioned will significantly affect the estimated cost of decommissioning. As examined in the preceeding section, many decommissioning cost factors such as the volume of materials to be shipped to a burial site will vary considerably with the size of the plant.

The type of plant involved may strongly affect the decommissioning cost estimate. Boiling water facilities are typically more costly to decommission than pressurized water reactors. The estimated cost of decommissioning these two types of facilities is shown in separate columns in tables 4-2, 4-4, and 4-6. Demolition and disposal costs can vary significantly especially when comparing plants with once-through cooling systems to those plants with cooling towers.

The scope of the decommissioning activity is often defined quite differently. The final removal of fuel assemblies is considered a part of the normal operating expense in some studies and a cost of decommissioning in others. The costly demolition of decontaminated concrete structures may or may not be included in the decommissioning cost. The extent to which the operating systems of the facility are dismantled and decontaminated may vary across studies. In some cases, the decontamination may be confined to the reactor vessel itself. In other cases, the decontamination of the reactor, the steam supply system, turbines, pumps, and other parts of the operating system is included. The scope of the decommissioning effort needed strongly influences the cost estimates.

A multiple-unit site can result in considerable economies. Continuing care at the site can be provided from personnel at those power stations still in operation. Also saving can be realized by decommissioning more than one nuclear facility at a time.[31]

The Refurbishment of Commercial Nuclear Power Stations

The useful life of a nuclear reactor may be significantly extended by replacing the reactor pressure vessel and repairing or replacing other equipment. One recently completed study indicates that at the end of a nuclear plant's life cycle the additional expenditure needed to extend the useful life of the plant for ten to twenty years will be an attractive investment opportunity.[32] The cost of extending the life of nuclear power stations is expected to be significantly less than the cost of constructing a new facility. However, the NRC has not as yet established regulations or standards for the requalification and operating license extension for refurbished nuclear power plants.[33]

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[31]Greenwood, op. cit., p. 3.

[32]C.A. Negin, et al., Extended Life Operation of Light Water Reactors: Economic and Technological Review, 2 vols. (Palo Alto, Cal.: Electric Power Research Institute, 1982), 1:II-1.

[33]Ibid., 1:V-2.

The potential for extending the useful life of a commercial nuclear power station has several implications for the estimation of decommissioning cost. Immediate dismantlement would be delayed by the ten to twenty years of the plant's additional operating life. Assuming a rate of increase in decommissioning costs which is less than the nominal rate of interest, the present value of immediate dismantlement costs would be reduced by the delay of final decommissioning. Similarly, the present value cost of decommissioning by safe storage or entombment would typically be reduced, since under any of these decommissioning options all cash expenditures would be shifted ten or twenty years further into the future.

Once a specific decommissioning option has been chosen and reasonable estimates of the decommissioning cost arrived at, the alternative means of funding these future decommissioning expenditures must be considered. The complex array of funding possibilities merits the detailed treatment presented in the following two chapters of this report.

CHAPTER 5

METHODS OF FUNDING DECOMMISSIONING AND THEIR POSSIBLE REGULATORY TREATMENTS

In this chapter, various methods of funding the costs of decommissioning are presented. The primary focus of this presentation is the regulatory treatment of these costs and their potential impact on the revenue requirement. The funding methods are presented according to the timing of the creation of the fund relative to the plant's useful life. Funding may occur prior to reactor start-up, over the plant's useful life, or at retirement before decommissioning. In each of these cases, it is assumed that the public utility commission has been provided with a reasonably accurate estimate of the costs of decommissioning a specific plant using a given decommissioning option. As a result, differences in the cost of decommissioning to be borne by consumers are due, in this analysis, solely to the way in which the fund is structured and the regulatory treatment of these costs. In addition, each of these methods of funding decommissioning could be supplemented by surety bonds, insurance, or government assurances. These supplements would be used to cover any inadequacy of the fund when insurable events leading to premature decommissioning occur. By coupling plant-specific methods of funding with these risk-pooling supplements, the utility can raise the level of assurance that decommissioning will be funded.

The regulatory treatment of the costs of decommissioning affects the revenue requirement in three general areas. First is the payment to the fund itself. Typically, these payments are discussed in terms of a schedule of payments that collect or recover the paid-in principal of the fund over the useful life of the plant. Choice of a payment schedule raises substantive issues concerning efficiency and intergenerational equity. The annual payment is based either on formulas for capital recovery factors or standard depreciation formulas. Equity and efficiency issues surrounding the determination of the annual payments are discussed in the next chapter. The second way the revenue requirement is affected is through the possible rate base treatment of the fund. This can be an issue particularly when the utility retains control over the fund. The merit of allowing the utility to earn a return on the fund or some portion of it depends for the most part on the funding method under consideration. These issues are treated with the presentation of each method. The third way in which funding the costs of decommissioning can affect the revenue requirement is through the tax expense. Since the effect of the tax expense on the cost of the fund to consumers is so pervasive, it is treated in a seperate section in this chapter.

This chapter is organized into five sections. In the first section, the effects of the tax expense on the costs of the fund are discussed. The methods by which the cost of decommissioning can be funded at or prior to reactor start-up and their regulatory treatments are discussed in the second section. In the third section, methods that accrue the cost of decommissioning over the plant's useful life are presented. In the fourth section, methods that allow the utility to fund the costs of decommissioning at the time of decommissioning are presented. Finally, in the fifth section, supplementary measures that pool the financial risks associated with premature decommissioning are discussed.

Tax Expenses

Taxes associated with funding decommissioning have a pervasive effect on the revenue requirement. Taxes can enter in the determination of the amount that the fund must accumulate, the growth rate of the fund, the annual payment toward or recovery of the cost of decommissioning, the net operating revenues, and the utility's corporate income tax liability. These effects on the revenue requirement come from four sources. First, the cost of decommissioning is a deduction from taxable income in the years that decommissioning occurs. The second tax effect concerns an IRS statement of position on the tax status of payments made to the fund to defray the costs of decommissioning. The third tax effect involves the tax rate applicable to interest income earned by the fund, if any and if taxable. The fourth tax effect concerns the utility's tax liability that may be incurred as a result of including the decommissioning fund in the utility's rate base. This inclusion can occur to generate monies to pay interest and dividends under the prepayment option or to pay a return to the fund under the modified sinking fund. Each of these tax effects has an impact on the revenue requirement. Since tax rates and Internal Revenue Service (IRS) policy are outside the control of public utility commissions, the effect of the tax expense on the cost of the fund to consumers can weigh heavily in the evaluation of the relative merit of different funding methods.

Under present IRS policy, a decommissioning expense is deductible in the year in which it occurs. This deduction as an expense creates a tax savings for consumers which a public utility with commission authorization must allocate among generations of consumers. One can think of this allocation in terms of normalization and flow-through of tax expenses though it is not exactly analogous. With normalization, the tax deduction is used to lower the principal paid to the fund over the life of the plant by the utility's consumers. The tax expense included in the revenue requirement for the years in which decommissioning occurs is left unchanged. The difference between the revenue requirement collected from consumers at the time of decommissioning and the actual taxes paid by the utility at this time provides remaining funds for decommissioning. This normalization procedure can be formalized as follows:

$$(1 - \tau_c)C_t \qquad (5.1)$$

where C_L is the present value of the escalated cost of decommissioning, and τ_c is the combined federal, state, and local income tax rate. This expression (5.1) is the amount on which the fund is to be based when the decommissioning expense is tax deductible and this deduction is normalized. At the time of decommissioning the fund provides $(1-\tau_c)C_L$, while the tax deduction provides $\tau_c C_L$ at the time of decommissioning. Through this normalization procedure, a public utility commission can allocate the benefits of the tax deduction to ratepayers who consume power from the nuclear facility. This allocation of the benefit of the tax deduction is in conformity with objective five in chapter 1. For the remainder of this chapter and chapter 6, it is assumed that all of the tax saving is allocated in this manner.

Of course, a public utility commission could allocate this tax savings in a different manner. Flow through of the tax deduction would use the actual tax liability the utility incurs in any given year as the tax expense included in the revenue requirement. Accordingly, the consumers at the time of decommissioning would have their taxes reduced by the amount of the tax deduction resulting from the decommissioning expense. In this case enough money must accumulate in the fund to cover the full cost of decommissioning. Flow through, when implemented in this manner, has the effect of increasing rates to ratepayers who consume power from the nuclear facility, but decreasing rates to consumers at the time of decommissioning.

Concern over normalization and flow-through may be moot if the fund is structured to meet certain IRS guidelines. If met, the payment of principal out of retained earnings to a private or public trustee would be considered non-income, and therefore not taxable. At the same time, however, the decommissioning expense, when incurred, would not be tax deductible under this guideline. This IRS policy has the same practical effect on the revenue requirement as did the normalization of the tax deduction. The substantive changes are the elimination of the uncertainty surrounding the utility's ability to use the tax deduction at the time of decommissioning and the uncertainty of the corporate tax rate several years in the future.

The IRS has indicated that the foregoing tax treatment is available in certain limited circumstances. To be eligible for the nonrecognition of income, a fund must operate in the following manner. First, funds collected from the utility's ratepayers for decommissioning must be immediately segregated from the utility's assets and deposited in a blind trust. The utility cannot have even short-term use of the funds. Second, the blind trust cannot invest the funds collected for decommissioning in the utility's assets. Third, control of the blind trust is vested in parties not normally involved in the utility's operations. Finally, if the payments to this fund exceed the actual cost of decommissioning, the excess funds should be paid back to the utility's ratepayers. If the excess is returned to the utility, the tax-exempt status of the fund could be jeopardized. The practical effect of this tax treatment of advanced payments to a public or private trustee is to place the utility in the position of collecting funds for another organization.

The third tax effect concerns the tax rate that is applicable to the return earned by the fund. When the utility controls the fund, the return earned by the fund is taxed at the rate determined by the combined federal, state, and local corporate income tax rate of the utility. When the fund is controlled by a trustee external to the utility, the applicable tax rate on the return earned by the fund depends on whether the fund is controlled by a private or public trustee. A privately held trust is subject to the tax rates applicable to the beneficiary of the trust, while a public trust administered by a state government is tax-exempt. In the case of a private trustee and a fund controlled by the utility, income taxes on the return earned by the fund can be avoided by investing in tax-exempt state or municipal securities.

The practical effect of taxes levied on the return earned by the fund is to change the growth rate of the fund. A fund designed such that paid-in principal plus interest earned over the life of the plant covers the estimated cost of decommissioning affects the revenue requirement differently according to the tax rate to which the return on the fund is subject. After-tax returns are the proper measure of return to use in evaluating the relative cost of an option for funding.

The final tax effect involves the regulatory treatment of the paid-in principal of the fund. In certain circumstances, a public utility commission may wish to include the paid-in principal of the fund in the utility's rate base when either the prepayment option or modified sinking fund is used. When this inclusion is deemed an appropriate policy, the tax on this return enters the revenue requirement.[1]

Funding at Commissioning

In this section, the prepayment of the estimated cost of decommissioning to a utility account or trustee is presented. Since the Nuclear Regulatory Commission staff supports this funding option, it merits careful consideration. A public utility commission may instruct a utility to implement the prepayment option in several ways, each of which raises substantive ratemaking issues.

The NRC staff has described the prepayment option as follows: "cash or other liquid assets that will retain their value for the projected operating life of the plant may be set aside or deposited, prior to reactor start-up, in an account controlled by the licensee or some public body. Such funds could cover the estimated cost of decommissioning at start-up or could be invested such that the principal plus accumulated interest over the useful life of the plant together were sufficient to pay decommissioning costs."[2] While this description of this funding option provides a strong conceptual basis, the regulatory treatment of the costs associated with the fund needs to be specified. How the fund is to be raised, how it is recovered from the utility's customers, the rate base treatment of the unrecovered amount, and the handling of the tax expenses will affect the cost of the fund to the utility's consumers. Each of these aspects of the prepayment option is discussed in this section.

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[1]If a public utility commission considers a utility's consolidated tax return for ratemaking purposes, the tax liability associated with the return earned on the paid-in principal included in the rate base might not be fully included in the utility's revenue requirement. In this case, the earnings of the subsidiary are being reduced to cover some portion of this tax liability.

[2]R.S. Wood, Assuring the Availability of Funds for Decommissioning Nuclear Facilities, NUREG-0584, Rev. 2 (Washington, D.C.: 1980), pp. 9-10.

The way in which the initial prepayment amount is raised by the utility is an important determinant of the cost of the fund to consumers. With one approach, the utility would raise the initial prepayment amount through an issuance of its own securities equal to the amount of the prepayment. Since the date of reactor start-up can be anticipated with reasonable accuracy, this issuance can be accomplished within the constraints of the utility's financial strategy. This approach creates additional interest and dividend expenses for the utility.

An alternative approach to raising the prepayment would be to use the retained earnings for the year in which commissioning takes place. The use of stockholder's equity in this way would create an obligation to pay a return on the use of their equity for this purpose. However, this approach could create financial difficulties for the utility. Therefore, it will be assumed that the utility raises the prepayment by issuing new securities.

The prepaid fund is invested by either the utility or by a trustee external to the utility in securities that will retain their value over the reactor's useful life. The ratemaking issues that a public utility commission needs to resolve are the methods by which the prepayment is recovered from the utility's consumers and whether consumers should be required to pay a return on the unrecovered portion of the prepayment. The rate base treatment of such a fund would probably be a controversial issue in rate hearings.

Once the fund is established, whether internal or external, the method by which the prepayment is recovered from the utility's consumers must be determined. Intergenerational subsidies and the determination of the cost of service are the primary issues the commission will confront. In general, annual payments over the plant's useful life would seem an appropriate policy by which to recover the prepayment. To impose these costs on the utility's consumers prior to reactor start-up or after the retirement of the plant from service would seem at face value to violate the objective that a funding mechanism be efficient and equitable. This objective requires that the ratepayers who receive the benefit from the nuclear plant's operation should bear the cost of the plant including the cost of decommissioning. It suffices to conclude at this point that this objective is best achieved by recovering the prepayment through annual payments over the plant's useful life.

Since the utility must issue securities to raise the prepayment, interest and dividends on the stocks and bonds must be paid to the holders of these securities. This obligation raises the question of including the unrecovered portion of the initial prepayment in the utility's rate base. This inclusion would generate the return necessary to pay the interest and dividends associated with the fund. This line of reasoning remains valid whether the fund is controlled by the utility or an outside trustee. The decisive issue would seem to be the "used and useful" status of the future decommission expense that has been prepaid.

Table 5-1 presents a set of formulas that can be used to determine the change in the revenue requirement when the cost of decommissioning is prepaid by the utility. Formula 5.2 shows that the amount of the present value of the escalated cost of decommissioning, C_L, must be adjusted in two ways to obtain the amount of the prepayment to the fund. As previously mentioned, the adjustment by the factor $(1-\tau_c)$ accounts for the normalization of the tax deduction of the decommissioning expense. The second adjustment by a factor, β, compensates the prepayment for the effect that income taxes have on the rate of return earned by the fund over the reactor's useful life. In formula 5.3, the amount of this prepaid principle that is to be recovered each year from consumers is determined by the factor α_t. Since this annual recovery comes out of retained earnings, taxes must be paid by consumers for the utility to have the annual recovery after taxes. This tax expense is given by formula 5.4. Formulas 5.5 and 5.6 show the change in the revenue requirement that is attributable to the inclusion of the unrecovered portion of the prepaid principal in the utility's rate base. The expression in brackets is the portion of the prepayment yet to be recovered in a given year, while r is

TABLE 5-1

FORMULAS FOR DETERMINING THE CHANGE IN THE REVENUE REQUIREMENT FOR THE PREPAYMENT OPTION

Revenue Requirement Entry	Formula	
Amount of the Prepayment to the Fund	$\beta(1 - \tau_c)C_L$	(5.2)
Annual Recovery of the Prepaid Principal	$\alpha_t \beta (1 - \tau_c)C_L$	(5.3)
Taxes Associated with the Annual Recovery	$\tau_c \alpha_t \beta C_L$	(5.4)
Allowed Return on the Unrecovered Portion of the Prepayment Included in the Rate Base	$r \beta(1 - \tau_c)C_L \left[1 - \sum_t \alpha_t\right]$	(5.5)
Taxes Payable on the Allowed Return Earned on the Unrecovered Portion of the Prepayment	$\tau_c r \beta C_L \left[1 - \sum_t \alpha_t\right]$	(5.6)

where

C_L - the present value of the escalated cost of decommissioning

τ_c - the combined federal, state, and local corporate income tax rate

β - tax adjustment factor for taxes levied on the return earned by the fund

α_t - the portion of the prepayment that is recovered annually

r - the utility's cost of capital

t - an index of years in the reactor's useful life

L - the useful life of the reactor

Source: Authors

the utility's allowed rate of return. Formula 5.5 yields the allowed return for a year in the plant's useful life, and formula 5.6 determines the tax liability associated with that after-tax return. The sum of formulas 5.3, 5.4, 5.5, and 5.6 yields the change in the revenue requirement for a given year in the reactor's life. The addition of formulas 5.3 and 5.4 yield the before-tax annual recovery of paid-in principal, while formula 5.5 and 5.6 yield the before-tax return on the unrecovered principal included in the rate base.

The present value cost of decommissioning at the end of the plant's useful life (C_L) is determined by the following computation

$$C_L = \frac{C_o (1 + \pi)^L}{(1 + i)^L} \tag{5.7}$$

where C_o is the cost of decommissioning in the year the reactor is commissioned; π is the assumed rate of inflation for decommissioning costs, and i is the appropriate discount rate for the cost of decommissioning.[3]

The β adjusts the prepayment amount to reflect the after-tax return on the securities in which the prepayment is invested. As previously noted, this after-tax return is the growth rate of the fund. This adjustment factor is given by

$$\beta = \frac{(1 + i_o)^L}{(1 + i_a)^L} \tag{5.8}$$

where i_o is the risk free rate of return, and i_a is the after-tax return earned by the fund.

The portion of the prepayment that is recovered each year, α_t, is determined by standard depreciation practices. Straight-line, accelerated, or decelerated depreciation formulas may be used to calculate α_t.

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[3]The period over which costs are escalated and discounted assumes that decommissioning occurs at the end of the reactor's useful life. If there is a cool-down period or a period of storage, the period over which costs are escalated and discounted changes accordingly.

Variations in the revenue requirement associated with the possible ways of setting up the prepayment option are attributable to the tax status of the return earned by the fund and, if taxable, the tax rate to which it is subject. When the utility controls the fund, it can invest the prepayment in taxable securities or tax-exempt state or municipal bonds. The possible values of the after-tax return (i_a) in equation 5.7 are as given by one of the following:

$$i_a = i(1 - \tau_c)$$

$$i_a = i^*$$

where i is the before tax return on taxable securities held by the fund, and i^* is the interest rate paid on tax-exempt securities. When the control of the fund is vested in a private or state trustee, the possible after-tax returns (i_a) are given by one of the following:

$$i_a = i$$

$$i_a = i(1 - \tau)$$

$$i_a = i^*$$

where τ is the income tax rate applicable to the income of the trust fund. The after-tax return is equal to the before-tax return when control of the trust is vested in the state. In these circumstances, the trust is tax-exempt rather than the securities in which it invests.

Funding Over the Plant's Useful Life

In this section, methods of raising the funds to cover the estimated cost of decommissioning over the plant's useful life are presented. The NRC staff has identified the external sinking fund and the internal sinking fund as two broad categories of this option. The external sinking fund is described by the NRC staff as follows: "[t]he funded reserve accumulated over the estimated life of the plant, or sinking fund, requires a prescribed amount of funds to be set aside annually in some manner such that the fund, plus any accumulated interest, would be sufficient to pay for costs at the estimated time of decommissioning."[4] The internal sinking fund is described to be similar to the external sinking fund, but the fund is held by the utility and segregated from the rest of its assets. The reserve in the fund can be invested in the utility's or any other company's securities. The external trustee holds a portfolio of securities, and the utility holds a portfolio when the fund is internally held. In both cases, the rate of return earned by the fund is not necessarily paid by the utility's ratepayers. Payments of principal to an external fund are potentially eligible for non-recognition as income. As previously discussed, this would make annual payments to the external fund tax exempt.

There would be several substantive differences in the regulatory treatment of internal and external funds. These involve (1) the impact on the revenue requirement resulting from the annual payment to the fund, (2) the regulatory treatment of payments to a utility account (internal sinking fund), and (3) the special tax treatment of annual payments to an external sinking fund.

The sinking fund approach to funding the cost of decommissioning builds a fund over the useful life of the plant. The annual payment of principal to the fund is based on the cost of decommissioning less the tax savings the utility incurs when decommissioning takes place. Associated with this annual payment to the fund is the annual tax expense. The annual payment of principal to the internal and external sinking fund is a use of retained earnings. In order to have retained earnings sufficient to cover the annual payment to the fund, taxes associated with the annual payment of principal must be included in the revenue requirement.

The annual payment of principal to the fund and the taxes associated with it are the two costs that enter the utility's revenue requirement for both the internal and external sinking fund. Formulas summarizing these

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[4] Assuring the Availability of Funds for Decommissioning Nuclear Facilities, NUREG-0584, Rev. 2, op. cit., p. 10.

entries are presented in table 5-2. The tax deduction the utility incurs at the time of decommissioning is deducted from the escalated cost of decommissioning. The present value of the resulting net cost is spread over the plant's useful life. This treatment of the tax deduction is depicted by formula 5.9 that determines the amount the fund must accumulate. The sum of formulas 5.10 and 5.11 yields the before tax effect of this funding option on the utility's revenue requirement.

TABLE 5-2

FORMULAS FOR DETERMINING THE CHANGE IN THE REVENUE REQUIREMENT WHEN FUNDING OCCURS OVER THE REACTOR'S USEFUL LIFE

	(A) Payments Considered Income		(B) Payments Considered Nonincome	
Amount that the Fund Must Accumulate	$(1 - \tau_c)C_L$	(5.9)	C_L	(5.12)
Annual Payment of Principal to the Fund	$\alpha_t(1 - \tau_c)C_L$	(5.10)	$\alpha_t C_L$	(5.13)
Taxes Associated with the Annual Payment to the Fund	$\tau_c \alpha_t C_L$	(5.11)	0	

C_L - the present value of the escalated cost of decommissioning

τ_c - the combined federal state, and local corporate income tax rate

α_t - the fractional payment of principal in year t

Source: Authors

Annual payments of principal to the fund are determined according to capital recovery formulas. These formulas are used to determine the α_t in expression 5.10 and 5.11 in table 5.2. The rates of return used in calculating this factor should reflect the risks associated with the utility's income. In addition, the capital recovery factor should be adjusted to reflect the impact of income taxes, if any, levied on the return of the fund. This adjustment is combined with the capital recovery factor.

Two distinct capital recovery factors can be used in the calculation of αt, the portion of the present value of the escalated cost of decommissioning paid to the fund each year. One capital recovery factor is used to compute constant nominal payments of principal to the fund each year. It is given by

$$\alpha_t = \left[\frac{(1 + i_o)^L}{(1 + i_a)^L}\right] \left\{\frac{r}{1 - (1 + r)^{-L}}\right\} \qquad (5.14)$$

where r is the utility's cost of capital, i_o is the risk-free rate of return, i_a the after-tax return earned by the fund, and L is the useful life of the reactor. The first expression in brackets adjusts the capital recovery factor for the effect of taxes on the return earned by the fund. The potential cost differences between internal and external funds would enter the revenue requirement through this term. The second expression in brackets is the annual cost of an annuity that has a present value of a dollar and that pays the utility's cost of capital. The product of these two expressions yields the portion of the present value of the escalated cost of decommissioning to be recovered each year so that constant nominal annual payments are made to the fund.

If, instead, constant real annual payments of principal to the fund are desired, the portion to be recovered in any given year is given by

$$\alpha_t^* = \left[\frac{(1 + i_o)^L}{(1 + i_a)^L}\right] \left\{\frac{(r - \pi)(1 + \pi)^{t-1}}{\left[1 - \left(\frac{1 + r}{1 + \pi}\right)^{-L}\right]}\right\} \qquad (5.15)$$

where t is an index of the years in the plant's useful life, π is the assumed rate of inflation for decommissioning costs. All other terms are used as previously defined. This capital recovery factor determines the annual payment considering inflation in the cost of decommissioning. It determines a constant annual payment in real dollars. The first expression in brackets on the right hand side adjusts the capital recovery factor for the after-tax return earned by the fund. The second expression in brackets adjusts the capital recovery factor for the effects of inflation. The inflation rate used in this calculation is the same rate of inflation used in the calculation of C_L in equation (5.7) above. This adjustment for inflation in the capital recovery factor only affects the time pattern of payments to the fund, not the amount to be recovered.

As noted above, the difference between internal and external sinking funds is attributable to the after-tax rate of return earned by the fund. The tax adjustment factor adjusts the growth of the fund for the effect of taxes levied on the return earned by the fund. The after-tax return can be one of the following:

$$i_a = i$$

$$i_a = i\ (1 - \tau)$$

$$i_a = i^*$$

where i is the before-tax return on taxable securities held by the fund and i^* is the return on tax exempt securities.

External funds can be held by a public or private trustee. In the case of a private trustee, the return paid by the fund is taxed at the tax rate applicable to the beneficiary. When the trust is controlled by a state trustee, the return on the fund is tax exempt irrespective of the tax status of the securities in which it invests. Finally, both a public and a private trustee can invest in tax-exempt state or municipal bonds.

An internal sinking fund can be invested in the utility's securities, the securities of other companies, or government securities, including tax-exempt state and municipal bonds. Interest income earned by the fund, irrespective of its source, could be reported as "Other Income" by the utility. With the exception of interest paid on tax-exempt securities, this other income is subject to the corporate income tax rate. These taxes reduce the rate of return earned by the fund (its growth rate) and, therefore, require larger annual payments.

The external sinking fund is a trust fund controlled by an entity outside the utility. As discussed previously, the IRS has indicated that under specific circumstances the annual payments to an external sinking fund can qualify for non-recognition as income. In essence, the fund must be structured so that the utility collects the payments for the trustee and at no time has access to or use of the fund until decommissioning occurs. At that time, only those funds necessary to defray the cost of decommissioning can be transferred to the utility. All remaining funds in the trust must be refunded to consumers, not to the utility. In these circumstances, the external sinking fund affects the revenue requirement differently from the other sinking fund approaches.

This approach is summarized in column B of table 5-2. When the annual payments to the fund are tax exempt, the annual payment to the fund is based on the estimated cost of decommissioning. This is shown by formula 5.12. There would not be a tax savings at the time of decommissioning because the decommissioning expense would not be deductible. Instead, the annual payments to the fund, as given by formula 5.13, are not considered income, and, therefore, not considered to be paid from retained earnings. This approach avoids the tax expense associated with the earnings when making payments from retained earnings. Thus, only the annual payment affects the revenue requirements. This approach is summarized in column B of table 5-3.

The capital recovery factors for computing the annual payment to the fund are the same as equations 5.14 and 5.15 above. Both of these factors adjust the annual payment to reflect the effect of taxes on the return earned by the fund. What has changed under this approach is uncertainty surrounding the tax deduction the utility could receive upon decommissioning under a standard sinking fund. Note further that the cost of the fund under this special tax treatment is the same as that under the ordinary sinking fund. The advantage of this nonrecognition of income is that public utility commissions do not have to explicitly allocate the tax deduction attributable to decommissioning to consumers of the power from the reactor.

Funding at Decommissioning

An unfunded reserve that uses negative net salvage value depreciation is discussed in this section. This depreciation accounting practice allows the estimated cost of decommissioning to enter the calculation of depreciation rates. This approach to funding decommissioning does not segregate the fund from the utility's assets. Instead, a reserve for decommissioning is established and retained earnings (assuming they are positive)[5] are appropriated on an annual basis. There are two general approaches to this funding option that are discussed below.

The negative net salvage value approach to funding decommissioning recognizes decommissioning as part of the salvage process. Yet, since the cost of decommissioning exceeds the gross salvage, net salvage value is negative. Traditional regulatory and accounting practice usually requires that net salvage be either received or incurred at the end of an asset's useful life. Thus, the recovery of the cost of decommissioning through the depreciation entry increases the revenue requirement because net salvage value is negative.

There are two important considerations related to the cost for decommissioning that one uses in the calculation of net salvage value.

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[5]The commission might declare that payments to the decommissioning reserve be made before dividends are paid to preferred and common stock.

First, there is the tax savings at the time of decommissioning that would be subtracted from the cost of decommissioning. This allocation of the tax saving is consistent with its treatment under the previously discussed approaches to funding. The second consideration is determining the cost on which to base negative net salvage value.

For computing the depreciable plant value, the standard accounting practice is to subtract the estimated salvage value in current dollars from the original cost of a plant. This salvage value is not discounted back to its present value before being subtracted from the plant's original cost. It is assumed to be a future value. If the same practice is applied to the estimated cost of decommissioning, the future value of this cost less the future value of the tax savings would be factored into the net salvage value and the depreciation rate. This treatment of the estimated net cost of decommissioning is different from the treatment of costs to be incurred in the future presented in the two previous sections where the cost included in the revenue requirement is based on the present value of the estimated cost of decommissioning. Thus, one can identify two potential treatments of the cost of decommissioning under the negative net salvage value approach. One approach is to apply standard depreciation practice, and the other approach is to use the present value of the cost of decommissioning. These two approaches are presented side by side in table 5-3: in column A is the standard accounting approach, and in column B is a modified sinking fund.

With either one of these two approaches, the monies to defray the cost of decommissioning are obtained from two sources at the time of decommissioning. One source is the tax savings the utility incurs upon decommissioning the reactor. The other source is the unfunded reserve. The negative net salvage value approach should amass the balance of the decommissioning cost in the unfunded reserve over the plant's useful life. The unfunded reserve is assumed to be invested in plant assets by the utility. At the end of the plant's useful life, securities are issued against these unencumbered plant assets.

TABLE 5-3

FORMULAS FOR DETERMINING THE CHANGE IN THE REVENUE REQUIREMENT FOR FUNDING AT DECOMMISSIONING

	(A) Negative Net Salvage Value		(B) Modified Sinking Fund	
Amount that the Fund must Accumulate	$(1-\tau_c)C_L(1+i)^L$	(5.16)	$(1-\tau_c)C_L$	(5.21)
Annual Appropriation to the Unfunded Reserve for Decommissioning	$\alpha_t(1-\tau_c)C_L(1+i)^L$	(5.17)	$\alpha_t(1-\tau_c)C_L$	(5.22)
Taxes Associated with the Annual Appropriation	$\tau_c \alpha_t C_L(1+i)^L$	(5.18)	$\tau_c \alpha_t C_L$	(5.23)
The Allowed Return on the Rate Base Entry Associated with the Unfunded Reserve	$-r \sum_t \alpha_t(1-\tau_c)C_L(1+i)^L$	(5.19)	$r(1-\tau_c)C_L \left[1-\sum_t \alpha_t\right]$	(5.24)
Taxes Payable on the Allowed Return Associated with the Unfunded Reserve	$-\tau_c r \sum_t \alpha_t C_L (1+i)^L$	(5.20)	$\tau_c r C_L \left[1-\sum_t \alpha_t\right]$	(5.25)

where

C_L - the present value of the escalated cost of decommissioning.

τ_c - the combined federal, state, and local corporate income tax rate

i - the discount rate applicable to decommissioning cost (see discussion in text)

α_t - the portion of the amount the fund must accumulate that is appropriated each year

r - the utility's cost of capital

L - the useful life of the reactor

Source: Authors

Standard depreciation practice would assure this outcome by calculating the annual payment to the fund on the basis of the undiscounted future value of the negative net salvage value. If straight-line depreciation is used, the original cost of the plant (a present value) less the salvage value of the plant (a future recovery of a cost) plus the cost of decommissioning (a future cost) less the tax savings (a future revenue), is divided by the estimated service life of the plant. This annual payment is the depreciation expense associated with the nuclear facility. The accumulated depreciation at the end of the plant's useful life will exceed the original cost of the plant by the unfunded amount.

The foregoing approach to negative net salvage value is not structured in such a way that the paid-in balance to the unfunded reserve earns interest income. The negative net salvage value is not part of the original cost of the plant that enters the utility's rate base as a used and useful asset, but only through the accumulated depreciation. As a result, at the end of the plant's depreciable life, the rate base entry for this plant is negative. This treatment of the negative entry implicitly has the utility paying a return to consumers for the balance in the unfunded reserve. The return to consumers is in the form of lower rates.

Formulas 5.16 to 5.20 in column A of table 5-3 summarize the impact on the revenue requirement from the standard accounting approach. The escalated cost of decommissioning is calculated as in equation 5.7 above except that its future value is explicitly given by the term $(1+i)^L$. This formulation emphasizes that this cost is a future value.

The annual payments to the reserve for decommissioning can be calculated using straight-line, accelerated, or decelerated depreciation schedules. These payments and the income tax liability associated with them are described by formulas 5.17 and 5.18.

The cost of decommissioning enters the rate base through the provision for accumulated depreciation. The annual deduction for depreciation is increased by the annual payment to the unfunded reserve. This amount is accumulated and the balance subtracted from the rate base. This procedure is depicted by formula 5.19 in table 5-3. As just mentioned, this treatment of the unfunded reserve has the effect of paying the consumer a return on the funds the utility is using through this negative entry and the return is paid to consumers in the form of lower rates. This negative return also has the effect of lowering the utility's corporate income tax liability. Formulas relevant to this rate-base treatment are equations 5.19 and 5.20 in table 5-3.

When the present value of the decommissioning cost net of the tax saving is used to compute the negative net salvage value, a different approach to the unfunded reserve is necessary. The regulatory treatment of the unfunded reserve must be modified so that a return is paid or imputed to the unfunded reserve. The most straightforward way to accomplish this is to consider the present value of the cost of decommissioning, net of the tax savings, as an integral cost of the plant. Accordingly, the present value of this cost is included as part of the plant's rate base entry. The annual payments to the unfunded reserve would constitute a recovery of this cost through standard depreciation practices. The unrecovered portion of the fund would earn the allowed rate of return and is paid by consumers through the revenue requirement. This is labeled the modified sinking fund approach.

This approach to the unfunded reserve would provoke controversy over whether the inclusion of the present value of the cost of decommissioning, net of the tax savings, in the rate base is antithetical to the regulatory concept of "used and useful property dedicated to the public use." The utility, at the time the plant enters service under this funding scheme, has not incurred this cost nor pledged monies, assets, or securities to the public use. Thus, the rate base entry for this unfunded reserve is a tool to accomplish a purpose and is not necessarily a used or useful asset dedicated to the public use. The advisability and desirability of pursuing this policy would depend on the relative cost of the two negative net salvage value approaches.

Formulas 5.21 to 5.25 in table 5-3 can be used to calculate the change in the revenue requirement resulting from this approach. The present value of the escalated cost of decommissioning is allocated over the plant's useful life using standard depreciation schedules. Equation 5.24 and 5.25 constitute the rate base treatment of the cost of decommissioning. The utility earns the allowed return on the cost of decommissioning yet to be paid by consumers. Associated with the return earned by the utility is the corporate income tax liability it incurs.

Supplementary Assurance Options

Plant-specific options for funding decommissioning can be supplemented with surety bonds, insurance, or government guarantees. These supplements can assure that the cost of decommissioning is covered in the event of premature shutdown that leads to decommissioning. Such supplements are necessary because plant-specific financing arrangements accumulate funds over time. As a result, the fund with risks properly taken into account will cover the cost of decommissioning only at the end of the plant's useful life. If decommissioning were to occur prior to the anticipated date of retirement, one cannot be certain that the costs of decommissioning would be fully defrayed by the fund. These supplements shift this risk to another (larger) entity from the utility's consumers and stockholders or pool the risks faced by all utilities with nuclear facilities.

In this section, these supplementary assurance mechanisms are presented. This presentation will be brief and descriptive because at present these supplements are unavailable to the nuclear industry. In addition, a brief discussion of insurable events is necessary. An NRC staff document seems to suggest that cost overruns due to bad cost estimates or mismanagement of the decommissioning can somehow be covered by these supplements. There is a problem with this view that is addressed below.

This section has four parts. First, the type of insurable event for which these supplements can be purchased is discussed. In the last three parts, surety bonds, government assurances, and risk-pooling insurance arrangements are described.

Insurable Events

As previously noted, the NRC staff has suggested that cost overruns might be covered by bonding, insurance, and government revenues. While the government might ultimately be called on to bail out a decommissioning project, surety bonds or insurance for these purposes may not be desirable or efficient. In fact, proper use of discounting and capital recovery factors can account for the cost and revenue uncertainties associated with decommissioning and its funding. To propose bonding or insurance to cover these risks might introduce a perverse incentive into the decommissioning process.

As is discussed in chapter 6, costs and revenues that are certain to occur or be realized are discounted using the risk-free rate of return. When uncertainty is present, a risk premium must be included in the calculation regarding future costs and revenues. Uncertainty concerning a future cost requires a risk premium to be subtracted from the risk-free return prior to discounting this cost. Uncertainty surrounding the revenue stream that will fund the decommissioning reserve requires a risk premium to be added to the cost of capital used to compute the capital recovery factor. By accounting for cost and revenue uncertainty in this manner, the fund's level of assurance at the end of the reactor's useful life is greatly enhanced.

Providing bonding or insurance to cover cost overruns in the actual performance of the decommissioning process can have an effect on the cost estimation. There would be a tendency to minimize the risks associated with revenue uncertainty which could lead to inaccurate estimates of the costs of decommissioning. Furthermore, the knowledge that a cost overrun might be covered could lead to poor performance in the decommissioning activity. Bonding and insurance companies would be hard pressed to formulate an annual premium to provide coverage for these cost, revenue, and performance uncertainties.

More properly, bonding and insurance companies could provide coverage for risks beyond the control of the management of the utility and for which risks can be computed. This category includes accidents leading to decommissioning and possibly certain kinds of obsolescence that would shorten the reactor's useful life. Focusing bonding and insurance on these classes of risky events avoids introducing perverse incentives into the process.

Surety Bonding and Lines of Credit

A surety bond is the assumption of responsibility by one or more persons for fulfilling another's obligations. In the case of decommissioning, a bond might be negotiated that guarantees that the amount up to the face value set for the bond will be paid in the event that the utility defaults in paying for decommissioning. In other words, the surety company will assume the responsibility of paying for decommissioning up to the face value of the bond. Therefore, surety bonding can provide relief for plant-specific funding arrangements to assure adequate funds in the event of premature shutdown.

A line of credit or bank letter has the same property as a surety bond in that it guarantees that the assured funds will be available from credit or bank industry when the utility defaults. However, to tap into such a long-term source of credit is quite expensive. According to an NRC study, it is estimated that a line of credit would cost 0.5 percent more than that of surety bonding while the latter would cost about 1.5 percent to 2 percent per year of the face value of the bond.[6]

Government Assurances

Funding for decommissioning can be paid out of general tax revenues, either at the state or federal level. This implicitly assumes that either

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[6] Assuring the Availability of Funds for Decommissioning Nuclear Facilities, NUREG-0584, Rev. 2, op. cit., p. 46.

the federal government or the state government has the responsibility for decommissioning. By paying out of general tax revenue, the assurance of funds for decommissioning, both expected and premature, may be guaranteed.

Risk-pooling Insurance Arrangements

The purpose of an insurance pool for decommissioning is to supplement the plant-specific funding mechanisms in providing adequate funds for decommissioning, particularly for the case of accident-related decommissioning. Decommissioning insurance can be defined as a general fund pooling mechanism which provides funds for premature decommissioning[7] and spreads the costs of risk over all participating nuclear plants. It is a risk-sharing arrangement in that the risk of inadequate funds for decommissioning a nuclear plant is shared by all the pool participants.

Currently, three categories of nuclear insurance are available: (1) replacement power insurance; (2) first-party property damage insurance; and (3) third-party liability insurance. These funds provide some property and liability coverages in case of an accident. No insurance, however, is currently available for decommissioning expenses.

Premature decommissioning can result from two causes. One is accident initiated, and the other is non-accident initiated. This latter case is the result of some economic or technological obsolescence. The decommissioning cost for a non-accident case may be less than anticipated because of the lower levels of contamination and activation. However, an accident in the plant which requires additional decontamination and then decommissioning could easily cost $1 billion or more in 1981 dollars as

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[7]The NRC report, NUREG-0586, Rev. 2, has a proposal to provide insurance for the expected decommissioning costs, also. In fact, the expected decommissioning costs are definite expenses that have to be paid at the expected time. As such, it is not a conventional type of insurable event.

compared to $50 million for a normal, expected decommissioning.[8] As a consequence, when determining the amount of coverage, these two cases can be considered separately.[9]

One preferred organizational form of the pool, if utilities choose to insure themselves, is an "ownership-share" corporation. The ownership shares could be structured in proportion to some measure of responsibility for the capacity of the pool. It takes the form of a corporation in order to limit the liability of the utility in case the pool defaults on its obligations. Mandatory membership in such an insurance pool might be in the interest of public health and safety.

Moral hazard could result from being insured. An owner/operator might take less care in operating the plants or in reserving for decommissioning expenses if they are insured. To prevent such problems, a differential risk classification could be structured so that different premiums would be charged to utilities with different risks. This is also attractive to those utilities who perceive themselves as good risks in joining the pool. Some incentive rate structures, such as deductibles and co-insurance,[10] could also be formulated to induce the owner/operator to take good care in operating and reserving funds for decommissioning.

In general, insurance appears to be a good surety-type mechanism. The risk of inadequate funds in the event of a premature decommissioning can be

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[8]The risk of cost overruns is not an insurable event as discussed above. However, this risk can be taken into account by using proper risk factors in discounting the revenue and cost to present value.

[9]For example, in one report it has been suggested that the insurance coverage will be in the range of $500 million to $1 billion for an accident-related decommissioning and of $100 million to $250 million for a non-accident related decommissioning. See P.L. Chernick, W.B. Fairley, M.B. Meyer, L.C. Scharff, Design Cost, and Acceptability of an Electric Utility Self-Insurance Pool for Assuring the Adequacy of Funds for Nuclear Power Plant Decommissioning Expense NUREG/CR-2370 (Washington, D.C.: 1981)

[10]A deductible is an exclusion from coverage of loss costs below a fixed amount, while co-insurance is an exclusion from coverage at a certain percentage of a loss cost, possibly above a deductible or below a coverage limit.

reduced efficiently by insurance arrangement. Currently, these are not available. The industry's apparent willingness to consider such arrangements is laudable and is an activity that state regulators may wish to encourage. [11]

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[11] R.S. Wood indicated that, so far, the nuclear industry has not shown particular interest in insurance for the decommissioning purpose, nor have nuclear insurance pools indicated a willingness to offer it. See his paper, "Funding for Reactor Decommissioning: The NRC Perspective," Nuclear News, Dec. 1981, pp. 85-88. However, a questionnaire survey reported to the NRC staff indicates that the concept of a self-insurance pool is generally acceptable to the electric utility industry. Of the ten responding utilities, five will accept an insurance pool for accident-initiated decommissioning, while only two will accept an insurance pool for non-accident related decommissioning.

CHAPTER 6

EVALUATION OF FUNDING ARRANGEMENTS

The discussion in chapter 5 indicated that nuclear decommissioning can be funded in a variety of ways. Several important distinctions are whether the fund is internal to the utility or is external, and if it is external, whether it is controlled by a private or state trustee, whether the payments into the fund as well as the interest earned by the fund are taxable or not, and whether the utility sells its own securities in order to prepay the decommissioning expense. Consumer equity, the riskiness of the fund, and the present value of the revenue requirement may be affected by these various treatments. The purpose of this chapter is to evaluate the funding proposals that were described in the previous chapter. The discussion is facilitated by first describing some evaluation principles that are important but which thus far seemingly have been ignored in regulatory discussions of future decommissioning costs. This background must logically precede the actual evaluation and so it is contained in the first section. The second section contains a discussion and evaluation of the various funding proposals using five objectives as the criteria. These objectives are described in the introduction to that section and were listed in chapter 1.

Revenue Risk, Cost Risk, and Portfolio Risk

The distinguishing feature of nuclear decommissioning cost is that it is in the future. Paying for these costs in advance raises several issues. Among these are three separate and distinct types of risks. These have to do with the uncertainty that surrounds the future cost itself, the uncertainty about the earnings of any fund collected in advance, and the uncertain nature of revenue because utility demand is random. Regulators have previously needed to be concerned mostly about the last of these, revenue risk, because most cost is current or in the past. Because the other two sources of risk are less familiar, a substantial amount of confusion and even incorrect financial analysis frequently has accompanied the regulatory discussion of nuclear decommissioning costs.

Revenue risk is the reason why the utility's cost of capital exceeds the risk-free interest rate, an example of which might be the yield on long-term government bonds. That is, the reason investors require a higher rate of return for riskier projects is that the future returns to that project are more uncertain. In common parlance, the cost of capital includes a risk premium because investors want to avoid uncertainty. The entire rate of return (including the risk premium) is relevant to regulators because investors use it to convert future, uncertain returns into present, certain cost. A stockholder, for example, agrees to exchange current dollars (about which there is no uncertainty) for a future claim to uncertain returns. The regulatory process simply reverses this and calculates the expected return or annual revenue requirement by multiplying the rate of return by the rate base. The important feature of the utility's rate of return is that it serves to convert future dollars that are uncertain (because of the weather, accidents, or changes in the regulatory environment) into present dollars about which there is no uncertainty at all. The conclusion is perhaps obvious--the cost of capital can and is appropriately used to discount future revenue, but it has nothing to do with the process of converting future decommissioning cost to present value. Most, if not all, previous studies of nuclear decommissioning cost have used the utility's cost of capital, at least implicitly, to discount future cost.[1]

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[1]The list includes the Temple, Barker & Sloane study, U.S. Nuclear Regulatory Commission, Financing Strategies for Nuclear Power Plant Decommissioning, NUREG/CR-1481, (Washington, D.C.:1980) and is implicit in the discussion of funding assurance by the U.S Nuclear Regulatory Commission, Assuring the Availability of Funds for Decommissioning Nuclear Facilities, NUREG-0584, Rev. 2 (Washington, D.C.:1980), pp. 22-37. The same analytical method is used by John S. Ferguson, "The Capital Recovery Aspects of Decommissioning Power Reactors," Public Utilities Fortnightly, (September 25, 1980); Barry C. Mingst, "An Analysis of Decommissioning Costs and Funding," in Decontamination and Decommissioning of Nuclear Facilities, Marilyn M. Osterhout (ed.), Plenum Press (New York: 1980); and Preston A. Collins, "Financial and Accounting Alternatives for the Reco very of Nuclear Plant Decommissioning Costs," in Decontamination and Decommissioning of Nuclear Facilities, Marilyn M. Osterhout (ed.), Plenum Press (New York: 1980). The same procedure has formed the basis of utility

The appropriate rate at which to discount costs is a separate and independent issue from revenue. It is true that future nuclear decommissioning cost can only be estimated and accordingly is uncertain. This cost risk has at least two components. One is the uncertainty about the engineering cost of meeting a given safety and health standard and another is the regulatory risk that the NRC may change the standard. No matter what the uncertainty is that surrounds this future cost, however, it is clear that it is distinct from the uncertainty about future revenue. The conventional treatment in those studies in footnote 1, for example, is to assume that costs are known with certainty. Suppose, for the time being, that costs are indeed certain. This supposition is relaxed later. The appropriate regulatory treatment is to discount the future certain cost with the risk-free interest rate and to separately find the annual revenue requirements over the plant's life so that the sum of their present values using the utility's risky cost of capital equals the discounted cost. This suggestion is appropriate solely in the sense that it makes the present value of revenue equal to the present value of cost, the natural extension of the conventional regulatory objective of recovering the cost of service.

Whether the decommissioning fund, the source of which might be a prepayment by the utility or the accumulation of annual consumer payments, is actually invested in the utility itself or the securities of other

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representatives testifying before the Michigan Public Service Commission, Case No. U-6150, and before the California PUC as discussed in California Public Utilities Commission, Study of Recovery of Decommissioning Costs, 52536, (San Francisco, CA: October 2, 1981). The general methodology of discounting costs and revenues with the same discount rate seems to be universally accepted in the regulatory community. See for example, the comments by California Energy Commission representative Vincent Schwent, "State Regulatory Impact on Decommissioning: Financing Approaches and Their Cost," Nuclear News (April 1980). Some of these observers believe that the cost advantage of internal funding arrangements that allow the fund to grow at the utility's relatively high rate of return is decisive, while others believe that other considerations, such as assurance of funding, are more important. All believe that the cost difference is real and important.

companies or governmental agencies, is yet a third distinct issue, and one that has its own distinct risks. Investing the decommissioning fund is essentially a matter of portfolio management. As such, it has no relevance to the choice of the discount rates used for either costs or revenues. Some analysts have previously used the risk-free interest rate to discount both costs and revenue if the fund is put into government securities and have used the utility's cost of capital if the fund is internal. Once the fund has actually received money, the issues surrounding the management of these liquid assets are no different from those that are relevant to managing any wealth. An efficient portfolio would include a well diversified set of securities, including so-called risk-free government bonds as well as a market basket of risky assets. Financial analysis indicates that the best possible return for a given level of risk will be earned by efficient portfolios.

The utility's cost of decommissioning, as it actually occurs in the future or as it is perceived in today's present value, and the utility's revenues from the sale of electricity, actual or perceived, are clearly unrelated to issues about whether or not the decommissioning fund is prudently managed. There are three separate risks to consider, two of which, future cost and portfolio management, are not typically encountered in public utility regulation.

The discount rates for all three risks, then, have separate and distinct risk premiums. All three discount rates, however, are related to the risk-free interest rate. The rate of return to an efficient portfolio, for example, is the market rate of return, which has some risk. To convert future, uncertain returns to present, certain value, would involve discounting with a rate higher than the risk-free interest rate. Such a procedure is well known to regulators. Less well known is that this procedure can be reversed so as to convert present, certain values into future, certain values. This simply requires that the present value be compounded at the risk-free rate. The two steps can be combined to convert future, uncertain values into future, certain values. First discount the risky future returns using the discount rate that includes the risk premium, and then use the risk-free rate to find the future value that has been adjusted to be free of risk. For example, suppose an efficient portfolio can earn 12 percent, of which 2 percentage points is the risk premium so that the risk-free rate of interest is 10 percent. Suppose we wish to know the adjusted, risk-free value of $112 that the market portfolio will return next year. The present value is $100, discounted by 12 percent, and this is worth $110 risk-free dollars next year since the appropriate risk-free interest earnings are 10 percent. Hence, the risk-free or certain-equivalent value of $112 next year is $110 next year.

The principle is the same for payments in many future years. To find the adjusted risk-free future value of any set of future risky returns, first discount these to present value using the risky discount rate and then find the future, risk-free value by the standard compound interest rate formula using the risk-free rate. Knowing the precise value of the interest rates is of course difficult, and regulators must estimate these. The risk-free rate should be easier to estimate, however, than the cost of capital that regulators have always considered.

Having a procedure for finding risk-free or certain-equivalent future values is important since it enables us to find the risk-corrected future value of any funding proposal. Converting these to the same level of risk facilitates their comparison. The procedure also helps to understand intuitively why the discount rate for revenue is the utility's cost of capital and yet the discount rate for future, certain costs is the risk-free rate. The reason is that the entire set of future revenue requirements (these are expected or average amounts of a random return) can be converted to present value using the discount rate that reflects the inherent riskiness. The risk-free value of these consumer payments at the future time of decommissioning then can be found by using the risk-free rate. Allowing revenue just sufficient to cover cost means that the risk-free future value of the decommissioning fund equals the risk-free future cost of decommissioning. That clearly is the same as requiring revenues whose present value using the risky cost of capital is the same as the present value of the cost using the risk-free interest rate.

A second intuitive argument of why separate discount rates are needed for revenue and costs is to imagine the opposite. Suppose it were true that the appropriate discount rate for costs were the utility's cost of capital. Since the discount rate is the same for both, whether both are converted to present or future value clearly makes no difference. The typical, indeed, conventional argument is that it would be cheaper for consumers if the decommissioning fund were internal to the utility since the funds needed to accumulate the future costs will be less if the rate of return and hence growth rate of the fund is higher. Since the utility's rate of return exceeds the risk-free interest rate, this logic seemingly implies that an internal fund would require a smaller annual consumer payment. If that reasoning were true, consider other outside funding. There are riskier investments in the U.S. economy than public utilities. According to this logic, it would be cheaper still to invest the decommissioning fund in these more risky firms. Indeed, if we could only find an investment risky enough to require about 23 percentage points of risk premium, consumers would need pay only about 1 percent as much as they would if the funds accumulated at a typical utility's rate of return. The difficulty with this reasoning is that accumulating funds at such a high risky rate means that the future accumulated fund is also quite risky.

It cannot be true that risk, of any type, reduces consumer's real cost. The regulatory community has long understood that revenue risk increases the consumers' payments for current cost. The same revenue risk also increases consumers' payments for future cost. The key is that the returns and cost must be adjusted to the same level of risk before they are compared.[2]

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[2]The preceding analysis is based on a particular view of regulation. In particular, the philosophy inherent in the above example is that the purpose of regulation, among others, is to allow the utility to break even (including a normal return), on average. That is, *ex ante* revenues are

In actuality, the risk premium which is appropriate for discounting consumer payments for decommissioning may not be precisely equal to the utility's cost of capital. The relevant risk premium depends on the risk of the payments themselves. The cost of capital reflects the average risk associated with the payments to bondholders and stockholders. The regulator may be able to arrange matters so that decommissioning payments are less risky. The risk depends on the seniority of the claim. If the regulator places contributions for decommissioning senior to dividends, for example, the risk should be about the same as for bonds, and consequently the contributions have about the same risk premium as bonds. Since the regulator is increasing the utility's cash flow and simultaneously placing a decommissioning claim prior to dividends, there should be only a minor effect, if any, on the stockholders' perceived risk. Another possible way to reduce the risk of decommissioning payments is to adjust the declining block rate structures so that most of the expense is rolled into initial blocks. Revenue fluctuates because of tail block prices so that increasing the initial blocks should make the decommissioning payments more certain. That is, total revenue uncertainty should not change much if the tail block rates are not raised when recovering decommissioning expense. Another possible way to reduce the uncertainty about whether future revenue will be adequate to make the payment to the decommissioning fund is to argue that ultimately, the state or even the federal government is the decommissioning agent of last resort. If the utility becomes financilly inviable, the state may be forced to use general revenues to pay for decommissioning. In

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calculated so that they equal costs on average. After the fact, actual realized revenue may sometimes exceed and sometimes be less than cost, but is calibrated so that there is no excess profit in an expected sense. An alternative view is that regulation should always eliminate excess profits _ex post_. This can be an important issue when funds are collected in advance for future costs and the question of whether investors or consumers receive the fund's surplus or pay for the fund's shortfall must be resolved. This is discussed more fully in regard to objective 1.

these circumstances, the regulator may wish to investigate the possibility of advertising in advance that the annual decommissioning payments are backed by the full faith and credit of the state, which, of course, would require legislative approval. By so doing, the regulator would reduce, if not eliminate, the risk of no payment, and since a riskless cash flow has been created, investors may be willing to buy securities based on that future, almost riskless, revenue. The above ideas of how risk might be reduced are ones that the regulator may wish to consider for further study. In the absence of such a study, the utility's cost of capital is implicitly used to discount decommissioning revenue in the remainder of this report.

The preceding discussion serves to illustrate that the discount rates for decommissioning cost and revenue are distinct and that neither is related to the return earned by the decommissioning fund's portfolio. Cost was assumed to be known with certainty even though it was in the future. In reality, future cost can only be estimated and consequently is also a risky matter.

Is it possible that cost uncertainty could be a reason for using the utility's risky rate of return to discount future cost? The answer is no. If it were true that risk increased the discount rate used to convert future risky cost into present worth, then more risk would seemingly reduce the present value of the cost. In fact, the effect of risk is always the opposite--risk increases cost.

The appropriate way to account for future cost uncertainty is to use a discount rate which is less than the risk-free interest rate. The reason can be illustrated easily. Actually choosing the discount rate is much more difficult.

Suppose first that the risk is the conventional variety in which future returns are uncertain. The risk-free interest rate is 10 percent.

One year from now, an investment project will pay off \$115 or \$105, with equal probability. The expected return is the average or \$110. The present value of these future risky returns depends on the attitudes or preferences that investors have about risk. If they are risk neutral, they would pay \$100 today for a chance to win either \$115 or \$105 in a year. The reason is that \$100 is equal to a risk-free \$110 in a year and the investor's expected profit is precisely zero. He wins \$5 half the time and loses \$5 the other half. An investor willing to pay \$100 is one, then, who would accept a fair bet. Most investors, however, are more prudent and risk averse so that fair bets are not accepted. Risk aversity means that the expected net payoff must be positive for a project in order to attract risk-averse investors. In this example, the offer of the risky future returns might be discounted in financial markets to a present value of \$98, for instance. If so, \$98 is worth \$98 x 1.1 or \$107.8 for certain in a year. If the project pays off \$115, the investor wins \$115 - \$107.8 or \$7.2 and if the payoff is \$105, the investor loses \$107.8 - \$105 or \$2.8. Each possibility is equally likely, so the expected profit is \$2.2. If the market has been reasonably efficient so that \$98 is the highest anyone would bid, then the \$2.2 of expected profit is the risk premium needed to attract wary investors. The discount rate then is about 12.24 percent, from (110/98)-1, meaning that the market adds about 2 percentage points to the interest rate because of the risky returns.

Now, suppose the example is reversed so that the future values are possible costs. Hence, the project's expected future cost is \$110, but could be as high as \$115 or as low as \$105. What is the present value of this cost? To discover the general principle at work here, suppose the same risk-averse investor described previously were approached with the following offer. He is asked to accept money today in exchange for the obligation to pay the actual future costs. If he accepts \$100, he can invest in riskless government bonds, have \$110 in a year, and have zero expected profits. If he would not accept such a fair bet about future returns, he will not accept it now when it involves random future payouts. He clearly would not accept anything less than \$100, since his expected profit would be negative. It is easy to show, in fact, that the investor would require an add-on before he would be persuaded to accept responsibility for random future costs, just as he required a discount before accepting random future returns.

Indeed, if the risk is the same and the investor's preferences about that risk also the same, then the add-on is the same as the discount. That is, the discount was $2 before; the investor would add $2 to the fair bet value of $100 and offer to be paid $102 now in exchange for the obligation to pay future costs. The reason is that $102 is worth $112.2 in a year ($102 x 1.1). If the project costs $115, the investor loses $2.8 and if it costs $105, he wins $7.2. Each possibility is equally likely and hence expected profit is $2.2. This is the risk premium needed to persuade investors to accept the risky project, and it is exactly the same as before, thus illustrating that the add-on equals the discount. In this case the appropriate discount rate for future costs is about 7.84 percent, 110/102-1. The percentage risk premium in this case is about 2.16 points that must be subtracted from the risk-free rate. In contrast, the risky return situation required 2.24 points to be added to the riskless rate. The two risk premiums are not exactly the same in percentage terms, but they are similar. The market, however, would make the absolute magnitude of the discount equal to the add-on.

This example can only convey the rudimentary reason why contracts about future costs or payouts are discounted at rates less than the risk-free interest rate. The financial analogy to evaluating future uncertain costs is a contract for selling short, so there is some relevant financial experience that regulators could study. The difficult aspect of evaluating future, uncertain nuclear decommissioning cost is estimating the appropriate risk factor to be subtracted from the interest rate. Previous experience in financial markets is not likely to be helpful since the future nuclear decommissioning problem is unique and its risk is largely unknown.

Without the appropriate market experience, the regulator must use a discount rate smaller than the risk-free rate, but can not be certain of which value to choose. In these circumstances, two simple procedures are possible, although there are undoubtedly others. One is to estimate and subtract the utility's current risk premium from the risk-free rate. The justification would be that the uncertainty surrounding nuclear decommissioning cost, about which we have only very limited experience, is at least as great as that which affects the utility's revenues, a subject that has a long history. The virtue of this approach is not particularly great, but it does offer a convenient rule of thumb that at least provides an interest rate correction in the appropriate direction. A second possibility is to examine several engineering cost estimates and calculate the statistical variance of these. This variance could then be used to estimate the risk factor to be subtracted from the risk-free interest rate. The idea is that the fundamental uncertainty about future nuclear decommissioning cost is the reason why competent engineers have differing cost estimates. The variance of these estimates is itself a good measure of the risk associated with decommissioning a nuclear plant.

Estimating the regulatory risk component associated with NRC safety standards is even more difficult. For instance, over the past several years the NRC has gradually reduced the standard for maximum radiation exposure for workers at nuclear facilities. The level of the standard thirty years from now is uncertain. Estimating an interest rate correction to account for this would be mostly speculative because these standards are often influenced by political events.

Evaluation of Funding Arrangements by Objectives

The preceding discussion is the foundation for evaluating the various funding arrangements described in chapter 5. The discussion of that evaluation is organized around five objectives or standards against which funding proposals can be judged. These objectives encompass all of the desirable properties for decommissioning funding that the study group could identify from the literature. The first objective is that the funds be sufficient to cover the estimated cost of decommissioning. As such, it is a measure of funding assurance and more fundamentally, of economic efficiency. The second objective is that the funds be available in the event of a premature decommissioning. This is a second criterion of funding assurance. The equitable sharing of decommissioning costs over time and among generations of ratepayers is the third desirable property. The fourth issue, although not stated as an objective, is that consideration be given to any risk associated with internal utility control over the decommissioning fund as opposed to external, possibly state control. The fifth and final desirable property is that the benefits of the tax deduction, many years in the future, be spread to those who pay for and benefit from the plant. This is a second intergenerational equity issue.

As mentioned, costs and revenues have distinct and separate risks, and the same discount rate cannot be appropriate for both. This section evaluates various funding proposals mostly as if the correct discount rates have been used. This implicitly means that an adjustment has been made so as to recover the same, risk-free, future value of the future cost. The procedure for these adjustments is described in the discussion of the first objective using a numerical example.

Objective 1: The Funding Mechanism Collects Revenues Adequate to Cover the Estimated Cost of Decommissioning

The issue addressed by this objective is whether or not the present value of the future revenue collected under a funding proposal equals the present value of the cost. That is, only the aggregate present value of all future years of revenue is important here. The time pattern of the consumers' payments is addressed in objective 3. This objective is essentially a way of assessing the economic efficiency of the funding arrangements in the sense that revenue should recover the cost of service.

A convenient way to begin a discussion of the many funding arrangements is to develop a numerical example. This seems particularly appropriate since we have claimed in this report that there is a proper way of discounting and there is some need, therefore, to demonstrate it. The details of the example are given in table 6-1. This example is our benchmark, and as such, other funding arrangements are compared to it later. The example is a prepaid, external fund controlled by a state trustee. The important features are that the utility sells its own securities that are backed up by the additional cash flow the regulator allows in advance for the future decommissioning expenses. The proceeds of the security sale are deposited with an external agency and controlled by a state trustee. The important aspect of this control is that the interest earnings of the fund are not taxed. Hence, the state trustee can invest in federal government bonds, earn the risk-free rate, and not pay taxes on the earnings. We argue later that this tax treatment is economically efficient. The choice of this example should not be interpreted by the reader to mean that it is somehow favored. It is simply a benchmark.

The numerical details are as follows. Suppose that currently the cost of decommissioning a nuclear plant is 100 million dollars. Suppose this is expected to grow at the rate of overall inflation, say 8 percent. The risk-free interest rate on government bonds exceeds the inflation rate by 2 points; so it is 10 percent. And finally suppose the utility's risk class requires it to earn 15 percent after taxes. The important calculations are summarized in table 6-1. The first step is to find the cost of decommissioning after 30 years of inflation which is $1006.26 million in this example. Since that future cost is certain, its present value, discounted at the risk-free 10 percent rate, is $57.67 million. Suppose the utility establishes a fund that is externally invested in 10 percent government bonds by selling its own 15 percent securities. The fund is only 54 percent of the present value since 46 percent is paid by the tax deduction of the cost in year 2012. Hence the utility sells $31.14 million of its own 15 percent securities and buys the same amount of 10 percent government

TABLE 6-1

COMPARISON OF A NEUTRAL REGULATORY TREATMENT
OF FUTURE NUCLEAR DECOMMISSIONING COST WITH TWO
NON-NEUTRAL TREATMENTS (MILLIONS OF DOLLARS)
USING THE ORDINARY ANNUITY FORMULA

Year 1982 Current Decommissioning Cost = $ 100.
Year 2012 Future Decommissioning Cost = $ 1006.26

Assumptions: 8% inflation rate in general and also for cost
10% risk-free inflation rate
15% utility cost of capital
46% corporation income tax rate

A Neutral Regulatory Treatment

A. Find present value of future cost: $\$1006.26/(1.1)^{30} = \$ 57.67$

B. The future tax deduction pays 46% of the cost in year 2012.
The remainder is financed by a prepayment:
Utility issues (1-.46)x57.67 = $31.14 worth of 15% bonds to its investors.
Utility buys $31.14 of 10% government bonds.
External fund receives the $31.14 of government bonds.

C. In year 2012:

External fund is worth $\$31.14\text{x}(1.1)^{30}$	=	$ 543.38
Tax deduction is worth .46 x 1006.26	=	462.88
Total can pay the decommissioning cost	=	$1006.26

D. Consumers annually pay a constant nominal amount whose present value is $57.67 at 15%. An ordinary annuity formula yields an annual payment of $8.7828. The uses of this payment are:

Taxes of .46 x 8.7828	= 4.0401
Interest payments to utility's investors of .15 x 31.14	= 4.6711
Remainder	= .0716
Total	8.7828

The remainder accumulates for 30 years at 15% and has a future value in year 2012 of $31.14, sufficient to pay the principal.

E. Note that the expected future value of a 30 year, 15% sinking fund receiving $8.7828 annually is $3818.28. The accumulated risk premium is thus 3818.28 - 1006.26 = $2818.02.

Previously Suggested Non-neutral Treatments

F. Annual payments to accumulate $1006.26 at 10% -- $6.1173.

G. Annual payments to accumulate $1006.26 at 15% -- $2.3146.

Source: Authors' calculations.

securities. After 30 years of growing at 10 percent, the external fund in which the government securities are deposited is worth \$543.88 million. The tax deduction is worth 46 percent of the future cost, or \$462.88 million. The total of these two components is exactly enough to pay the expenses.

Consumers must pay the actual cost of decommissioning including the risk premium associated with the random nature of their demand. In this example, this means they must pay an annual amount that is sufficiently large that the present value over the 30 years equals the present value of the cost. The important feature here is that the appropriate discount rate to use in converting uncertain future revenue into certain present value is the one that includes a risk premium. There are various ways of computing the annual revenue requirement. Rate base treatments are discussed later. For now, suppose the consumers' payment is calculated using the ordinary type of sinking fund in which a capital recovery factor is multiplied by the cost to be recovered. The formula is in equation (5.14) and was discussed in chapter 5. This recovery method has the expositional advantage that the annual nominal payments are constant over time so that a single number can be used to compare this example to other funding suggestions. Using an ordinary annuity formula at 15 percent for 30 years shows the annual payment is \$8.7828 million.

The consumers' annual payment of \$8.7828 million has three uses. First, it is taxed at 46 percent so \$4.0405 million is paid annually to the IRS. The utility's security holders are paid 15 percent, or .15 x 31.14 million or \$4.6711 million. This leaves \$.0716 million that can accumulate in an internal sinking fund for 30 years at 15 percent. The expected future value of this sinking fund is exactly the value of the principal borrowed, or \$31.14 million.

This regulatory treatment is neutral in the sense that it results in exactly the same financial conditions for both customers and investors whether the cost is \$1006.26 million in 30 years or \$57.67 million today.

Thus far, the discussion has focused on the type of regulatory treatment that would make the recovery of future costs equivalent to the present way of handling current costs. Our suggested neutral method was illustrated by supposing that the utility's investors initially lend the funds despite the fact that the funds are not needed for 30 years. This is sometimes referred to as a prepayment plan, although consumers are not prepaying, investors are. Suppose investors are not asked to prepay the decommissioning expense. Perhaps accumulating the funds without any initial borrowing would be cheaper. Two examples of this type of suggestion are included at the end of table 6-1. The first, point F in table 6-1, is to find the even annual payments that are needed to accumulate the cost, \$1006.26 million, at the risk-free 10 percent rate over 30 years. This proposal is sometimes advocated by consumer groups apparently based on the notion that the rate of interest earned by the fund somehow becomes the appropriate discount rate for uncertain revenue. With this reasoning, one concludes that only \$6.1173 million is needed annually, 30 percent less than the benchmark.

A second suggestion, often supported by representatives of electric utilities, is to note that if the fund is allowed to grow at the utility's implicit rate, the cost of capital, an even smaller annual payment is required. Indeed, using a 15 percent rate of return, the annual required revenue is only \$2.3146 million, a 74 percent reduction over the consumers' cost in the benchmark case.[3]

These unfunded methods seemingly are cheaper than the payments required by our neutral treatment. The tempting conclusion is that even though it might be true that our neutral procedure treats future and current costs similarly, the fact that the costs are in the future allows

[3]An ordinary sinking fund has been used here because the resulting even annual payment is easily compared to the benchmark case. There are many other ways, however, to accumulate a fund which has a final, expected value equal to the future decommissioning cost. These are all essentially the same as point G in table 6-1 except that the time pattern of payments is not constant. The negative net salvage approach is an example of this.

society to consider some financial arrangements that are not usually feasible. Specifically, if the utility's investors do not have to be paid 15 percent, society can provide the funding more cheaply. If indeed such a thing were possible, it would be the financial equivalent of an economic free lunch and should by all means be exploited. Unfortunately, free lunches are infrequent.

The unfunded financial methods shift society's risk sharing arrangements in subtle ways. Table 6-2 compares various aspects of the three funding treatments. The second and third rows refer to methods that accumulate an expected value of $1006.26 million at 10 and 15 percent respectively. The temptation is to interpret the annual payments under all three arrangements as constant, known values about which there is no uncertainty. Of course, these revenues are not certain because if they were, there would be no risk premium in the utility's cost of capital in the first place. The reason for the risk is that regulators make calculations that ultimately set prices. Random demand then creates random returns. These returns are sufficiently risky that the market tells us to discount them at 15 percent. If we evaluate the second row of table 6-2 using the risky interest rate, we find that expected annual payments of $6.1173 million have a present value of $40.16 million, which is equivalent to a risk-free value of $700.87 million in year 30.

The expected value after 30 years is much higher, $2659.47 million. Indeed, the risk-free component is only 26 percent of the expected value. The remainder, 74 percent, is the accumulated risk premium which is $1958.60 million for this case. If society were to choose this type of unfunded financial arrangement, in effect the utility's consumers are being asked to invest in the utility. If the consumers perceive the same riskiness as the market, they will evaluate the $6.1173 million annual payment at 15 percent and conclude that it is a certain-equivalent to $700.87 million, which is $305.33 million less than what will be needed to decommission the plant.

TABLE 6-2

RISK ADJUSTED VALUE OF THREE FUNDING LEVELS*
(MILLIONS OF DOLLARS)

Funding Arrangements	Annual Payment	30 Year Risk Free Value	30 Year Expected Value	Cumulative Risk Payment	Consumer's Perceived Cost of Capital†
Neutral Treatment	8.7828	1006.26	3818.28	2812.02	15%
10% Sinking Fund	6.1173	700.87	2659.47	1958.60	10%
15% Sinking Fund	2.3146	265.19	1006.26	741.07	1.24%

Source: Authors' calculations.

*All three risky time patterns of payments are discounted at the 15% risky cost of capital.

†This is the discount rate that makes the risk-adjusted future value of the fund equal to the decommissioning cost.

If the regulator, on behalf of the consumers, believes that a payment of $6.1173 million is truly the same as $1006.26 million certain, then he must also believe that the consumers evaluate the utility's returns with a perceived cost of capital equal to 10 percent. But if consumers in the utility's market area perceive 10 percent as the appropriate discount rate, they must believe that the utility's returns, and hence their own payments, are less risky than the market perceives. Indeed, consumers must perceive that there is no risk at all. If that were true, the cost of electricity would indeed be lower. Any consumer having such beliefs should be willing to invest in the utility directly regardless of any nuclear decommissioning issue, since he or she can obtain an actual 15 percent average return that is perceived to be riskless. Such an investment is far superior to the 10 percent risk-free government bonds. The resulting arbitrage would eliminate the differences in perceptions since the utility's common stock price would be driven up until the annual returns were 10 percent of the firm's value. Hence, in reality the consumers' perception of risk cannot persistently differ from the market's.

The third row in table 6-2 shows the method that has been suggested by some utilities and some depreciation analysts. The idea is to structure the consumers' payments so that they accumulate sufficient funds to pay the decommissioning cost in the future. The required payment is quite low. To evaluate the riskiness of such a proposal, the expected annual revenues can be discounted at 15 percent to find that they have a total present value of $15.20 million. Using the risk-free 10 percent interest rate, these payments are equivalent to a risk-free fund of only $265.19 million at the time of decommissioning as reported in table 6-2. This is only 26 percent of the cost. It is true that the suggested annual payment does have an expected value equal to the future cost; however, the actual accumulated total is random and because of that is not worth as much to risk-averse consumers or investors. As an aside, an investor would have to discount at 1.24 percent to believe that this funding level provides the necessary risk-free funds, which is of course most unlikely.

The conclusion is that funding alternatives to accumulate funds at the utility's risky rate of return are substantially more risky. Furthermore, the risk of adequate funding at the scheduled time of decommissioning can be quantified. It is possible to assess the risk-free future value of any proposed funding scheme, and also it is possible to adjust the revenue requirement so that the risk-free value of the fund equals the risk-free cost that must be paid.

Perhaps the most important result is that the consumer cost of decommissioning is higher than has been reported previously. Discounting revenues with the utility's rate of return and cost with the risk-free interest rate always yields a higher annual revenue requirement than discounting solely with either rate. It is important to realize that the adjustment for risk that is inherent in our method is independent of portfolio risk. Indeed, the implicit assumption has been that the fund is invested in an efficient, well diversified portfolio under all three methods discussed thus far and all others discussed in relation to objective 1. Objective 4 addresses portfolio management directly.

Several types of funding arrangements can now be easily compared in the context of table 6-1. First, it should be clear that there is no difference in the annual revenue requirement whether or not the decommissioning fund is prepaid as long as the risk-free future value of the fund equals the risk-free cost. Previous analyses that have suggested it would be cheaper if the prepayment were avoided have implicitly increased the risk of adequate funding. These methods have quite low annual revenue requirements, the present value of which is less than the present value of the cost. In any other circumstances, regulators would conclude that consumers are not paying the full cost of service. A similar conclusion is appropriate when the costs happen to be in the future.

A second consequence of carefully considering risk is that there is no inherent difference between internal and external mechanisms as long as the tax treatment and assurance of funding are the same for both. The determination of both the capital recovery factor and the present value of cost is the same whether the fund is controlled by the utility or outsiders.

Several types of capital recovery mechanisms that are internal to the utility are identified in chapter 5. Thus far, the example in this chapter is based on an ordinary type of internal sinking fund. An alternative is to use a so-called modified sinking fund or conventional rate base treatment. With this procedure, the annual revenue requirement for nuclear decommissioning cost is calculated as annual depreciation plus a return on the undepreciated portion of cost. This modified sinking fund typically results in a pattern of consumer payments that decline over time because the rate base declines. The negative net salvage value method is essentially an example, although it is a negative rate base that so declines. Its time pattern is described in the discussion of the third objective. This method accumulates a fund that has an expected value equal to the future value of the cost. It does not have the same risk as one that accumulates the same risk-free value as cost; that is, the negative net salvage value method results in a set of annual revenue requirements that has a present value equal to the present value of the cost, if both revenue and cost are incorrectly discounted using the utility's cost of capital. Hence, the adoption of this accounting convention implicitly means that future cost is evaluated using the risk premium that is due to the uncertain nature of demand, which is clearly inappropriate.

The most straightforward way to use a rate base treatment to provide for a risk-adjusted funding level is to enter the present value of the cost, using the risk-free interest rate, into the rate base. This may be controversial in view of current accounting practices. The reason for this discussion is to point out that there is a way of using all of the standard ratemaking practices to account for future costs in a risk-adjusted manner. In particular, there is no real difference whether an ordinary or modified sinking fund is used--both procedures can be structured so that objective 1 is fulfilled.

Although the several matters just discussed do not affect consumer bills, there are five main factors that do affect the revenue required for future costs: the inflation rate, the risk-free interest rate, the risk premium in the utility's cost of capital due to revenue risk, the risk premium associated with the future cost uncertainty, and the tax treatment of the earnings of the decommissioning fund. Holding the remaining four factors constant, a higher inflation rate clearly increases cost and required revenue is correspondingly higher. A higher risk-free interest rate lowers the present value of the cost and hence reduces the revenue requirement. Higher risk always increases cost, whether it is revenue risk or engineering cost risk. Finally, a requirement to pay taxes on the interest earnings of the decommissioning fund will increase the required revenue. The effects of risk and taxes are briefly described below.

Table 6-3 shows the effect that both revenue and cost risk have on the annual revenue requirement for the numerical example that was presented in table 6-1. The inflation rate and risk-free interest rate are the same as before. The expected value of the engineering cost is the same also, except now this cost is only estimated and is not known with certainty. Suppose the cost risk can be quantified into a risk premium that then can be subtracted from the risk-free interest rate as explained in the first section. Table 6-3 shows three levels of this type of risk premium--zero, one, and two percentage points with the associated discount rate in brackets. Each row in the table corresponds to a different level of cost risk. The appropriate discount rates for future cost are 10, 9, or 8 percent, respectively. The other distinct type of risk is due to revenue uncertainty. The three columns in the table correspond to three levels of this type of risk premium. Revenue risk is the ordinary reason why the utility's cost of capital exceeds the risk-free rate. The revenue requirements in table 6-3 are calculated as described in table 6-1. The present value of the expected future cost is first found using the discount rate for cost. Then, the even annual payments are found such that their present value using the utility's cost of capital equals the present value of cost. The table shows that either type of risk serves to increase the required annual payments--a characteristic that makes intuitive good sense.

TABLE 6-3

ANNUAL REVENUE REQUIREMENT FOR THREE LEVELS
OF REVENUE AND COST RISK
(MILLIONS OF DOLLARS)

Year 1982 Current Decommissioning Cost = $100
Year 2012 Future Decommissioning Expected Cost = $1006.26

Assumptions: 8% inflation rate
10% risk-free interest rate

Risk from Cost Uncertainty, Expressed As Cost Risk Premium (%)	[Discount Rate (%)]	Risk from Random Revenue Expressed As Revenue Risk Premium (%) [Cost of Capital (%)]		
		0 [10]	1 [11]	2 [12]
0	[10]	6.12	6.63	7.16
1	[9]	8.05	8.72	9.42
2	[8]	10.61	11.50	12.41

Source: Authors' calculations.

TABLE 6-4

ANNUAL REVENUE REQUIREMENT AND TAXES

Tax Treatment of Fund	Type of Security	Tax Rate	Risk-Free Interest Rate	After-Tax Interest Rate	Annual Revenue Required*	Relative Magnitude
Non Taxable	Federal	0%	10%	10%	8.7828	1.00
Taxable	State & Local	0%	7%	7%	20.1332	2.29
Taxable	Federal	50%	10%	5%	35.4596	4.04

Source: Authors' calculations and table 6-1.

*Millions of dollars

Table 6-4 shows the effect that taxation of the fund's earnings has on the required annual payment. The first row in the table repeats the example developed previously in table 6-1. Suppose the fund's earnings are taxable, however. The second row shows the needed revenue if the fund is invested in tax-free securities such as state or local bonds, as a way of reducing the tax burden. The example follows the logic developed in table 6-1. In order for the fund to have the same risk-free future value after 30 years, about 2.29 times as much must be initially invested if the fund can grow at only 7 percent. (Typically, the rate on tax-free bonds is about 70 percent of the taxable, risk-free rate.) If the fund is invested in taxable securities, and the tax rate is 50 percent, then the after tax interest rate is only 5 percent. That is, only the after-tax earnings are available to be reinvested in the fund and thereby provide the growth of the fund. The third row of table 6-4 shows that the annual revenue requirements are 4.04 fold higher in these circumstances. Clearly, the taxing of the fund's earnings has a very large effect indeed.

It is clearly cheaper for electricity consumers to pay for future decommissioning costs if the fund's earnings are not taxed. In addition, overall social efficiency is promoted by not taxing these earnings. The reason is that the risk-free interest rate is the basic price of capital for all corporation investment decisions. A few percentage points may be added or subtracted because of risk, but the benchmark is the risk-free rate. This is an after-tax interest rate to begin with and as such already reflects the effects of the corporation income tax. No further taxation is appropriate. In addition, the fact that earnings taxation reduces the rate at which the decommissioning monies can grow is essentially a portfolio issue. Regardless of this tax treatment the appropriate discount rates for cost and revenue remain the same. The present value of the tax-induced higher revenue using the utility's cost of capital clearly exceeds the present value of cost. We know this because the first row in table 6-4 has been calculated so as to have the property that revenue exactly covers cost. Hence, the revenues indicated in the second and third rows of table 6-4 obviously are more than the cost. The taxes that are causing this inflated consumer payment are clearly inappropriate because consumers are paying, in effect, both the corporate income tax and a personal tax on the fund's interest earnings for the labor and materials expenses of decommissioning. No other expense is treated similarly.

Only an internal unsegregated mechanism and also a state controlled external fund have the property that the fund's earnings are not taxed regardless of the securities purchased by the fund. Regulators may wish to investigate the possibility of legislative relief. One precedent for exempting decommissioning funds from taxes is the Black Lung Revenue Act of 1977 which allows coal companies to establish tax-exempt trusts as a way to insure against future liabilities for black lung claims.

Objective 2: The Funding Mechanism Ensures That the Funds Collected From Ratepayers Are Adequate in Case of a Premature Decommissioning

In the event that the nuclear plant must be decommissioned early, the available funds may be inadequate. One reason for this is that uncertain future costs may turn out to be higher *ex post* than previously forecast.

None of the funding mechanisms has any real capability of dealing with this problem. The only possible exception is insurance; however, cost overruns, if they occur, are likely to be pervasive throughout the industry which would imply that this is not a matter where risk sharing is possible and consequently this is not an insurable risk. Hence, all of the plans are equally incapable of handling this contingency, and none has any real advantage.

Another reason that the funds may be inadequate is due to the relation between the interest rate and the rate of cost inflation. For example, in table 6-1, the risk-free interest rate exceeds the rate of cost inflation by two percentage points. Accordingly, only $31.14 million needs to be prepaid despite the fact that the current after-tax expense is $54.00 million, (1 - .46) x $100 million. After 30 years, the fund grows from $31.14 million to $543.37 million since its growth rate is 10 percent. The after-tax portion of costs, on the other hand, grows only at 8 percent and consequently increases from $54 million to the same final value, $543.37 million. If the plant were decommissioned early in its fifteenth year, for example, the fund would be $130.88 million while the after-tax portion of the expenses would be significantly larger, $171.30 million. This gap narrows as the scheduled decommissioning time approaches and finally goes to zero at the end of the plant's normal life.

Surety bonds or insurance would be appropriate in this instance. Such financial instruments could increase the assurance that adequate funding would be available in the event that early decommissioning is required. The amount of insurance needed would decline over time since the gap to be filled also declines. The premium for this insurance would also decline, in real value, over time. The current premium is part of the current cost of service and would be included in the required revenue. Such a treatment seems equitable since ratepayers who are served in years when the gap is large are responsible for that year's gap.[4] The situation is similar to

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[4]This is true if the premature shutdown is due to an Act of God, economic obsolescence, or other cause outside the utility's control. Ratepayers might not be considered responsible for the gap in other cases where the

a declining term life insurance policy that is designed to fill a family's financial gap before the family has accumulated the assets needed for retirement. Such a family expects to pay a lower premium in years when the insurance coverage is low. Neither surety bonds nor insurance is currently available for premature nuclear shutdowns. Regulators may wish to encourage the industry to consider such arrangements.

A third reason why the funds seemingly may be inadequate is that the fund was not prepaid, but rather is only accumulated through the ratepayers' annual contributions. For instance, suppose the unexpected shutdown occurs in the fifteenth year. Suppose further that the example in table 6-1 describes the actual economy for the previous 15 years and \$8.7828 million has been collected each year and after taxes \$4.7427 million has been deposited, on average, in a fund of government securities. The certain-equivalent value of the fund after 15 years is only \$115.85 million, while the prepaid funding arrangement was valued at \$130.08 million at this same year. The actual cost (after-taxes) is \$171.30 million in the fifteenth year. Hence, there is an apparent additional gap of about \$15 million in year 15 when the fund is not prepaid. It is added to the \$41 million gap that is due to the difference between the interest rate and the inflation rate.

This new gap, apparently caused by the lack of prepayment, cannot be analyzed separately from the issue of whether future ratepayers are to be held responsible for continuing their payments for decommissioning that had been planned previously but for which those consumers now will receive no benefit, that is, no electricity. If the regulator requires decommissioning payments to be made according to the original schedule or possibly

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utility or the builder of the plant are responsible for the premature shutdwon. See Kaufman, Alvin, et al. Unplanned Shutdowns: A Study in Risk Allocations, NRRI Report 80-19, (Columbus, Ohio: 1980).

earlier, despite the fact that the plant is not in use, then there is no new gap at all. The regulator could require that the utility issue revenue bonds to fill the gap. The remaining consumer payments are exactly sufficient to back up the needed securities. An alternative is to impose the expenses associated with this new gap on the consumers during the time of decommissioning, which may be a fairly long period allowing the costs to be spread over several years. This is essentially a self-insurance type of scheme. A second alternative is to buy insurance so as to spread this risk over several utilities. Since the insurance premium is not now known, the alternatives can not be compared readily to the first arrangement.

In considering these three arrangements, however, the regulator may also wish to consider whether future ratepayers would continue to pay planned decommissioning expenses after a premature shutdown if the fund had been prepaid by the utility's investors, in which case future cash flow is needed to pay interest on decommissioning bonds, for instance. If the answer is yes, then the same policy in the absence of a prepayment would allow revenue backed securities to be issued at the time of any premature decommissioning and there is no new gap for which insurance is needed. If the answer is no, there is a gap. If insurance is used to fill this gap, the premiums would be paid by consumers prior to the premature shutdown. In this case the regulatory policy essentially places the decommissioning burden on ratepayers who benefited from the plant. Ratepayers after the shutdown would bear no burden. It is important to realize that this type of gap and subsequent need for insurance is due solely to the regulator's policy that post-shutdown consumers will not pay for decommissioning. With such a policy, the gap is the same whether or not the fund was prepaid. The reason is that the regulator can require a supplemental issuance of securities if future ratepayers bear part of the decommissioning burden and no prepayment was previously made.

The conclusion is that there is nothing inherent in any of the funding mechanisms that gives one of them a clear superiority over the others in providing for assured funding in case of an early need for the money. This conclusion is based on the annual payments for each type of fund being set so that each provides for the same risk-adjusted value of the fund at the scheduled time of shutdown. Some previously suggested methods had a much lower annual payment than the neutral regulatory treatment adopted here. For these, the funding is quite inadequate in early years. It is inadequate in these years, however, because the payment level does not provide the same risk adjusted level of funding even at the scheduled time of shutdown. That is, there is a greater risk of inadequate funding in all years, and the large gap at the beginning is not a problem that should be blamed on the internal nature of the arrangement, for example, but rather on a particular choice of interest rates as discussed before. All of the funding mechanisms, then, may need some additional insurance or surety bonding to fill the financial gaps in early years.

Objective 3: The Funding Mechanism is Equitable and Imposes the Decommissioning Cost on Those Ratepayers Who Receive the Benefit From the Nuclear Plant

The objective is to spread the nuclear plant's decommissioning costs over the plant's predicted lifetime so that consumers living in a particular year pay for the benefits received in that year. Such an outcome appeals to the sense of fairness and equity of many regulators and consumers. This same objective is also consistent with economic efficiency in the sense that consumers in each year are receiving the correct price signal--one that reflects the cost of service in that year. The effect of tax treatment on the time patterns of revenue requirements is discussed later. This section presents five examples of significantly different time patterns of revenue recovery.

Table 6-5 summarizes the five methods. The annual revenue requirement is only reported for three particular years in the table for brevity. These are the first, fifteenth, and last years of a thirty-year plant. The examples are based upon the one first presented in table 6-1. Inflation is

8 percent and the cost of capital is 15 percent. All five methods are designed so as to recover the cost; that is, the present value of the sum of annual consumer payments is equal to the present value of the cost, using the appropriate discount rate for each.

Table 6-5 first describes the results for three variations of rate base treatment, or modified sinking fund. The first of these is the negative net salvage value method in which the annual revenue requirement is the straight line depreciation of the future value of the cost plus a negative return on the accumulation of prior depreciation. As explained previously, the present value of the revenues under this method equals the present value of the cost if the cost is incorrectly discounted at the utility's rate of return. To make all five methods in table 6-5 comparable, the negative net salvage value example has been calculated so that the present value of the revenues discounted at the cost of capital, or 15 percent, equals the present value of the cost, discounted at the risk-free interest rate. To do this requires that the negative rate base be multiplied by an arbitrary and artificial rate of return which cannot be determined analytically but which is between the two interest rates. The details of finding this psuedo-rate of return are unimportant. It suffices to say that it makes this procedure comparable to the remaining four in the table.[5] Table 6-5 shows that the negative net salvage value method results in a highly unusual time pattern of revenue requirements. These begin very high and become negative by the tenth year. (This is a negative incremental revenue due to decommissioning--total annual revenue is, of course, positive.) By the final year, the negative nominal consumer payment is 82.14 million and although this is only a negative $8.82 million in real terms, it is a very large refund when compared to any of the other payments in the table.

[5]In this example, the pseudo-rate of return is 11.893 percent.

TABLE 6-5

TIME PATTERN OF PAYMENTS
FOR FIVE EXAMPLES OF FUNDING ARRANGEMENTS
(MILLIONS OF DOLLARS)

Assumptions: Same as table 1
15% Discount rate for revenue
Inflation rate is 8%
All five methods have the present value of the sum of all 30 annual payments equal to $57.67 million, the present value of the cost.
Earnings of fund are not taxed.

	Nominal Value of Revenue Requirement (in future millions of dollars)	Real Value of Revenue Requirement (in year-1 millions of dollars)
<u>Rate Base Treatments</u>		
Method 1: Negative Net Salvage Value		
Year 1	33.54	33.54
Year 15	-22.31	-7.60
Year 30	-82.14	-8.82
Method 2: Straight Line Depreciation		
Year 1	10.57	10.57
Year 15	6.54	2.23
Year 30	2.21	.24
Method 3: Decelerated Depreciation*		
Year 1	8.77	8.77
Year 15	8.56	2.70
Year 30	4.28	.37
<u>Ordinary Sinking Fund Treatments</u>		
Method 4: Constant Nominal Payment		
Year 1	8.78	8.78
Year 15	8.78	2.99
Year 30	8.78	.94
Method 5: Constant Real Payment		
Year 1	4.76	4.76
Year 15	13.98	4.76
Year 30	44.35	4.76

Source: Authors' calculations.
*This particular example of decelerated depreciation used the reversed sum-of-digits method.

Method 2 in table 6-5 is a modified sinking fund in which the present value of the decommissioning cost is entered into the rate base and the annual revenue requirement is straight line depreciation plus a return on the rate base. The rate base is reduced by all previous depreciation. Because the portion of rate base associated with decommissioning cost declines over time, the nominal value of the annual payments declines over time as shown in table 6-5. The second column of table 6-5 shows that if these future payments are converted to real terms by adjusting for inflation this method results in a pattern of rapidly declining annual payments. The real payments decline at about 14 percent per year.

Method 3 also recovers the decommissioning cost using a rate base treatment. To partially overcome the rapidly declining real payments associated with the second method, the annual depreciation is calculated so as to become larger in later years. The particular, *ad hoc* scheme illustrated in the table is to reverse the conventional sum-of-digits accelerated depreciation method so that the first year depreciation is only one unit when compared to the sum of digits while the final year depreciation is 30 units of that sum.[6] There have been other *ad hoc* suggestions in the literature that are not reviewed here. This particular depreciation pattern happens to result in nominal payments that actually increase in the first seven years and then decline thereafter. The overall pattern is one that declines both in nominal and real terms, but not as rapidly as the pattern associated with the straight-line depreciation. Overall, the real payments decline between the first and last years at an average rate of about 12 percent. This is a modest improvement over the 14 percent decline resulting from the first method.

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[6]That is, α_t in the formula presented in table 5-1 is $t/[n(n+1)/2]$, where t is the current year and n is the life of the plant. The term $n(n+1)/2$ is the sum of digits from one to n.

Method 4 is the ordinary type of sinking fund. This particular example has been calculated so that the nominal value of all 30 annual payments is the same. The real value of these payments is declining at 8 percent, the rate of inflation. Some regulators may believe that fairness would be served if the real value of these payments were constant over time.

Method 5 is an ordinary type of sinking fund except that the nominal annual payments have been computed so as to grow at the assumed rate of inflation. This type of adjustment results in the real payment remaining constant. The Michigan PSC staff called this type of adjustment skewing. The amount of skewing need not be the assumed rate of inflation but could be less, for example. A partial skewing results in a real payment schedule that declines if the inflation rate indeed remains the same for the next 30 years. Since it is unlikely that inflation, in fact, will remain at its current high level, a partial skewing may be preferable.

Another important intergenerational equity issue arises when the estimated cost of decommissioning changes as the scheduled shutdown time is approached. If the cost estimate increases, for example, the regulator must decide who will bear the added burden. There is no practical way for previous ratepayers who received electricity from the plant to pay what might be termed their fair share of the cost change. Either future ratepayers or the utility's investors therefore must bear the entire burden of the unexpected rise in cost. To the extent that any funding mechanism adjusts the annual revenue requirement during the life of the nuclear plant in order to accommodate the most recent estimates of decommissioning cost, the burden of the cost change is thereby placed on future consumers. All of the funding arrangements described in chapter 5 can be dynamically adjusted so as to incorporate any new cost information. This report does not emphasize the relative ease with which such adjustments can be made in comparing the various funding arrangements because the static risks of cost, revenue, and portfolio management seem more important in light of recent analyses, and because formula flexibility, although a desirable property, can not overcome the practical limitation that prior customers escape responsibility if costs have been underestimated. If the contrary were true, that costs were underestimated perhaps because of an unforeseen technical breakthrough, the opposite difficulty arises. In this case the issue becomes how to dispose of the excess monies.

Objective 4: When Considering Whether the Control Over the Fund Is External or Internal, the Cost of the Risk Differential That Results From Leaving the Utility in Control Versus External Control Over the Fund Is Considered

It is the position of the NRC staff that assurance of funding is the most important criterion in evaluating the various funding proposals. In NUREG-0586, the NRC staff states that it is "...NRC's responsibility to protect public health and safety by assuring that funds are available for safe decommissioning..."[7] The Temple, Barker and Sloane (TBS) study on financial strategies for the NRC staff estimated that the present value of the cost of external funding is more than twice as high as that for internal funding.[8] The reason for the TBS result was their selection of external and internal interest rates as discussed previously. The NRC staff, in reviewing the TBS findings states

> Furthermore, whichever funding mechanism is used should not significantly impact on the cost to customers. One study has estimated that the difference in cost between the various funding mechanisms would result in less than a one percent difference in the total bill of a representative utility customer.[9]

In effect, it is the NRC staff position that a procedure that doubles the cost of decommissioning is not significant because decommissioning expense is such a small fraction of the utility's cost that electricity prices rise by less than one percent. Similarly, the Administrative Law

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[7]See U.S. Nuclear Regulatory Commission, Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, NUREG-0586 (Washington, D.C.: 1981), p. vi.

[8]See U.S. Nuclear Regulatory Commission, Financial Strategies for Nuclear Power Plant Decommissioning, op. cit.

[9]See U.S. Nuclear Regulatory Commission, Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities, op. cit. p. 2-17.

Judge (ALJ) writing in the Michigan generic hearings stated that "...although the cost to the ratepayer is a significant factor to take into consideration, the difference in cost between an external and internal fund is not determinative for purposes of this proceeding. All parties are in agreement that assurance of decommissioning funds availability at the time of decommissioning is of utmost importance."[10] The Michigan ALJ found that external funding provides more assurance than internal methods. Since both the NRC staff and the Michigan ALJ opined that the external funding method is more expensive but prefer it on assurance grounds, it is important to identify the source of greater security.

The NRC, the Michigan Administrative Law Judge, and others discussed by Schwent[11] do not provide a detailed description of their perceived differences between the financial assurances of internal and external funding methods. Without attempting to speak for any of these individuals or agencies, the source of their discomfort may be related to the interest rate issue that has been discussed in this report. That is, the utility or possibly an independent analyst may claim that an unsegregated, negative net salvage value approach results in an annual revenue requirement which is only 25 percent of the amount that would be required if an external method is used, as described in the examples in table 6-1.

Assuming the external fund has no tax disadvantage that makes it expensive, regulators are naturally skeptical that the utility's plan has the same chance of covering the future expenses when they are due. This skepticism is well justified as the first section of this chapter explained. The utility's calculation may seem appropriate, but it undoubtedly involves determining the revenue requirement so that the annual payment to an internal fund accumulates the decommissioning cost at the future shutdown date. Such a procedure accumulates risky annual revenues

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[10]Michigan Public Service Commission, Case No. U-6150, op. cit. p. 18

[11]Schwent, op cit.

so as to create a fund with a future expected value equal to the future costs. The actual future value of the fund, however, is random because it is being built out of random revenues. Because it is not certain, its value to investors or regulators today is not the average or expected amount. Risk averse investors and risk averse regulators would discount such a value and section 1 of this chapter demonstrates how to calculate that discount. The regulator's and specifically the NRC's intuition that the internal fund is more risky is correct.

Since standard financial concepts and formulas provide a precise way to calculate the revenue requirement so as to yield the necessary, risk-free, future cost, however, there is no reason why the various funding arrangements cannot be adjusted so as to have the same risk. The way to do this has already been described in this chapter. Once this is done, the internal and external methods have equal levels of funding assurances, and the apparent financial advantage of the internal fund disappears.

Which party controls the fund also raises the issue of portfolio management. The actual monies collected in advance of decommissioning must be invested. An internal, unsegregated funding method such, as negative net salvage value, implicitly invests this money in the utility itself. An internal segregated fund managed by the utility may or may not be invested more broadly. An external trustee, on the other hand, would manage the fund prudently if he or she purchased a well diversified portfolio, possibly the market basket of all securities. Such a portfolio would be efficient, or at least approximately so, in the sense that it yields the highest possible return for the overall market value of risk. Investing the money solely in the utility or even disproportionately in the utility does not have this characteristic. That is, the utility is not itself an efficient portfolio, although it is some small fraction of an efficient, well diversified portfolio. Accordingly, external control of the actual monies is far superior to a narrow, internal investment in the utility.

This particular risk differential is difficult to quantify. The risk premium inherent in the utility's cost of capital reflects what financial analysts refer to as systematic risk. This is the portion of the utility's random returns that remains when it is combined with other securities to form an efficient portfolio. The residual or unsystematic risk is irrelevant in such portfolios since it washes out when the utility's returns are combined with others. The currently used concept of cost of capital measures only the systematic risk of the utility when it is part of a well diversified portfolio. No investor would hold an inefficient portfolio consisting solely of the utility's securities since it would expose him to the unsystematic portion of the risk which can be easily avoided. Since we have no measure of the utility's unsystematic risk, there is no way of estimating the amount of additional risk that the utility's consumers would face if the decommissioning monies were reinvested in the utility. Regardless of the magnitude, however, it seems clear that such diversifiable risk is best avoided. Again, external control seems plainly superior on these grounds.

A remaining issue is the status of decommissioning funds in the event of bankruptcy. There is little real danger that an electric company will declare bankruptcy and then literally disappear, leaving society with a nuclear plant that must be safely dismantled. The assets of a bankrupt utility remain and would be sold to new owners. The new owners might be a neighboring utility, a holding company, or a new management team organized after a court-appointed trustee has paid the creditors and rearranged the company's capital structure. Regardless, the new owners would be informed by state regulators of their obligation to safely dispose of the nuclear plant. This undoubtedly will affect the price that the new investors are willing to pay for the assets. A utility's assets, however, are so much larger than any potential decommissioning expense that there is some positive price that would induce the new investors to jointly accept the assets and the decommissioning responsibility.

Hence, if the external and internal funding alternatives have the same tax status and are funded with the same level of annual payments, the risk of inadequate funding in the event of a bankruptcy is the same. The fundamental reason is that future regulators can require that the new owners of the bankrupt elecric company accept the obligation to decommission any nuclear plant. There is no real danger that there will be no new owners willing to accept such an obligation since the utility's assets are far more valuable than the decommissioning cost.

If the utility is threatened by less serious financial troubles, short of bankruptcy, it is possible that it might have difficulty raising capital against an internal unsegregated decommissioning reserve. This could happen if its creditors for whatever reason attach the utility's property so as to have a superior claim on the property that would secure the reserve. Such a situation might also arise if the utility had a segregated internal reserve and if the applicable state laws do not exempt the segregated reserve from attachment or other remedies provided to creditors. Such actions by creditors might delay the time of decommissioning but are unlikely to prevent it. A financially sound utility would eventually settle any such disputes with its creditors. Protracted disputes with creditors could well lead to bankruptcy and new owners who must accept the decommissioning responsibility.

Overall, if the consumer payments are adjusted so that they have the same risk-free future value, the principal difference between internal and external control is a matter of portfolio management. An external well-diversified portfolio seems clearly preferable to an internal reinvestment program. If, in addition, the level of consumer payments is set very low, because future cost is implicitly discounted at the risky rate of return, there is an additional risk that an internal fund would be inadequate even if it were invested in an efficient portfolio (which, of course, it would not be). This risk can be quantified as was shown in the discussion of objective 1 in this chapter; the inefficient portfolio risk is more difficult to measure.

Objective 5: The Tax Treatment Spreads the Tax Payments and the Benefits of the Deductible Expense of the Decommissioning Cost Across Those Who Paid for and Received the Benefit of the Plant

Two important tax issues confront regulators. The first and most important is the treatment of the earnings of the decommissioning fund. If these are taxed, consumer payments increase. Indeed, the present value of the revenue requirements needed to accumulate the risk-free future value of decommissioning exceeds the present value of the cost itself. This result is inefficient as was explained in the discussion of the first objective. This inefficiency can be avoided only by an external state trustee, an internal unsegregated fund, or federal legislation.

The second tax issue is who receives the value of the tax deduction that occurs in the future when the decommissioning expense actually occurs. The sense of justice of most regulators is served if this tax deduction is assigned to ratepayers who pay for the decommissioning cost during the life of the plant and not to the ratepayers during the actual decommissioning phase. This equitable spreading of the tax deduction implicitly has been assumed in the numerical examples throughout this report. There are several ways to achieve this.

The first method, and the only one solely available to state regulators, is simply to mandate that the tax deduction be allocated to current ratepayers. To explain this requires a brief discussion of terminology. The tax treatment of the consumer payments in advance for decommissioning is sometimes said to depend upon whether taxes are normalized or flowed through. These labels can be confusing. The California PUC prefers the Pacific Gas and Electric terminology of partial recovery method instead of normalized and full recovery method instead of flow through. It is important to understand that this particular choice of tax treatments does not affect the present value of the customer payments. It does have an important bearing on the time pattern of these payments, however.

Under the full recovery method, income taxes and the decommissioning cost provision are included in the revenue requirement during the plant's life. With a corporation income tax rate of 50 percent (to approximate the actual 46 percent rate), customers would pay about two dollars for every dollar of decommissioning expense during the life of the plant. The tax collections would be returned to future ratepayers when the expense is deducted for tax purposes. The result is that the future value of the payments correctly equals the decommissioning cost if the reduced payments of future customers during the decommissioning phase are included in the total. The time pattern of these payments, however, is grossly inequitable since the recipients of the plant's electricity pay double the actual expense while those customers living during the decommissioning receive a tax deduction for expenses that have no bearing on the cost of providing electricity to them.

The partial recovery method alleviates this inequity by requiring only one dollar of revenue for each dollar of decommissioning cost. The IRS still collects 50 percent of this so that the provision for decommissioning is only 50 percent. The remainder of the actual decommissioning cost is paid by the reduction of income taxes when the expense occurs.

A second method for achieving the equitable spreading of the tax deduction is embodied in current legislation, HR-3498, which seeks to amend the Internal Revenue Code to allow the increase in any decommissioning reserve to be tax deductible. This legislation promotes intergenerational equity in the same way as the partial recovery method.

Yet a third method for achieving the same result is for the fund to apply to the IRS for tax-exempt status. The IRS has established four guidelines that it will evaluate for each individual application. These were described in chapter 5. Meeting these, however, does not automatically confer the status. As described by the NRC staff, the earnings of the fund would not be tax-exempt, however, which substantially reduces the social value of such a status. See the discussion of objective

1. In the absence of this tax status or HR-3498, a state PUC could achieve the same objective by mandating the so-called partial recovery method.

Summary

The discussion in this chapter has focused on the underlying economic and financial issues that confront state regulators with regard to the decommissioning of nuclear power plants. The issues are complicated, and it is worthwhile to summarize briefly the main points of the discussion.

The assurance of funding was discussed first for normal, scheduled decommissioning (objective 1). Four points in particular need to be emphasized.

1. The adoption of any particular funding method results in the use, perhaps implicitly, of an interest rate to discount future cost. The negative net salvage value method, for example, implicitly discounts decommissioning cost at the utility's cost of capital.

2. The utility's cost of capital reflects revenue risk due mostly to demand uncertainty. Any uncertainty and hence riskiness, associated with the decommissioning cost is separate and distinct. Consequently, the same discount rate is not appropriate for both utility revenue and decommissioning cost.

3. The degree of risk of adequate decommissioning funding for any funding method can be measured. The procedure is to find the risk-free future value of the decommissioning fund. There are two steps. First, determine the present value of the set of annual revenue requirements associated with decommissioning under any funding proposal using the utility's cost of capital. Second, find the risk-free future value of this present value at the scheduled decommissioning time using the risk-free interest rate. Finding the risk-adjusted future value of the fund facilitates a comparison of the fund itself with the estimated future cost and also facilitates a comparison of various funding methods one to the other. The annual decommissioning revenue requirements of any funding proposal can be adjusted so that the risk-free future value of the fund equals the risk-free future value of

the cost. The amount of adjustment required is a measure of risk. Determining the risk-free interest rate in the rate hearing environment may involve expert testimony, however, in much the same manner as determining the cost of capital.

4. Previous studies have found significant differences in required revenues depending on whether the fund is prepaid or not, and whether the fund is internal or external. In each case, however, the difference can be traced to the use of different interest rates to discount future cost. In reality, the appropriate interest rate for future cost depends on the uncertainty of the decommissioning cost estimates and not on the internal or external status of the fund or whether it was prepaid. Using the appropriate interest rate, for example the risk-free rate if cost is known with certainty, results in annual revenue requirements that eliminate the apparent differences in revenue requirements, for either of the two reasons discussed above.

Two of the points discussed with regard to adequate funding in the event of a premature decommissioning (objective 2) need to be highlighted. These have to do with the existence of possible funding gaps. They are numbered consecutively with the previous points.

5. Because of the difference between the anticipated, risk-free, interest rate and the anticipated growth rate of decommissioning costs, it is possible that the decommissioning fund will be inadequate if it is needed prematurely. In particular, if the growth rate of the fund exceeds the cost escalation rate, a prepaid fund can be set initially smaller than the cost in anticipation that the fund will grow faster. It would be economically efficient to fill the gap between the current value of the fund and the current decommissioning cost with insurance; however, such insurance is not presently available. State regulators may wish to encourage the electricity industry to consider such insurance.

6. Previous studies have asserted that this gap is larger if the fund is not prepaid, that is, if the fund only accumulates the annual payments. Such an assertion is

based upon a somewhat narrow viewpoint. The more important issue is whether or not regulators will continue to require consumers to make decommissioning payments after a premature shutdown. The larger gap identified by previous studies exists between two particular funding arrangements. These are a) a prepaid fund together with a continuing obligation to make payments, following the premature shutdown, on the securities issued to fund the prepayment, and b) an accumulating fund that consumers do not pay after the plant is shutdown. The difference between these two arrangements is the ratepayers' obligation following an early shutdown. Yet another arrangement, and one that illustrates this issue, is as follows: the fund is not prepaid but consumers continue their annual payments for decommissioning. In this case the utility could issue decommissioning securities at the time of the premature shutdown. These would be backed up by the revenue allowed by the regulator, which is the same kind of collateral that backs up the securities issued for any initial prepayment. This supplemental issuance of revenue securities at the time of premature shutdown is exactly enough to fill the apparent gap between prepaid funding and funding that accumulates over time. Hence, no gap exists simply because of the lack of prepayment. Instead, the gap is due to a difference in regulatory policy regarding the payment for facilities no longer useful.

The discussion of intergenerational equity (objective 3) raises the following point.

7. Recovery of decommissioning cost using a traditional rate base treatment or some variation thereof imposes larger real payments on early generations of ratepayers. This problem is not unique to nuclear decommissioning cost. All plant and equipment cost recovered with rate base accounting has a similar, large, front-end financial loading that becomes larger as the rate of inflation increases. Commissions that do not wish to raise the very complicated issue of rate base accounting in inflationary times can alleviate the intergenerational equity issue in the case of nuclear decommissioning by considering ordinary sinking fund methods of cost recovery.

Another point, developed in the discussion of objective 4, concerns internal versus external control of the decommissioning fund itself.

8. If an external trustee were to invest the prepaid or accumulated decommissioning monies, he or she would be required to invest in a well diversified portfolio. Such a portfolio is efficient in the sense that the greatest return is earned given the market value of risk. Investing the money solely in the utility does not have this characteristic, and exposes the fund to what is called the unsystematic risk of the utility's returns. This unsystematic risk component washes out when the utility's returns are combined with those of other securities. A prudent trustee would not expose the fund to this additional portfolio risk. External control of the fund seems superior to an internal, unsegregated fund on these grounds.

Two points were developed regarding equity and efficiency in tax treatment (objective 5).

9. There are three possible ways to spread the benefits of the future tax deduction of decommissioning expenses. Of these, only one is solely in the control of state regulators. This is the so-called reverse normalization or partial recovery method. Intergenerational equity is served and economic efficiency promoted by spreading the tax deduction to current ratepayers.

10. The tax status of the fund itself, as opposed to the tax status of the securities held by the fund, determines its after-tax rate of earnings. It is economically efficient for the fund to be tax exempt. (See also the discussion at the end of objective 1). This can be accomplished by an external state controlled fund, by an internal unsegregated fund, or through federal legislation.

The complexity of these issues is not due to the fact that the facilities are nuclear; instead, it can be traced to the policy of collecting money in advance for a rather large, future cost. In addition to the revenue risk normally dealt with in regulatory hearings, dealing with future costs raises important matters of cost risk, portfolio risk, and the tax status of the collected funds. These are also relevant for other technologies such as coal if the cost of removing the plant were to become large relative to its salvage value.

APPENDIX

SUMMARY OF STATE LEGISLATIVE ACTIVITY RELATED TO
REACTOR DECOMMISSIONING FOR THE PERIOD JANUARY 1975 TO JANUARY 1982

The Nuclear Regulatory Commission staff has been keeping track of state legislation pertaining to nuclear facility decommissioning. An NRC staff member supplied the authors with a copy of this summary material. The material is reproduced here unedited, but discussions of legislation that pertain only to non-reactor facilities, such as waste disposal sites, have been deleted.

Bills Enacted into Law Relating to Reactor Decommissioning Funding

New Hampshire - 1981

Decommissioning H-1. Requires operating utilities to assume complete fiscal responsibility for the decommissioning of nuclear power plants. Establishes the "Nuclear Decommissioning Financing Committee," responsible for ensuring that safe decommissioning and subsequent surveillance of nuclear reactor sites will be provided. The committee will also administer the payment of monies into the nuclear decommissioning financing fund, also created by this bill. The full amount of payments into the fund will be established by the committee. Details organization of and funding determinations by the committee. (Enacted 5/4/81.)

Maine - 1979

Decommissioning Study H-632. Creates a Joint Selection Committee on Decommissioning Nuclear Generating Facilities to study: the need for decommissioning, the procedures available, the overall cost, and methods of funding. The study is due to the legislature by 1/5/81. (Approved 6/25/79.)

Bills Introduced Relating to Reactor Decommissioning Funding

New York - 1981

Decontamination and Decommissioning A-174. Would require the affected utility to establish electric rates to provide for a sinking fund for the decontamination and decommissioning of nuclear generating facilities. Would require that adequate funds be available to restore the site to unrestricted use, wherein measured levels of radiation are no higher than previously established background levels for the site. (Introduced 1/7/81.)

Vermont - 1981

Decontamination and Decommissioning H-36. Would establish a three-member Decommissioning Board. Would empower the Board to: (1) require the licensee of a nuclear facility to file with the State the necessary bond or insurance to provide funds for emergency response to and decontamination of radiation accidents, and (2) require the licensee to deposit funds quarterly into trust funds sufficient to provide for decontamination, monitoring, and supervision of the nuclear site. (Introduced 1/7/81.)

New Hampshire - 1981

Decommissioning Nuclear Power Plants H-1. Would establish an 8-member Nuclear Decommissioning Financing Committee to ascertain the cost of decommissioning any nuclear electric generating facility in the State. This Committee would establish a monthly payment schedule whereby the owners of the facility would pay the required amount into a Decommissioning Fund, under the jurisdiction of the State Treasurer. (Enacted 5/4/81.) (Introduced 1/7/81.)

Indiana - 1981

Decommissioning of Nuclear Plants S-532. Would create the Nuclear Power Plant Decommissioning Trust Fund, with funds to come from a special kilowatt hour assessment, to provide for the decommissioning of each nuclear power plant in the State after it is retired from service. Would establish a sinking fund account in the Trust Fund for each nuclear power plant, including a target fund amount which contains an inflation adjustment factor, with means for adjusting the kilowatt hour assessments to achieve the target fund amount. (Introduced 1/19/81.)

Oregon - 1981

Energy Facility Financing H-2572. Would require the Energy Facility Siting Council find, before issuing a site certification, that the applicant has adequate financial resources for the retirement of a proposed energy facility. Authorizes the Council to adopt rules for retirement of and maintenance of physical security for energy facilities. (Introduced 2/11/81.)

Maine - 1981

Decommissioning Fund LD-1099. Would establish a decommissioning fund to be administered by the Treasurer of the State. The fund would finance the eventual decommissioning of any nuclear power plant in the State, with annual payments made as necessary to meet the cost when the operating license expires. All funds authorized by the PUC and collected by electric utilities in intrastate sales from ratepayers shall be deposited in the fund. (Introduced 3/3/81.)

Wisconsin - 1981

Decommissioning Management Funds A-915. This bill will require utilities operating nuclear power plants to submit to the PSC a decommissioning and high-level radioactive waste disposal financing plan. The financing plan must include plans for establishing a trust account to pay for the decommissioning and disposal costs. The trust account will be derived from a surcharge on electricity sold by the utility. The PSC will approve or disapprove each financing plan. If the financing plan is disapproved the Commission may order the funds placed in escrow along with any funds collected in the future. The Commission will review approved plans at least once every 3 years. The start of a new plant and the continued operation of an existing plant is contingent upon compliance with a financing plan. (Introduced 11/19/81.)

Massachusetts - 1980

Decommission Costs H-3938. Would direct the Department of Public Utilities to order utilities to develop comprehensive plans for decommissioning nuclear installations, the charges of which would be included in costs passed on to the customers. (Introduced 1/18/80.)

Missouri - 1980

Nuclear Facility Siting H-1167. Would prohibit the construction of a nuclear facility in the State until the State Department of Natural Resources finds that 1) no legal limits exist on the right to bring suit and collect for damages resulting from the operation or existence of a facility; 2) the effectiveness of all safety systems has been demonstrated; 3) the radioactive materials from the facility can be contained with no reasonable chance (as determined by the Department) of intentional or unintentional escape or diversion into the environment so as to cause substantial or long-term harm or hazard; and 4) the owner of a nuclear facility has posted a bond with the Department of not less than 30% of the total capital cost of the facility to pay for the decommissioning of the facility and decontamination of any area contaminated with radiation as a result of the operation or existence of a facility. If the Department decides to issue a certificate for the construction of a nuclear facility, its recommendation must be approved by a majority of the voters of the State in a State-wide election. These provisions would not apply to any aspect of a nuclear facility over which the Federal government has exclusive jurisdiction or for a nuclear facility already under construction or in operation on the effective date of this act. Finally, the Governor would be required to annually publish and review emergency evacuation plans in conjunction with certain State agencies. (Introduced 1/9/80.)

Florida - 1980

Nuclear Plant Siting S-461. Would prohibit the Department of Environmental Regulation from issuing any new site certification for any nuclear plant until safety studies and evacuation plans have been developed and the facility has posted a bond equal to at least 30% of the cost of decommissioning the plant. Also would require existing nuclear facilities to mail a summary of emergency evacuation plans to all customers within a 50-mile radius of the facility every 3 months. (Introduced 4/8/80.)

Missouri - 1980

Proposition No. 11 Initiative Petition. (Defeated.) This proposition would have prohibited the operation of electric power facilities utilizing nuclear fission, unless federally-approved sites existed for permanent storage of spent fuel and other radioactive material anticipated to have been produced during the life of the facility; and, the owners or operators would have posted a bond securing the cost of decommissioning the facility. (Defeated 11/4/80.)

Kansas - 1979

Decommissioning Cost Study S-87. Would direct the State Corporation Commission to study the costs of decommissioning a nuclear reactor from the viewpoint of the costs borne by ratepayers. The report would be due to the governor and legislature by 1/1/80. (Introduced 1/11/79.)

New York - 1979

Decommissioning Fund A-5566. Would require that the PUC establish sinking funds to provide for the decontamination and decommissioning of nuclear facilities. The PUC would determine the preferred methods of decommissioning. Cost determinations would have to be reviewed every five years. A report would be due to the legislature and governor by April 1, 1980 reporting decommissioning cost estimates and the impact they would have on rates. A plan for phasing in costs to current rates would have to be identified. (Introduced 3/6/79.)

New York - 1979

Funds for Decommissioning S-3869. Would require the Public Service Commission to establish a sinking fund for decontamination and decommissioning of nuclear generating facilities. (Introduced 3/13/79.)

New Hampshire - 1979

Decommissioning H-805. Would create a nuclear decommissioning financing committee for each nuclear plant in the State to determine the amount and monitor a decommissioning fund which would be held by the State. The utility would pay into the fund monthly. The charge would be passed on to the ratepayer as a separate item on his bill. (Introduced 4/5/79.)

Vertmont - 1979

Decommissioning Nuclear Facilities H-363. Would create a Nuclear Decommissioning Board to establish regulations governing a radiation protection fund which requires licensees to file bonds with it to cover expenses related to emergency responses to accidents, default or inability of licensee to meet the requirements of the Board; and would create a perpetual care fund to provide monies for maintenance and surveillance if the licensed activity ceases. The intent is to prevent the State from assuming financial responsibility for decontaminating and decommissioning nuclear facilities. The bill would also require the Board to establish security requirements for each class of licensee within the State. (Introduced 2/27/79.)

Bills Enacted into Law Relating To Premature Decommissioning, Its Funding, and/or Post-Accident Recovery Efforts

Pennsylvania - 1981

Federal Impact Aid HR-6. Petitions Congress to appropriate Federal impact aid through a sharing formula between the Federal government, the electric utility industry and the nuclear manufacturing industry to pay for replacement fuel costs due to the shutdown of the Three Mile Island plant and for the cleanup and repair of the damaged facility. (Enacted 4/21/81.)

Bills Introduced Relating to Premature Decommissioning, Its Funding, and/or Post-Accident Recovery Efforts

Vermont - 1981

Costs of unscheduled Shutdown of Electric Utilities H.40. Would prohibit an electric utility from passing along to the customers the costs of unscheduled shutdowns due to equipment malfunction until the utility has exhausted all legal remedies against the designers and manufacturers of the faulty equipment. (Introduced 1/7/81.)

Connecticut - 1981

Costs of TMI Accident and Cleanup H-6265. Would prohibit the Department of Public Utility Control from allowing costs for damages associated with the accident or cleanup of the TMI nuclear incident to be passed through to

Connecticut utility ratepayers, except as provided by Federal law in force at the beginning of the accident. (Introduced 1/26/81.)

New Mexico - 1981

Liability Limit H-262. Would prohibit insurance companies from issuing property damage policies which exclude or limit the liability for loss or damage caused by nuclear reaction radiation or radioactive contamination. (Introduced 2/2/81.)

Pennsylvania - 1981

Clean-up Costs H-958. Would require electric utility companies to carry insurance to cover the cost of cleaning up the plant and the cost of purchasing electricity for resale after a nuclear accident. The cost of the insurance would come exclusively from that part of the rate allocated to the corporate profits of the utility company. (Introduced 3/23/81.)

Pennsylvania - 1981

Rate Changes after Nuclear Accidents S-1025. The rates of an electric utility company which suffers a lack of generating capacity as a result of a failure of a nuclear reactor shall not include any cost resulting from such failure, including, but not limited to, the purchase of energy in excess of the average costs incurred by the utility during the past 12 months, repairs to the facility, clean-up costs, decommissioning costs, unsalvageable costs, or liability resulting from the accident. (Introduced 8/12/81.)

Vermont - 1980

Rate Changes H-694. Would prohibit changes in electricity rates if they are due to shutdowns of nuclear plants caused by errors in the plant design, management, or operation. (Introduced 1/8/80.)

West Virginia - 1980

Nuclear Liability S-25. Would prohibit the costs of indemnifying the nuclear industry from liability resulting from a nuclear incident from being charged to State customers through the utilities' rate base. In addition, utilities serving State customers and operating nuclear facilities in other States would be prohibited from charging State customers the expenses it could incur as a result of a nuclear incident. (Introduced 1/9/80.)

Alabama - 1980

Pass Through of Costs H-414. Would prohibit any public utility in the State from charging its customers for any reparation expenses incurred by such utility because of any accident or mechanical malfunction at one of their nuclear plants which results in any radioactive emission. (Introduced 2/12/80.)

New York - 1980

Temporary State Commission on Nuclear Power A-9010 & S-7618. Would create a temporary State commission on the phaseout of nuclear power plants to examine, evaluate, and make recommendations on how existing nuclear plants in the State could be phased out. (Introduced 2/12/80.)

Maine - 1980

Nuclear Fission Control Act - Initiated Bill-2. Would ban generation of electricity by nuclear power in Maine. This would include existing plants, as well as future construction. (Introduced 3/7/80.)

Maine - 1980

Initiative No. 1. (Defeated.) This proposition would have prohibited generation of electric power by nuclear fission in the State at existing or proposed nuclear power plants. (Defeated September 23, 1980.)

Pennsylvania - 1979

Rate Changes After Nuclear Accidents S-632. Would prohibit passing through the costs resulting from a lack of generating capacity at a reactor including the purchase of replacement electricity, repairs to the facility, liability in excess of that paid by insurers unless a finding is made by a jury that the utility was not at fault. The jury would be convened in the county in which the reactor is located. (Introduced 4/23/79.)

Pennsylvania - 1979

Charges in Rate Base H-1359. No additional charges could be included in any utility rate base which would include costs as a result of a nuclear accident. (Introduced 5/22/79.)

Bills Enacted Into Law Relating to Reactor Decommissioning Generally

Maine - 1981

Decommissioning LD-454. Continues the Joint Select Committee on Decommissioning of Nuclear Generating Facilities. Extends the expiration date for its study and recommendations to December 2, 1981. Allocates per diem and other expenses to each member of the committee for each meeting attended. (Enacted 4/1/81.)

Massachusetts - 1979

Siting Restriction S-1786. The State Senate requests that the PUC and Energy Facility Siting Council (EFSC) delay for a two-year period any decisions which would encourage further construction of nuclear power plants or until in-depth studies of the safety standards for the design, construction, operation and decommissioning of nuclear power plants. Also, urges the PUC and EFSC to accelerate development of alternate energy sources. (Adopted 4/17/79.)

Oregon - 1979

Energy Cost-Effectiveness S-570. States that energy cost-effectiveness must be considered in all agency decisionmaking relating to energy facilities. Waste disposal and decommissioning costs are included in the definition of cost effective. (Approved 7/24/79.)

Bills Introduced Relating to Reactor Decommissioning Generally

New York - 1981

Decontamination and Decommissioning A-174. Would require the affected utility to establish electric rates to provide for a sinking fund for the decontamination and decommissioning of nuclear generating facilities.

Would require that adequate funds be available to restore the site to unrestricted use, wherein measured levels of radiation are no higher than previously established background levels for the site. (Introduced 2/7/81.)

Maine - 1981

Nuclear Power Plant Decommissioning LD-861. Would prohibit mothballing or entombment as methods of decommissioning any nuclear power reactor in the State. (Introduced 2/13/81.)