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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:
Charles Bechhoefer, Chairman
Dr. Frank F. Hooper
Glenn O. Bright

RECEIVED
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U.S. NUCLEAR REGULATORY COMMISSION

In the Matter of: :
: Docket No. 50-358
CINCINNATI GAS & ELECTRIC CO., ET AL. :
:
(William H. Zimmer Nuclear Station) :
:

MIAMI VALLEY POWER PROJECT'S ANSWERS TO APPLICANT'S SEVENTH SET OF INTERROGATORIES

1. James H. Feldman, Jr. answered this interrogatory. His address is 216 East Ninth Street, Cincinnati, OH 45202. He is an attorney.

   Answer: CG&E's response to November 27, 1978 NRC Request for Additional Financial Information (as revised November, 1980)

   Accountants for the Public Interest, An Analysis of Decommissioning and Premature Shutdown Costs of Nuclear Power Plants, August, 1980.

   Public Utilities Fortnightly, Progress of Regulations - Nuclear Plant Decommissioning Cost, April 26, 1979.

   Iwler, Louis, "Industry Developments, Regulatory Bodies Ready for In Plant Retirements" Electrical World, 7-15-78, p. 19.

   U.S. General Accounting Office, "Cleaning Up the Remains of Nuclear Facilities - A Multi-Billion Dollar Problem," Washington, D.C., U.S. Govt. Printing Office, EMD-77-46, 6-16-77.

   Vider, Elise, "What Happens When a Nuke Dies", Valley Advocate, 7-26-78.

   Article in Mother Jones, December, 1980.

2. All documents listed in answer to question 1. Also answered by James H. Feldman, Jr.

3. James H. Feldman, Jr. answered this interrogatory.

   Answer: George G. Suckarieh, Ph.D., P.E.
   671 Riddle Road
   Cincinnati, OH 45220
   (513) 751-2533

   Education: Ph. D. Civil Engineering, Ohio State Univ.
   MBA, Ohio State University

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After this was typed, we were given the name of Dick Can Aggelen, a CPA in San Fransisco, CA who may testify. His phone number is (415) 431-6109

ME, University of Cincinnati
Current Employment: Professor of Construction Management, University of Cincinnati, College of Applied Sciences.

Thomas R. Herman, J.D.
3434 Riverdell Dr.
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Educational background: Undergraduate degree in economics, University of Cincinnati, Cincinnati, OH.

Juris Doctor, Salmon P. Chase College of Law.

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Ralph Estes
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Educational Background: DBA from Indiana University
MBA and BS from University of Kentucky
CPA

Current Employment: Chairperson, Department of Accounting, Wichita State University.

4. See answer to interrogatory 3.

5. The individuals listed in response to interrogatory 3 may be called as witnesses.

Summary of testimony of witnesses: These witnesses will generally testify that the Applicants have underestimated the costs of decommissioning the Zimmer Plant.

James H. Feldman, Jr. prepared the answer to this interrogatory.

6. James H. Feldman, Jr. prepared the answer to this interrogatory.

Answer: None.

7. James H. Feldman, Jr. prepared the answer to this interrogatory.

Answer: See answer to interrogatory 3 and 5.

8. James H. Feldman, Jr. prepared the answer to this interrogatory.

Answer: Attached please find the Accountants for the Public Interest Report: An Analysis of Decommissioning and Premature Shutdown of Nuclear Power Plants.

MVPP also intends to use any independant calculations cited in

MVPP's answers to interrogatory 1. MVPP does not currently have copies of these other documents, but will provide them as soon as possible to any party so requesting them as soon as possible.

9. James H. Feldman, Jr. prepared the answers to this interrogatory.

JAN 26 1981
Office of the Secretary
Docketing & Service
Branch

Answer: Leah Kosik
Saul Rigberg
Tom McDonald

VERIFICATION

STATE OF OHIO)
COUNTY OF HAMILTON) SS.

James H. Feldman, Jr., being duly sworn and cautioned says that he is the Attorney for MVPP in the above-captioned proceeding; that the foregoing answers to the interrogatories are true as he believes.

James H. Feldman, Jr.

Sworn to before me and subscribed to in my presence this 20 day of January, 1981.

KAREN D. NORTHCUTT
Notary Public, State of Ohio
My Commission Expires Jan. 22, 1985

CERTIFICATION

I hereby certify that a copy of the foregoing answers to applicant's seventh set of interrogatories were served on all individuals on the service list by regular U.S. Mail, with the exception of local counsel for Applicants, who was served by leaving a copy at his office this 20 day of January, 1981.

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Office of the Secretary
GH

AN ANALYSIS OF DECOMMISSIONING AND PREMATURE SHUTDOWN COSTS OF NUCLEAR POWER PLANTS

Digest

The debate over nuclear power plants has been particularly vigorous, often acrimonious and frequently emotional. It has expanded in recent years to add economic issues to those of a technical and engineering nature.

Many of the economic issues have been the object of study and investigation by Congress, the nuclear industry, and others advocating or opposing nuclear power. Two of these issues, however -- decommissioning costs and the economic effects of premature shutdown -- have received little attention. This report presents the results of an indepedent analysis of these issues for the guidance of regulatory agencies, Congress, and others who must make decisions concerning nuclear power.

In this report we cite a number of estimates made by others concerning the possible magnitude of decommissioning costs, useful lives of nuclear plants, and capacity factors to provide exemplary parameters for our analysis. Such citations do not represent an endorsement of these estimates, which involve nonaccounting issues in which API has no special competence.

TABLE OF CONTENTS

Our study included a review of relevant literature including material from advocates and opponents of nuclear power. We obtained information, advice, and reactions from nuclear engineering consultants and from a number of other organizations and individuals. Costs have been projected on the basis of a range of assumptions. Based on analysis of these data, we conclude that the following actions would be in the public interest:

Recommendations:

I. Utility regulatory agencies should require utility companies to:

   a. include decommissioning costs in rate-setting procedures; and

   b. finance decommissioning by means of a funded reserve through an external trust established in a financial institution and controlled to insure the safety and preservation of the fund.

   A formula is presented on page 18 to estimate the cost of decommissioning to ratepayers per kilowatt hour used.

II. Internal Revenue Service Regulation 1.167(a)-11(d) should be amended to permit an income tax deduction for amortization of estimated future decommissioning costs.

III. Utility regulatory agencies should recommend the use of the units-of-production method for computing depreciation on nuclear plants, as a more appropriate method for recovering costs and charging users with the power actually consumed. Alternatively, regulatory agencies should assure periodic reassessment of estimated life and capacity factors.

IV. The nuclear power industry should seek declining term insurance to cover, in the event of premature shutdown, the unrecovered capital costs and the unfunded costs of decommissioning. Whether nuclear power generation is vital to the public interest is not an accounting question and is consequently one on which we take no position. If such power is deemed to be in the public interest, and if private insurance coverage cannot be developed, Congress and appropriate Federal agencies should give immediate consideration to the development of a nuclear power insurance pool partially or wholly supported by the Federal government.

I. INTRODUCTION

Few public issues in the recent history of the United States have been debated more intensely and with more emotion than the matter of nuclear power -- and with good reason. Its proponents assert that nuclear power must play an important role in energy production if we are to become independent of foreign sources of energy; that nuclear power is cheaper than its present primary competitor, power from coal-fired plants; that it is safe and environmentally benign, etc.

Opponents of nuclear power deny virtually all of the claims of its adherents. They point to conservation and solar energy as alternative "sources," assert that coal is cheaper, point to the accident at the Three Mile Island #2 nuclear plant in March of 1979 to demonstrate that it is unsafe, etc.

It has become increasingly apparent that the future of nuclear power could well depend upon economic factors. Notwithstanding the plethora of studies and reports from governmental agencies, industry representatives and public interest groups, Amory Lovins, testifying on September 21, 1977, before the Environmental, Energy and Natural Resources Subcommittee of the Committee on Government Operations of the U. S. House of Representatives, stated: " . . . the projected costs of nuclear electricity depend on nearly 50 main variables of which all are disputed, probably none is known within a factor of two, and few if any are independent of each other, so that almost any position is supportable (however disingenuously)."

More recently I. C. Bupp of Harvard Business School wrote, in Energy Future:

> A tangle of contradictory expert opinions similar to that which for years had characterized the nuclear safety imbroglio had by 1977 overtaken the question of whether nuclear was, or ever could be expected to be, a relatively cheap source of electricity. It was virtually impossible to make any substantive statement about the economic performance of nuclear power without offending one of the parties in an arcane and increasingly rancorous dispute.
>
> The controversy touched every important factor on which the economic performance of a nuclear power plant depended: the respective investment costs of coal and nuclear generating stations; the proper way to deal with inflation in allocating this investment cost to each kilowatt hour of electricity produced by the plants during their assumed lifetimes; respective fuel and fuel-related costs; and the appropriate way to discount future cash flows in allocating the fixed and variable costs of nuclear and coal-fired power plants.
>
> After weeks of expert testimony on the subject in early 1978, the Public Service Commission of Wisconsin concluded that "there is a wide range of views in this record concerning the relative economics of nuclear and coal-fired generation. These views range from nuclear power's being much less costly than coal to coal's being much less costly than nuclear, and include the view that it is impossible to tell." Several months later, the staff of another state public service commission--New York's--summarized yet another lengthy review with a terse conclusion: "There is no credible bottom line comparison of the total generating costs of nuclear and fossil facilities which can be extracted from this record."
>
> In my opinion, no credible bottom line comparison can be extracted from any existing data. In short, almost six years after OPEC quadrupled the price of fossil fuels--and almost fifteen years after nuclear power supposedly first gained a competitive edge over coal--it is still plausible to assert that atomic energy is or is not competitive by a choice of assumptions that suit one's interest.
>
> Whether an analyst supports or opposes nuclear power, he or she adopts assumptions and cites evidence about relative capital and fuel costs, power plant capacity, and other factors that maintain one or the other position [1, pp. 123-4].

Many billions of dollars have been spent, are committed to be spent, or are presently planned on being spent for nuclear power plants in this country. This report will review and analyze some of the issues involved in accounting for these costs.

Accountants for the Public Interest (API)

API is a national nonprofit accounting organization devoted to public interest accounting, including research and analysis of the financial implications of public policy issues. Since 1972, API has provided independent and objective accounting studies through its largely volunteer staff at the national office and its local affiliated organizations.

Affiliates participating in this study were:

CPAs for the Public Interest (Chicago)

Community Accountants (Philadelphia)

Accountants for the Public Interest of
Rhode Island, Inc. (Providence)

Oregon Accountants for the Public Interest (Portland)

This project has been supported by grants from an anonymous donor and from the following:

CR Fund of the Youth Project

W. H. and Carol Ferry

The Max and Anna Levinson Foundation

API maintains absolute independence in performing analyses of public policy issues. In keeping with this policy, no donor influenced nor attempted to influence any part of this study or report.

The Study

Accountants for the Public Interest is neither for nor against nuclear power. We have no "position" as to the economic advantages or disadvantages of various forms of power production. We also recognize that there are a great many complex non-economic factors which must be weighed by Federal and state legislatures and regulatory agencies in establishing future energy policies and directions. These include a variety of social, moral, civil rights, political and health issues. We take no position on these matters, nor on many of the other economic and financial factors which have been the focus of attention in Congress, the media, and by governmental agencies and special interest groups representing both sides of this important controversy.*

Two aspects of nuclear economics, however, have received comparatively little attention and consideration: the possible effects of decommissioning costs and earlier-than-expected retirement of nuclear plants on ratepayers, taxpayers, utility companies.

These initial focal points of our study were modified so... ...at after the accident at the Three Mile Island #2 (TMI) nuclear plant, which occurred shortly before we commenced our work. TMI brought vividly to our attention the possibility that decommissioning and early retirement could be intimately related. We had previously conceptually viewed the

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*Such as waste management costs, availability of capital, tax advantages, capital cost escalation, insurance and other government subsidies, uranium supply, replacement power, etc.

two as rather unrelated; that is, funds (however much) could be accumulated over the life of the plant (however long).* Since it became clear very soon after the accident that there was a significant possibility that TMI might never reopen, we were forced to look at decommissioning in a different light--that a plant might have to be decommissioned very soon (after a few <u>months</u>, in the case of TMI) after it commenced producing electricity.

This reasoning led us to examine other relationships not originally contemplated in our study. If capacity factors are lower than those originally estimated by the nuclear industry, would, therefore, estimated lives be longer than those projected? And does the straight-line method of depreciation make sense in view of the widely varying capacity factors and uncertain useful lives?

Because of the complexity of the subject matter and our limited resources, we found it necessary to carefully focus the study and limit its scope. Therefore, we have made no attempt to analyze similar cost factors for coal-fired plants. We must leave for future analysis the question of whether our comments on decommissioning, early retirement, etc., are significant with respect to coal--the commonly compared competitor of nuclear power.

In performing this analysis, API retained the services of nuclear engineering consultants and obtained advice from a number of experts in the field, as well as comments from both pro- and anti-nuclear advocates (see Appendix C). All analysis and evaluation was, however, performed independently by API staff and volunteers, and conclusions and recommendations contained in this report are those of API alone.

II. DECOMMISSIONING

Introduction

Decommissioning may be defined as the process of retiring, by dismantling or decontaminating, nuclear plants when they are no longer producing power.

According to the General Accounting Office,

> As with every industry, nuclear facilities and equipment may be shut down, replaced, or become obsolete. Cleaning up the remains of nuclear activities, however, presents special problems because of radioactivity and contamination which can endanger public health and safety. Some radioactivity remains hazardous for thousands of years, making final and absolute disposal at best a difficult and expensive task [16, p. i].

Permanent disposal of radioactive materials is presently not authorized at nuclear power plant sites. Thus, at some time the plant will need to be decontaminated and the radioactive materials removed from the plant site. This will require that all waste materials be removed from storage tanks on site. In addition, the entire nuclear plant primary system, including major portions of the structures, foundations, drain system, pumps, valves and piping systems must ultimately be cleaned up, disassembled, packaged to meet the required shipment regulations, and transported to permanent waste burial grounds for long-term storage.

NRC's Present Policies

The present decommissioning regulations, originally promulgated by the Atomic Energy Commission,* are contained in Sections 50.33(f) and 50.82 of 10 CFR Part 50. These regulations require applicants for power reactor operating licenses to furnish the Nuclear Regulatory Commission with sufficient information to demonstrate that they can obtain the funds needed to meet both operating costs and the estimated costs of permanently shutting down the facility and maintaining it in a safe condition. The development of detailed, specific decommissioning plans for nuclear power plants is not currently required until the licensee seeks to terminate his operating license. Should license termination be desired, Section 50.82 of 10 CFR Part 50 requires that the licensee provide the Commission with information on the proposed procedures for disposal of the radioactive material, decontamination of the site and procedures to assure public safety.

Alternative Forms

NRC Regulatory Guide 1.86 describes four alternatives for retirement of nuclear reactor facilities which are considered acceptable by the Commission staff. The NRC has, however, not yet issued definitive regulations on decommissioning. The Guide is published by the NRC as an example of a procedure that would be expected to be approved subsequent to a formal review, but the guide is not binding on the NRC or the reactor owner. The four methods are:

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*In January 1975 the Atomic Energy Commission (AEC) was split into two Federal agencies, the Nuclear Regulatory Commission (NRC) and the Energy Research and Development Administration (ERDA). ERDA was subsequently melded into the Department of Energy.

a. Mothballing. Mothballing of a nuclear reactor facility consists of putting the facility in a state of protective storage. In general, the facility may be left intact except that all fuel assemblies and the radioactive fluids and waste should be removed from the site. Adequate radiation monitoring, environmental surveillance, and appropriate security procedures should be established under a possession-only license to ensure that the health and safety of the public is not endangered.

b. In-Place Entombment. In-place entombment consists of sealing all the remaining highly radioactive or contaminated components (e.g., the pressure vessel and reactor internals) within a structure integral with the biological shield after having all fuel assemblies, radioactive fluids and wastes, and certain selected components shipped offsite. The structure should provide integrity over the period of time in which significant quantities of radioactivity remain with the material in the entombment. An appropriate and continuing surveillance program should be established under a possession-only license.

c. Removal of Radioactive Components and Dismantling. All fuel assemblies, radioactive fluids and waste, and other materials having activities above accepted unrestricted activity levels should be removed from the site. The facility owner may then have unrestricted use of the site with no requirement for a license. If the facility owner desires, the remainder of the reactor facility may be dismantled and all vestiges removed and disposed of.

d. Conversion to a New Nuclear System or a Fossil Fuel System. This alternative, which applies only to nuclear power plants, utilizes the existing turbine system with a new steam supply system. The original nuclear steam supply system should be separated from the electric generating system and disposed of in accordance with one of the previous three retirement alternatives. The conversion of the non-nuclear portion of a retired nuclear power plant is beyond the scope of this study and, consequently, will not be addressed in this report.

Experience to Date

Since 1960, 5 licensed nuclear power reactors, 4 demonstration reactors and 6 licensed test reactors have been decommissioned in the United States [20]. Much has been learned from the decommissioning of these small or experimental reactors. But each of those reactors was much smaller than the current generation of commercial nuclear plants and each was generally operated for such short periods of time at reduced average power levels, that it is fair to say that there is not yet any significant experience either in the United States or elsewhere in the world on decommissioning of large light water reactors. Only one of the reactors, Elk River, was actually totally dismantled.

Cost Estimates

Cost estimates for decommissioning have varied greatly and have been hotly debated. The disagreements have centered around the method of decommissioning, inflation factors, which years' costs should be used, etc. This controversy has been fueled by the absence of experience of decommissioning one of the larger, new generation nuclear plants, and the uncertain applicability of the experience with older and much smaller facilities.

Appendix A reports several estimates for costs of decommissioning a nuclear plant, ranging from $24 million to over $100 million. It should be noted that some estimates refer to different forms of decommissioning, some use different base years, some use contingency factors, some are based on other studies, and some do not indicate the size or cost of the plant for which the estimate is made.

Our purpose is not to predict which of these estimates is the most reasonable, but rather to demonstrate the possible effects of decommissioning costs on ratepayers based on a range of both costs and estimated useful lives of the plant. Our computations are based on the need to provide for decommissioning costs at the time of plant retirement. If the dismantlement option is taken, these costs will be incurred soon after retirement. If mothballing or entombment is chosen, costs may be incurred over or deferred for a number of years. In all three cases, however, it is appropriate to view decommissioning costs at the time of plant retirement as the discounted present value of all decommissioning costs subsequent to that date, regardless of the option chosen. When we have used a decommissioning cost of $50,000,000, for example, this could represent the cost of dismantlement at the time of plant retirement, or the present value at that point in time of expected costs over several years for mothballing or entombment.

Financing Decommissioning Costs

According to the House Committee on Government Operations:

> The Nuclear Regulatory Commission should require applicants for construction and operating licenses for nuclear power plants, as a condition of such licenses, to amortize the full cost of radioactive waste disposal, spent nuclear fuel management, perpetual care, contingencies, and decommissioning costs over the expect useful lifetime of each power plant. . . . Funds sufficient for such costs should be levied by the power facility on its customers, and such amounts should be held in trust for purposes of such costs [17, p. 76].

Even dissenting Congressmen agreed, "There was virtual unanimity in the hearings that the cost of decommissioning and decontaminating should be paid by the users of nuclear generated electricity." [17, p. 98]

Less than 10 months before, the General Accounting Office reported: "A conference of state officials has recommended that states protect themselves from financial loss should a company not be able to pay to decommission its facilities. However, only seven states require some form of bonding or advance accumulation of funds for decommissioning." [16, p. iii]

The GAO report outlines three approaches by which utilities could collect from current users:

- By means of a direct charge to customers, and the setting of these aside in an escrow or trust fund.
- Through depreciation charges, which would enable the utility to collect the funds but would not guarantee the money would be available when needed.
- With a bonding arrangement, which might protect the governmental body if the licensee were unable to pay for the decommissioning.

In responses from 32 utilities (representing 48 operating reactors) to a GAO questionnaire:

> Seventeen stated that they use depreciation accounts to reflect decommissioning costs which ultimately wind up in utility rates. However, even though funds collected through this method are an advance recovery of costs, these funds are not set aside in special accounts. Instead the funds are used in current operations in lieu of borrowing. These utilities expect to be able to pay the eventual decommissioning costs from whatever future budget is affected. The 15 other respondents are presently doing nothing to accumulate funds for decommissioning [16, p. 17].

The GAO report concludes, on this point:

> We believe the cost of decommissioning should be paid by the current beneficiaries, not by future generations. . . . private companies have an obligation to accumulate funds for decommissioning during the life of their projects. NRC should make advance planning for decommissioning mandatory at the time of licensing, including provision for funding [16, p. 25].

Management consultant John Ferguson agrees: "While regulatory inaction may lead to public funding as a solution, collection from customers who benefited from the plants prior to their decommissioning makes more sense, economically and politically and is consistent with generally accepted depreciation accounting practices." And: "Consideration of funded reserves for accomplishing the decommissioning of nuclear power plants is clearly an issue whose time has come." [7, pp. 37 and 40]

The NRC now seems to be moving in this direction. In a lengthy and comprehensive position paper issued in July of 1979, Robert S. Wood, Assistant to the Chief of the Antitrust and Indemnity Group, Office of Nuclear Reactor Regulation, U. S. Nuclear Regulatory Commission, states:

> . . . decommissioning for most nuclear reactors will not take place for 30 to 40 years after start-up; if the delayed dismantling option is chosen, it may be 60 to 100 years before a reactor is dismantled. No matter what the current financial health of a utility is, financial solvency of any particular enterprise cannot be projected with confidence so far into the future [18, p. 3].

Wood considers many alternatives based on several criteria developed by the NRC:

1) probability that the method will actually provide funds when needed;

2) cost of providing the assurance;

3) relative equity of the alternative;

4) degree to which the alternative is responsive to technical and economic changes;

5) ability to accommodate differing ownership and jurisdictional arrangements.

He eliminates bonding as a possibility, based on a survey conducted by the NRC of the ten largest surety bonding companies--all of whom indicated that bonds would not be available in that large an amount ($50 million) for that long a term (40 years). Similarly the method used by the 17 respondents to the GAO survey, depreciation with no funded reserve, is rejected as not fulfilling the first and most important of the GAO criteria--assurance that funds will be available when needed.

Wood recommends that the utilities be required to put up a deposit at the time of plant start-up to assure fund availability. While it would provide maximum protection to taxpayers, we believe this approach is overly conservative and imposes an excessive and unwarranted penalty on utility companies, a penalty that would ultimately by borne by ratepayers, stockholders, or both. His second choice, a funded reserve (or sinking fund) method, is more defensible, and is supported by Ferguson and the House Committee report, as indicated earlier in this section. Under this method, a trust fund would be established in a financial institution under which investments would be diversified and thus safer than funds accumulated by a utility and invested only in itself.

Since decommissioning costs represent a future obligation of the utility that would most likely be borne by taxpayers in the event of company insolvency or bankruptcy, taxpayers' interests require that a decommissioning fund be accumulated that cannot be used for other purposes. We believe that the most appropriate means of accomplishing this end is through an external trust at a bank or other financial institution. While a company-managed sinking fund is a second alternative, such a fund would not be adequately protected from other uses, and would provide no advantages to ratepayers since earnings from a fund maintained by a third party could still accrue to the utility company.

Income Tax Considerations

Internal Revenue Service (IRS) Regulation 1.167(a)-11(d) requires that the cost of dismantling, demolishing, or removing a plant in the process of retirement be treated as expense in the year incurred. Therefore, the annual provision for depreciation (as in the case of the utilities noted in the GAO study) or addition to the reserve fund (as herein recommended) would not be deductible for Federal income tax purposes under present regulations.

Ferguson urges that:

> Immediate consideration should be given to having nuclear decommissioning costs specifically collected from the customers and to having this collection considered exempt funds to the utility by virtue of such monies being collected and paid into a tax-exempt fund. Under current tax regulations, the actual expenditures for decommissioning would be deductible in the year incurred. Delaying the collection of taxes would help the situation, but the most realistic approach would be to currently defer taxation of the fund receipts and earnings until used by the utility in payment of decommissioning cost [7, p. 39].

Wood discusses this matter at length and reports on the results of discussions between the NRC and IRS [18, pp. 14-15]. He indicates that the IRS would approve the arrangements suggested by Ferguson, provided that the utility does not have even short-term use of these funds. He describes the IRS' reasoning for refusing to allow decommissioning deductions until the expense is incurred by distinguishing it as an expense rather than a depreciable asset.

We recommend that IRS regulations be changed to allow estimated decommissioning costs to be treated as "negative salvage value" and provided for through periodic depreciation charges over the life of the plant. There is ample precedent in tax law that salvage value must be taken into consideration in computing allowable depreciation. Thus, a \$100,000 piece of equipment with a \$5,000 estimated salvage value at the end of its 10-year estimated life, would be depreciated at the rate of \$9,500 per year on a straight-line basis. We believe that decommissioning represents negative salvage value by definition, and thus should be added to the equipment cost and be depreciable currently. In the above illustration, a $5,000 negative salvage value would result in annual depreciation of $10,500.

In addition, this treatment would be in consonance with economic reality and sound utility economic theory which calls for customers to pay for services they currently receive. It would also be consistent with generally accepted accounting principles.* (It should be noted that the effects of decommissioning costs on a utility's rate base is a major financial issue which is beyond the scope of this study.)

Possible Effects of Decommissioning Costs on Ratepayers

If ratepayers are charged for future decommissioning costs on the basis of current consumption, the cost per kilowatt hour can be calculated in three steps:

1. Estimate decommissioning costs at the time of plant retirement:

$$C_{dec}(1 + r)^n$$

where: C_{dec} = estimated decommissioning costs in today's dollars

r = expected annual rate of inflation over remaining life of facility

n = estimated years of remaining facility life

---

*For example, the AICPA"s Accounting Research Study No. 7 notes that "costs of sales and expenses should be appropriately matched against the periodic sales and revenues" and "appropriate charges should be made for depreciation and depletion of fixed assets and for amortization of other deferred costs." [8] (Emphasis supplied) Also, Statements of International Accounting Standards provide, with respect to the use of salvage or residual values in calculating depreciation: "The gross residual value in all cases is reduced by the expected costs of disposal at the end of the useful life of the asset. [3] In a situation somewhat similar to that encountered with nuclear power plants, the eight companies that own interests in the Trans-Alaskan Pipeline System are currently providing in their financial statements for expected future dismantling costs.

2. Determine the annual deposit required to accumulate the fund needed at the time of retirement, by dividing estimated future decommissioning costs by a factor representing the compounded amount of an annuity of $1 in arrears:*

$$\frac{C_{dec}(1 + r)^{n}}{[(1 + i)^{n} - 1]/i}$$

where: i = expected average annual earnings rate on decommissioning fund over remaining life of facility

3. Divide the amount of the required annual deposit by the estimated number of kilowatt hours to be generated each year, calculated as follows:

$$u \times K \times H$$

where: u = expected average capacity utilization rate during remaining life of facility

K = maximum capacity of facility in kilowatt output per hour

H = the expected average number of operating hours per year (24 x 365, or 8760, if the plant is operated continuously)

These steps may be combined into the following formula to obtain the appropriate cost or charge to ratepayers per kilowatt hour:

$$C_{kwh} = \frac{C_{dec}(1 + r)^{n}}{[(1 + i)^{n} - 1]/i} \times \frac{1}{(u)(K)(H)}$$

or more simply:

$$C_{kwh} = \frac{C_{dec}(1 + r)^{n}(i)}{[(1 + i)^{n} - 1](u)(K)(H)}$$

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*Quantities for the future value of an amount, $(1 + r)^{n}$, and for the compounded amount of an annuity are readily available in standard mathematical tables.

Assuming charges are made to ratepayers on the basis of this formula, proceeds are placed in a fund at the end of each year and invested at a rate of earnings i, estimates are reasonably accurate, and charges are adjusted annually in response to changing conditions, the fund will accumulate to an amount sufficient to cover decommissioning costs at the time of normal plant retirement.

In Table 1, this formula is used to calculate costs per KWH under several possible sets of assumptions. The reader is not restricted to these assumptions; the formula allows complete flexibility in the use of any set of assumptions appropriate in a given set of circumstances.

This formula, and the calculations in Table 1, do not reflect the effect of income taxes. This effect will vary from one state to another, and will depend in part upon a particular company's recent tax history, its depreciation policies, and future changes in state and Federal tax laws and regulations. Nevertheless, appropriate allowance must be made for tax effects in a given situation before an accurate estimate of cost to ratepayers can be made.

It should further be noted that this formula assumes equal annual deposits to an accumulating decommissioning fund. It may instead be desirable to provide for annual deposits that reflect constant purchasing power but that increase in nominal terms in response to inflation.

The various decommissioning costs per KWH mentioned in the House report range from .04 mills to 1.4 mills [17, pp. 131-2]. The estimates in Table 1 are within this range for decommissioning costs of $25,000,000.

Table 1. Illustration of Decommissioning Costs, in Mills per KWH, for a 1 Million Kilowatt Plant Under Various Assumptions.

Decommissioning Cost (C_{dec})	Plant Life (n)	Capacity Factor (u)	Rate of Inflation (r)				
			.07	.10	.12	.15	.18
			Return on Decommissioning Fund (i)				
			.08	.12	.10	.15	.17
$25,000,000	40	75%	0.22	0.22	0.80	0.57	0.91
		65%	0.25	0.26	0.92	0.66	1.05
		55%	0.30	0.31	1.09	0.78	1.24
	30	75%	0.26	0.28	0.69	0.58	0.84
		65%	0.30	0.32	0.80	0.67	0.97
		55%	0.35	0.38	0.95	0.79	1.15
	20	75%	0.32	0.36	0.64	0.61	0.80
		65%	0.37	0.41	0.74	0.70	0.92
		55%	0.44	0.48	0.87	0.83	1.09
$50,000,000	40	75%	0.44	0.45	1.60	1.15	1.82
		65%	0.51	0.52	1.85	1.32	2.10
		55%	0.60	0.61	2.18	1.56	2.48
	30	75%	0.51	0.55	1.39	1.16	1.69
		65%	0.59	0.63	1.60	1.34	1.94
		55%	0.70	0.75	1.89	1.58	2.30
	20	75%	0.64	0.71	1.28	1.22	1.60
		65%	0.74	0.82	1.48	1.40	1.85
		55%	0.88	0.97	1.75	1.66	2.19
$100,000,000	40	75%	0.88	0.90	3.20	2.29	3.64
		65%	1.02	1.04	3.69	2.64	4.20
		55%	1.20	1.22	4.36	3.12	4.97
	30	75%	1.02	1.10	2.77	2.32	3.37
		65%	1.18	1.27	3.20	2.67	3.89
		55%	1.39	1.50	3.78	3.16	4.60
	20	75%	1.29	1.42	2.56	2.43	3.21
		65%	1.49	1.64	2.96	2.81	3.70
		55%	1.76	1.94	3.50	3.32	4.37

As indicated in Appendix A, however, such costs are sometimes estimated to run to $50,000,000 or even over $100,000,000. In such cases the charge to ratepayers per KWH could be 3 or even 4 mills per KWH, depending on the inflation and earnings rates, useful life, and capacity factors experienced. Based on a typical residential rate of $0.05 per KWH, a 3 mill additional charge would represent an increase of 6%, or about $24 per year at an annual usage of 8,000 KWs.

Whether a charge to ratepayers for decommissioning would be significant depends on the several variables as well as the circumstances of the individual ratepayer. If a plant should be forced into a premature and permanent shutdown, however, a different situation arises. The company would probably be faced with substantial costs without having had the opportunity to accumulate an adequate fund through charges to ratepayers. In the Three Mile Island case, shutdown occurred about three months after the plant began generating power. The NRC's Mr. Wood states the situation clearly:

> A compounding problem arises in the case where a utility is forced because of accident or for other reasons to permanently shut down its reactor prematurely. If one or more reactors owned by a utility is forced to be shut down and decommissioned, and such reactors contribute substantially to the utility's rate base, even a previously financially sound utility could be forced into bankruptcy and default on its decommissioning obligations. Certainly the accident at Three Mile Island indicates that a utility can rapidly find itself in a precarious financial position with the resulting uncertainties that such a position raises [18, p. 3].

Wood later goes on to examine at length the possibility of purchasing insurance to cover premature shutdowns. Although insurance may become available, it is not currently being written.

Recommendations

Based on our evaluation of studies and proposals made by the House Committee on Government Operations, the General Accounting Office, the Nuclear Regulatory Commission and others, and after careful consideration of relevant accounting principles and of the public interest, we make the following recommendations:

1. Utility regulatory agencies should require utility companies to:

   a. include decommissioning costs in rate-setting proceedings; and

   b. finance decommissioning by means of a funded reserve through an external trust established in a financial institution and controlled to insure the safety and preservation of the fund.

2. The nuclear power industry should seek declining term insurance to cover the unfunded costs of decommissioning in the event of a premature shutdown. If private coverage cannot be developed, and if nuclear power generation is deemed to be vital to the public interest, consideration should be given to sponsorship of such an insurance program by the Federal government.

3. IRS Regulation 1.167(a)-11(d) should be changed to permit a Federal income tax deduction for amortization of estimated decommissioning costs.

III. PLANT PRODUCTIVITY AND COST RECOVERY

Introduction

Because of their capital intensive nature, the economic viability of nuclear power plants depends substantially on the productivity of these plants over their lifetimes. The two determinants of a plant's productivity are the average capacity factors attainable during its lifetime and the useful life of the facility. The former has received substantial attention during the past few years, while the latter has received very little.

Industry and government expectations when nuclear plants were first authorized have been described by David Comey:

> In order to conform to the requirements of the National Environmental Policy Act, the Atomic Energy Commission has been required to prepare Final Environmental Statements for all of the nuclear power plants in operation or under construction. In these Statements, the AEC is required to conduct a cost-benefit analysis in order to determine whether the nuclear plant should be built or operated. In the Final Environmental Statements for the nuclear plants currently operating, the AEC assumed in its cost-benefit analyses that the principal benefit was the fact that the nuclear plant would produce electricity over its 30-year life at an average capacity factor of 80%. In some Final Environmental Statements, the utilities predicted even higher average capacity factors of 85% or 86% [2, p. 3].

In this section we will discuss each of these two vital cost factors and consider the relationship between them.

Plant Life

One of the few undisputed facts about nuclear power is that no one knows what the useful life of a plant will be. The reasons are relatively simple. No commercial plant has been in existence long enough to provide empirical evidence, and the technology itself differs sufficiently from mature forms of power generation to preclude meaningful extrapolation.

Nuclear plants are licensed for 40 years; most are considered to have an estimated productive life of 30 to 40 years. Commonwealth Edison (Illinois) expects a useful life of 40 years for Dresden 1, and 35 or 36 years for its other nuclear plants. Portland (Oregon) General Electric uses 30 years for its Trojan plant. According to that utility company, however, "A new item such as a nuclear generating plant, of course, has very little history to be of value in determining life or salvage [13].

Several areas of concern have been raised by other observers which could have a significant bearing on plant life. We take no position on these non-accounting issues, but offer them as background for our discussion and computations.

A. Aging

The issue of the unknown effect of aging on nuclear power plants was raised in the peer review of the AEC-funded Reactor Safety Study (the Rasmussen Report). As stated in Appendix XI of that report, "It should be recognized that the study did not include extreme aging considerations since the applicability of its results is limited to only the next five years." [21] The significance of this uncertainty is noted by Yellin:

> The problem of aging most severely affects those components of the primary core cooling system which are designed to serve without replacement through the 25 to 40 year life of the reactor pressure vessel . . . the principal issue is whether manufacturing, fabrication, and in-service testing, as presently practiced, are

adequate to ensure pressure vessel reliability throughout design life. [23]

B. Allowable Radiation Exposure Levels

One regulation with a significant bearing on plant operability is the standard governing occupational exposure to radiation at nuclear plants. The current maximum allowable exposure to an individual has recently been criticized as too lax. To quote from a recent Electric Power Research Institute article:

> As plants age, the long-term trend is toward higher radiation dose rates at individual components, while the corresponding long-term trend for regulation is for lower total absorbed doses. These two trends are inconsistent . . . [14].

C. Radiation Buildup

The problem of radiation buildup, or increasing radiation levels, which could make maintenance so difficult and expensive as to impair the economic usefulness of the plant, has been described by David Comey:

> One factor peculiar to nuclear plants that will virtually ensure a decline in performance with age is radiation buildup. The primary coolant system in light water reactors is subject to the buildup of radioactivity from fission and activation products in the primary coolant.
>
> This radioactivity accumulates as the plant gets older, and eventually means that repair work on this system consumes enormous amounts of time and personnel in order to avoid excessive radiation exposure to the workers during the repairs. A worker can receive his maximum permissible quarterly exposure after working on the primary coolant system in just a few minutes, thus burning him out for the next three months.
>
> In order to avoid exceeding each worker's maximum permissible radiation exposure, a large number of men must work sequentially within a confined space to make repairs. This has meant in some cases that thousands of workers have had to participate

in the repair of a single nuclear plant, causing a long outage and thus lowering the capacity factor of the plant.

Since the radioactivity of these plant systems increases with plant age, repairs are likely to become even more time-consuming as the plant gets older, leading to longer outages and decreased capacity factors [2, pp. 8-9].

D. Waste Storage and Disposal

Another possibility which must be considered is the potential inability of the government and other responsible organizations to resolve satisfactorily the issue of acceptable disposal of nuclear waste. At the present time no permanent waste repository exists, and nuclear plant spent fuel storage capacity will probably be saturated by approximately 1985 with some plants potentially in trouble several years before that date. While it is probable that additional temporary storage facilities will be built to relieve this political/technical problem, another Three Mile Island-type accident could create an atmosphere which would make it very difficult or impossible to obtain public approval to site such a storage facility in any one of the fifty states. In that eventuality a possible course of action would be the early shutdown of plants followed ultimately by the decision to permanently mothball or dispose of them. According to Professor Bupp: "Today, the nuclear industry faces widespread shutdowns of operating plants starting as early as 1983 unless the problem of handling spent fuel can be resolved." [1, p. 221]

E. Safety Standards

Because of the exacting safety standards required to protect the public health and welfare in the case of nuclear accidents and the associated need to upgrade plants as operating experience is obtained, the need for retrofitting or for implementing such changing safety standards gives some indication that nuclear plants may not be able to achieve calculated design life. As Bupp notes: "The safety questions highlighted by Harrisburg (the Three Mile Island plant accident) could, obviously, force shutdowns at any time." [1, p. 221]

If a nuclear plant is retired sooner than originally contemplated because of any (or a combination) of the above factors, it is possible that the regulatory agency will have advance knowledge of that event some years beforehand and can provide for complete capital cost recovery through increased depreciation allowances.

This type of "early" retirement should be distinguished, however, from a "premature" retirement caused by the occurrence of an unforeseen event such as a serious accident. Should that happen early in the life of a nuclear plant, not only would there be a serious problem relating to decommissioning fund accumulations (as discussed in Part I of this report), but there would also be problems with the recovery by the company of the undepreciated capital costs and the related continuing inclusion of a nonproductive asset in the rate base.

The Three Mile Island accident has made this more than a remote and insignificant concern. Such a premature shutdown and retirement might produce one of the following consequencies:

- In the largest utility companies, a substantial loss borne by future ratepayers to the extent allowed by the regulatory agency, and otherwise borne by stockholders.

- In smaller companies, default on bonds or even bankruptcy, possibly resulting in a public "bailout" or takeover using tax revenues.

These consequences would appear to be inconsistent with orderly markets in utility securities, continued availability of investment capital, and an equitable distribution of costs among ratepayers. The not insignificant risk of premature shutdown and retirement points to a need for insurance that is not presently available. Because of the magnitude of possible losses, it may not be realistic to hope that private insurers will put together an acceptable insurance pool. Consequently, Congress along with the Nuclear Regulatory Commission should give immediate attention to (a) the appropriateness of spreading such costs among taxpayers generally, as opposed to ratepayers in a particular, impact locale; (b) the need for a nuclear power insurance pool, to cover both premature facility shutdown and possibly unfunded decommissioning costs; and (c) the desirability of Federal participation in developing and funding a nuclear power insurance pool.

Although not an accounting issue, the question of whether nuclear power development is essential to the public interest clearly must be resolved before any public funds are contributed to such a nuclear power insurance pool.

Capacity Factors

Capacity factor may be defined as the ratio between actual use and maximum use. The capacity factor of a power plant is the ratio of electric energy actually delivered during the period in question to that which would have been delivered if the plant produced throughout the period at the maximum level for which it was designed.

The importance of the capacity factor is clearly stated by investment banker Saunders Miller:

> It is a critical number because it directs the ultimate price of power. The cost of building a plant is a fixed amount that must be amortized over the number of kilowatt-hours produced; thus, the more electricity sold, the lower the allocation of fixed cost per KWH. With numerous questions being raised about nuclear plants because of capacity factors significantly lower than projected, an inquiry into the reliability of nuclear and coal plants is essential to a thorough economic analysis [12, p. 67].

The effect on unit electricity costs can thus be quite dramatic because of the relationship between capital-related charges and the total costs of generating nuclear power. Comey states that electricity produced by a plant operating at a 43% capacity factor is approximately 70% more expensive than that produced by a plant operating at an 80% capacity factor [2, p. 10]. Miller asserts that, at a capacity of 55%, the effective capital cost is 36% higher than that projected at the base level of 75% [12, p. 68].

Pacific Gas & Electric Co., in testimony before the California Public Utilities Commission on December 3, 1968, submitted information on the Diablo Canyon 1 nuclear plant which indicated a 4.5 mills/KWH cost of power at 90% capacity and 7.1 mills at 50% capacity.

Although the relatively brief history of the newer generation of large nuclear plants does not offer definitive evidence of what capacity factors can be expected in the future, there seems to be no other more reliable evidence on which to base projections. We therefore set forth a few of the public comments on historical and projected capacity factors in Appendix B. As in the cases of decommissioning costs and useful lives of nuclear plants discussed above, we take no position on the accuracy of these past calculations or future predictions. They are presented as background information to the reader, and to provide parameters for the range of assumptions used in the computations in Table 2 below.

Relationship Between Plant Life and Capacity Factors

It will be many years, perhaps many decades, before sufficient historical data exist to accurately predict how long nuclear plants will last and the average capacity factors they can expect to achieve. However, it is clearly not too early to question the reliance on the original 30 year/80% formula set forth by the Atomic Energy Commission.

We now know that capacity factors have fallen far below 80% on the average, especially for the larger, newer generation plants. We have also reviewed the reasons that nuclear plants may not last those 30 years. We believe that these two critical and related cost factors should no longer be considered separately. The crucial element is the number of units of electricity which the plant will produce. Other things being equal, the same number of units of electricity would be produced if a plant runs at 80% for 30 years, 60% for 40 years, or 40% for 60 years.* For this reason,

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*It would appear that lower than expected capacity factors would result in a longer life for a nuclear plant (such as might be the case with we believe that the units-of-production method of depreciation should be used for nuclear power plants.

Effects of Useful Life and Capacity Factors on Depreciation

To facilitate evaluation of the cost effect of capacity and useful life interaction, Table 2 presents the depreciation cost, in mills per kilowatt hour (calculated on a units-of-production basis), for different combinations of capacity utilization and useful life based on a 1 million kilowatt plant costing $1 billion net of future salvage value.

The costs in Table 2 may be compared with the cost of 4.76 mills per KWH for the same plant using the AEC's earlier estimates of 80% capacity and 30 year life.

Clearly, the costs per kilowatt hour are quite sensitive to capacity factors and estimated useful lives. The analyst, regulator, legislator or voter must decide which combination is most realistic. A 60% capacity factor for 20 years of estimated life results in depreciation of 9.51 mills per KWH, which is double the amount based on the AEC's original estimates. On the other hand, a 75% capacity factor for 40 years produces a cost of 3.81 mills per KWH, 20% lower than the AEC's estimate.

Recommendations

Based on the foregoing analysis, we make the following recommendations

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certain types of machinery, equipment, and motor vehicles). This assumption has been questioned, however, by MHB Technical Associates: "Until additional experience and quantification of aging effects are available, it should not be assumed that reduced capacity factor operation will result in longer operating plant lifetimes." [10]

Table 2. Depreciation Cost, in Mills per KWH, of a 1 Million Kilowatt, $1 Billion Plant for Various Useful Life and Capacity Factors.

Capacity Factor	Years of Useful Life				
	20	25	30	35	40
75%	7.61*	6.09	5.07	4.35	3.81
70%	8.15	6.52	5.44	4.66	4.08
65%	8.78	7.02	5.85	5.02	4.39
60%	9.51	7.61	6.34	5.44	4.76
55%	10.38	8.[illegible]	6.92	5.93	5.19
50%	11.42	9.13	7.61	6.52	5.71

* Illustration of calculation: KWH generated = 24 hours per day X 365 days X 1 million kilowatts X 75% = 6,570 million KWH per year; 6,570 million KWH X 20 years = 131,400 million KWH over life of the plant; $1 billion divided by 131,400 million KWH = $0.00761 per KWH, or 7.61 mills per KWH.

relating to nuclear power plant productivity and cost recovery:

1. Utility regulatory bodies should recommend the use of the units-of-production method for computing depreciation of nuclear plants as a more appropriate method for recovering costs and charging users with the power actually consumed. Under the present method (straight-line) used by most electric utility companies, consumers pay the same amount for depreciation whether a plant operates at 30% of capacity or 90%. Under the recommended method, the regulatory agency would decide, before a plant commences operations and based on the latest available technical information, how long the plant would be expected to last and the average capacity factor it would be expected to achieve. Periodically thereafter (perhaps every two years) the data should be re-evaluated so that the then-remaining unrecovered cost can be divided by the newly estimated remaining productive capacity to arrive at a revised depreciation rate per KWH to be used until the next review. One possible by-product of the use of this method relates to an extensive outage and the utility's need to purchase supplementary power to meet customers' needs. In these circumstances, it has been traditional for the utility to seek approval from the regulatory commission for a surcharge to pay for the replacement power. With the units-of-production method, it would be possible for the commission to partially offset this surcharge by reduced depreciation related to the

lower-than-expected production caused by the outage, thus eliminating part of the double charge and offering some relief to ratepayers.

If units-of-production depreciation is not required by a regulatory agency, it should, as a minimum, provide for periodic review of assumptions concerning capacity and useful life of nuclear facilities, and revision of depreciation rates as appropriate.

2. If further development of nuclear power is deemed to be required by the public interest (a question without significant accounting ramifications and thus not addressed in this analysis), Congress and the Nuclear Regulatory Commission should give immediate consideration to the need for the appropriateness of a nuclear power insurance pool, partially or wholly supported by tax revenues, to provide for unrecovered capital costs and possible unfunded decommissioning costs in the event of premature shutdown. (Also see recommendation 2 on page 22 regarding insurance for unfunded decommissioning costs.)

APPENDIX A: REFERENCES ON ESTIMATED COSTS OF DECOMMISSIONING

· The Atomic Industrial Forum estimated the costs in 1975 dollars to be \$31 million for the removal/dismantling option of a large boiling water reactor (BWR) and \$27 million for a pressurized water reactor (PWR), not including a 25% contingency factor as used by others [11].

· An international nuclear magazine recently indicated that a study in Germany quoted a cost of \$100 million for a 1,200 megawatt PWR, and concluded, "The general consensus is that the cost of dismantling a nuclear station will be about 10 to 15% of the original capital cost, escalated to the time of dismantling." [5]

· In a study for the NRC issued in August 1979, Battelle Pacific Northwest Labs estimated that, in constant 1978 dollars, it would cost \$31 million for immediate dismantlement. The combination mode of safe storage followed by dismantling deferred for 30, 50, and 100 years (to allow for reduced radioactivity and safer and easier handling) was estimated to cost \$40.8, \$35.8, and \$39.7 million respectively [22]. (It should be noted that these cost estimates have been reduced by from \$11 to \$12 million each by excluding costs for building demolition and shipments of final core of fuel elements which were included in the AIF study referenced above.)

· According to testimony of W. A. Verrochi before the Pennsylvania Utility Commission concerning the Three Mile Island #1 plant, the costs in 1974 dollars for in-place entombment were estimated to be \$40 million, and for dismantling, \$117.5 million.

· In testimony before the California Public Utilities Commission in June, 1979, Pacific Gas and Electric Company representative William Gallavan indicated estimated decommissioning costs of $105 and $88 million respectively for Diablo Canyon plants 1 and 2, based on a preliminary report from Nuclear Utilities Service Corp.

· According to the June 23, 1977, issue of Nucleonic Week, Commissioner Richard Jones of the Connecticut Public Utilities Control Authority, testifying before the Subcommittee on the Environment and Atmosphere of the House Science and Technology Committee a week before, said: "The absence of reliable cost data is a serious problem . . . Connecticut finally decided on a figure of 10% of construction cost as an estimate of decommissioning costs, assuming mothballing as the technique to be used."

· Decommissioning costs for the Trojan plant in Oregon are estimated at $24 million in 1976 dollars, which represents about 5% of the original construction cost.

· The Illinois Commerce Commission has recently raised its decommissioning estimate to $42 million, a figure which has been accepted by Commonwealth Edison.

APPENDIX B: REFERENCES ON CAPACITY FACTORS

David Comey found that nuclear plants operated at an average capacity factor of 54.6% during the years 1973 through 1976. He further calculated that plants larger than 1,000 megawatts in size had cumulative capacity factors over their lifetime (through 1976) of only 42.3% [2, p. 1].

The Federal Energy Administration published data which indicated an average 57.6% capacity factor for those same years [6].

Charles Komanoff has been performing analyses of power plant performance since 1976, and has provided consulting services to the GAO and many state and local government agencies. His comprehensive third annual analysis of nuclear power plant operating reliability, for the year 1977, examines a number of variables, including reactor manufacturer, individual reactors, utility company ownership, regions, age, vintage, and prototype/duplicate status [9].

· Of the 51 commercial-size reactors in the U.S., the 19 BWR's (manufactured by General Electric) had an average capacity factor in 1977 of 58%, raising their cumulative average from 55% to 56%.

· The other 32 were PWR's (manufactured by Westinghouse and two other companies) and had an average capacity factor in 1977 of 67%, raising the cumulative average from 59% to 61% [9, p. 7].

· Large nuclear plants (over 800 MW capacity) have consistently had lower capacity factors than smaller plants. Through 1977, the results were 53% and 65% respectively. This is particularly significant because only the larger plants are now being built [9, p. 14].

• The overall average was 63.9% in 1977, raising the cumulative average from 58.5% to 59.8% [9, pp. 6-7].

• Komanoff projects a 59% levelized capacity factor for 1,150 MW PWR's and 50% for similar-sized BWR's over the first ten years of operation--the planning horizon given the present limited operating experience [9, p. 4].

The NRC's Final Environmental Statement for Black Fox 1 and 2 in early 1977 indicates that a reasonable range of capacity factor expectations is 50% to 70%, and concludes, "The historical experience with plants over 1,000 MWs is insufficient to make conclusions from a simple average of capacity factors to date."[19]

Pacific Gas & Electric Co., which had been predicting 80% or 90% (and probably 90%) in 1966, has since then substantially reduced its expectations for Diablo 1, as indicated in the following table [4]:

	1978	1979	1980	1981	1982	1983
Capacity factor	60%	60%	66%	66%	70%	73%

The U. S. General Accounting Office, in analyzing costs of three nuclear power plants in the Pacific Northwest, suggested a capacity factor of 65 percent:

> In calculating annual power costs both WPPSS and Ebasco assumed a plant capacity factor of 70 percent. This 70 percent capacity factor appears to be a common industry index but, we believe, may be somewhat optimistic in light of the annual power generation experience of currently operating nuclear power plants and the frequency of unscheduled shutdowns. Based on our analysis of available data, it appears that a more realistic capacity factor would be 65 percent [15].

APPENDIX C: ORGANIZATIONS AND INDIVIDUALS CONSULTED DURING THIS STUDY

As a matter of policy, strict independence and objectivity is maintained during any API study. To insure that all sides were considered in this analysis of certain controversial aspects of the economics of nuclear power, the following organizations and individuals were consulted and were asked to provide information or to react to preliminary drafts of this report. Their assistance is gratefully acknowledged. They should not, however, be considered responsible for any part of this analysis or for the recommendations, which are those of API alone.

Atomic Industrial Forum, Washington, D. C.

Eugene P. Coyle, Economic Consultant, Berkeley, California

Ray Czahar, California Public Utilities Commission, San Francisco

Dr. Ian Forbes, Technical Director, Energy Research Group, Waltham, Massachusetts

Charles Komanoff, New York City

MHB Technical Associates, San Jose, California

Zack Willey, Environmental Defense Fund, Berkeley, California

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