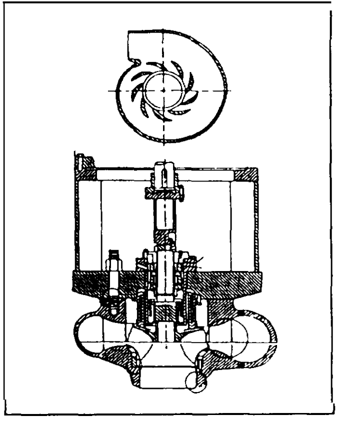
Overview and Policy Issues 1

Long-term prospects for the Nation's 107 operating nuclear power plants are increasingly unclear. Proponents argue that these plants, which supply over 20 percent of the Nation's electricity, are vital to reliable, economic electricity supplies; have environmental benefits (e.g., they emit no greenhouse gases such as carbon dioxide); and reduce dependence on imported oil. Opponents, however, argue that nuclear plants bring risks of catastrophic accident, create unresolved waste disposal problems, and are often uneconomic. As these plants age, issues related to plant lives and decommissioning are likely to become much more visible and draw more public attention.

The past few years brought unexpected developments for nuclear plant lives and decommissioning. Since 1989, six nuclear power plants have been retired early, well before the expiration of their NRC operating licenses.[1] Owners of several other plants are investigating the economics of early retirement as well. The owners of the frost large commercial nuclear power plants planned for decommissioning anticipate costs much greater than estimates made only a few years earlier. And after a several year effort, the two lead plants in a program to demonstrate the NRC's plant license renewal process halted or indefinitely deferred their plans to file an application-in one case as part of an early retirement decision. While work continues to develop and eventually demonstrate a regulatory process for license renewal, it will be several years before the first application is filed and acted on. Absent license renewal, about 3 dozen operating nuclear power plants will have to retire in the next 20 years.



[1] In this report, the term early retirement refers to plant closure prior to expiration of the operating license issued by the NRC.

Despite these substantial challenges, there has also been good news for the U.S. nuclear industry recently. Reversing a decades long trend of rapid growth, average nuclear power plant operating and maintenance costs have decreased in recent years. Average plant reliability and availability have improved substantially. Safety performance has also been good. There have been no core damage accidents since Three Mile Island in 1979, nor an abnormal number and severity of events that could have led to core damage, much less any actual offsite releases of large amounts of radioactivity. Average occupational radiation exposures, already well below NRC limits, also declined substantially.

The Federal Government has a longstanding role in supporting a safe, environmentally sound, and economic supply of electricity for the Nation. Given the recent unexpected developments for existing nuclear power plants, this report, requested by the Senate Committee on Governmental Affairs and the House Committee on Energy and Commerce, examines the following:

- the outlook for the Nation's existing nuclear power plants as they age, focusing on safety management (ch. 2) and economy (ch. 3) during their remaining operating lives;
- the outlook for decommissioning (ch. 4); and
- Federal policies that could help address economic and safety issues for existing nuclear power plants as they age and as they are decommissioned (ch. 1).

SUMMARY OF POLICY ISSUES

Current and planned nuclear power plant aging management practices are designed to identify and address challenges before they become a threat and to provide a reasonable assurance of adequate safety. These practices depend heavily on elaborate plant maintenance programs and ongoing research. There will always remain some risk, however, and continued industry and Federal regulatory vigilance is crucial. Attention to aging issues is crucial not just in considering license renewal but in a plants original license term as well.

The industry and the NRC are working to address aging safety issues, but their efforts could be accelerated to determine better the long-term prospects for existing plants and to assure adequate long-term safety. For example, the NRC could intensify its review of aging safety research for possible regulatory applications. Greater attention to aging safety issues during a plant's original license term could also help justify a substantial simplification of the NRC's still-undemonstrated license renewal process.

Many nuclear power plants face severe economic pressures. The six early retirements occurring between 1989 and early 1993 give a sense of the variety of plant-specific issues likely to be involved in the future, as economic life decisions are made (box l-A). In three of these decisions, aging issues played a prominent role. Other factors besides aging degradation and its effects on long-term safety and economy have played prominent roles in determining plant lives and will continue to do so in the future. Other important factors include: rising operational costs; disposal of radioactive waste (discussed below); public attitudes toward nuclear power (box l-B); and the changing electric industry context, including increased competition and attention to environmental externalities.

Responsibility for judging a plant's economic attractiveness lies primarily with the owning utility and State regulators. The Federal role is relatively indirect. However, Federal activities such as spent fuel disposal, safety regulation, and policies addressing oil import security, global climate change, and other environmental challenges can all have major economic impacts both directly and as they affect the judgments of other interested parties.

While future economic conditions are highly uncertain, some analysts have suggested that as many as 25 plants may be retired in the coming decade. However, the economy of most nuclear power plants appears at least moderately attrac-

Box 1-A—Taking Early Retirement: Recent Nuclear Power Plant Closures

Six **commercial nuclear** power plants in the United States have shutdown permanently since 1989, all well before their operating licenses were due to expire. The reasons behind these closures vary and are summarized briefly here.

Rancho Seco

This 873 MW pressurized water reactor (PWR) operated almost 15 years. The operating license was issued to the Sacramento Municipal Utility District (SMUD) on August 16,1974. The plant was shut down on June 7,1989 by a local voter referendum. The basis of the referendum was public concern about plant safety coupled with poor economic performance.

Shoreham

After years of construction delays, cost overruns, and legal and political battles, the 819 MW boiling water reactor (BWR) received a full power operating license on April 21,1989. For several years, the State of New York had refused to accept the emergency evacuation plan proposed by the plant operator, the Long Island Lighting Co. (LILCO). The State argued that the population living near the plant was too large to evacuate quickly enough during an accident. As a result, just 2 months before receiving its operating license, on February 28, LILCO agreed to sell the plant to the State for decommissioning. The utility had pursued the full-power license to demonstrate the reactor was operable. In preparation for full-power operations, Shoreham was tested intermittently at low power between July 1985 and June 1987. Final shut down was on June 28,1989, and the average fuel burnup in its brief life was the equivalent of about 2 days of full-power operation.

Fort St. Vrain

The Fort St. Vrain Nuclear Generating Station is a 330 MW high-temperature gas-cooled reactor owned by the Public Service Co. of Colorado, Although the operating license was issued December 21, 1973, this unique reactor operated only from 1979 to 1989. The plant was permanently closed August 18, 1989 due to several concerns: problems with the control rod drive assemblies and the steam generator ring headers, low plant availability (only about 15 percent), and prohibitive fuel costs. The plant operator became the first commercial nuclear utility to receive a possession-only license from the NRC since the Commission adopted decommissioning rules in 1988.

Yankee Rowe

This 185 MW PWR operated 30 years. The plant began commercial operations on July 1,1961. On October 1, 1991, the reactor was taken offline for a combination of safety reasons and officially retired for related economic reasons on February 26, 1992. During its review of license renewal efforts, the NRC questioned the extent and impact of possible age-related embrittlement of the reactor pressure vessel (RPV). The plant owners estimated that demonstrating the adequacy of the RPV to the NRC's satisfaction would cost at least $23 million and possibly more since no agreement had been reached on what would constitute a demonstration of adequacy. Yankee Rowe also faced previously unexpected poor economic prospects caused by an economic downturn in New England that resulted in excess generating capacity and large amounts of lower cost competitive power, including much fueled by natural gas.

San Onofre

San Onofre Nuclear Generating Station Unit 1, a 410 MW PWR operated by Southern California Edison (SCE) Co., began commercial operation January 1, 1968. Under an agreement with the California Public Utilities Commission Division of Ratepayer Advocates (DRA), SCE retired the plant November 30, 1992, 12 years prior

(Continued on next page)

Box 1-A–Taking Early Retirement: Recent Nuclear Power Plant Closures--(Continued)

to its license expiration. The settlement was triggered by economic analyses of the costs and benefits of a 2-year, $135-million capital additions program required at the plant. Steam generator degradation also had resulted in a modest lifetime capacity factor. The DRA concluded that the plant was uneconomic. Although SCE disagreed with that assessment, it opted for the retirement settlement rather than pursue either a further hearing process or assume the risks and rewards of plant operation.

Trojan

The most recent early nuclear plant retirement to date, the 1,175 MW PWR operated for about 16 years before closing permanently January 4, 1993; the operating license was Issued November 21, 1975. The plant had been off line since November 9, 1992 due to age-related tube leaks in one of its steam generators. The licensee, Portland General Electric (PGE), decided earlier in 1992 to closethe plant in 1996 rather than invest the estimated $200 million needed to replace its steam generators. The recent tube leaks, however, coupled with uncertainty regarding future regulatory treatment of microflaws in the tubes, led to a final closure decision in January 1993. For several years, Oregonians repeatedly voted in State-wide referenda on whether to retire the plant. Although those referenda were defeated by large margins each time, these public campaigns put pressure on the nuclear plant that PGE did not have to face for its other generating resources.

SOURCE: Office of Technology Assessment, 19S3.

tive, assuming the recent leveling of costs continues.

There is great diversity among plants and plant performance. Electricity market conditions across the country are also diverse and changing, making the long-term prospects for nuclear plant lives neither uniform nor clear. Thus, no single safety or economic development is likely to affect uniformly the future of the Nation's existing nuclear power plants. Any tendency to judge the industry by early retirements may give a misleadingly dim view of the remaining lives of other plants. Rather, the future of the existing plants are likely to be determined individually over time as individual conditions change based on a host of separate decisions of utilities, State utility commissions, and Federal regulators. Integrated resource planning (IRP) and other elaborate analyses performed by States and utilities to assess plant economics are likely to play a growing role in future decisions about whether to continue operating existing plants.

Several decommissioning issues remain unresolved, although work is ongoing to address them. Residual radioactivity standards, which will determine the level of cleanup necessary at retired plant sites, are under development at the NRC. Depending on their stringency, such standards could have substantial impacts on decommissioning timing and costs. There also remains substantial uncertainty in decommissioning costs and the adequacy of decommissioning financing in cases of early retirement or rapid cost escalation. Although decommissioning costs are uncertain and large if viewed as a one-time expense, they are not large relative to lifetime plant production costs. Greater use could be made of early retirements as case studies to learn about the prospects for decommissioning costs and performance. Perhaps of greatest importance, however, is the future disposal capacity and cost for radioactive waste. Estimated low-level waste disposal costs have increased tenfold in the past decade, and there has been limited progress in developing new disposal facilities.

Box 1-B–Public Views and Existing Nuclear Power Plants

Public perceptions and preferences about the nature of risk and the willingness to incur different types of risk can be critical issues in determining the future role of existing nuclear power plants. Public views have played a role in some recent early retirement decisions (see Shoreham, Rancho Seco and Trojan descriptions in box 1 -A.) In ail three cases, the public pressures were long-standing rather than recent developments. in two of those, the concerns were combined with troubled economic operating histories.

With regard to decommissioning, public concerns about site remediations standards maybe a significant factor in cleanup decisions. Under the current NRC framework, decommissioning will lead to license termination and the potential cessation of regulatory oversight suggesting that public concerns about health and safety protection may be as great or greater than during plant operations.

As is true for many modern enterprises, the risks and benefits of nuclear power plant operation are imperfectly understood by the public and, to a lesser degree, by the scientific community.[1] Public preferences and perspectives for different dimensions of risk appear related to several factors, including whether the risk is voluntary or imposed; involves low probability y, catastrophic accidents, or frequent accidents of limited extent; is well understood scientifically and by the public; is natural (e.g., radiation exposure from radon or sunlight) or technological (radiation from nuclear power plant accidents); accompanies highly beneficial activities (e.g., are the alternatives to nuclear power preferable?); or is familiar or unfamiliar. From the perspective of public perception and acceptance, nuclear power has scored poorly on these counts.[2]

At the same time, the nuclear power industry notes that its national public opinion polls over the last several years have consistently found support for nuclear power. For example, in a 1992 poll three-quarters of the American public responded that nuclear power should play an important role in future U.S. energy supplies, and two-thirds of respondents agreed that the existing plants have served the country well.[3]

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1 Public perception of risk often varies significantly from the best scientific evidence. For example, some studies have found that public perceptions of risks from nuclear power plant operation are far higher than indicated by scientific and medical evidence.

2 p. Slovic, "Perception of Risk From Radiation," N.K. Sinclair (cd.) *Proceedings Of the 25th Annual Meeting of the National Council on Radiation Protection and Measurements: No. 11. Radiation Protection T&y-the NCRP at Sixty Years* (Bethesda, MD: NCRP, 1990), pp. 73-97; and L.C. Gould et al., *Perceptions of Technological Risks and Benefits* (New York, NY: Russel Sage Foundation, 1988).

3 A. s. Bisconti, "The Two Faces of Nuclear Energy: U.S. Public Opinion from the Forties to the Nineties," Speech delivered at the American Nuclear Society Annual Meeting, Nov. 18,1992, *Vital Speeches of the Day,* Mar. 1, 1993, vol. 59, No. 10. pp. 317-318.

The nuclear plants currently in operation are generally larger and more contaminated than the plants decommissioned to date. However, experience with decommissioning small reactors and with major maintenance activities at large plants suggests that the task of decommissioning can be performed with existing technologies. Final decommissioning of all but a few very special cases will likely not be performed before early in the next century. Rather, most retired plants will go through a waiting period of between 5 years and several decades, allowing short-lived isotopes to decay.

As with many other modem societal activities, decommissioning cannot provide absolute protection of public health and safety, even if all radionuclides associated with the plant are removed from a site. For example, there will be some radiological risks associated with the waste disposal site, and nonradiological transportation

Table l-A—Federal Policy Considerations

Assuring adequate aging safety	
	Accelerate ongoing aging-related safety activities
	Simplify the license renewal rule
	Revise public participation provisions
	Apply NRC's safety goal policy to aging Issues
Supporting economic decisions	
	Address aging-related regulatory safety Issues
	Address federal obligations for nuclear waste
	Expand analyses of nuclear plant economics
	Cofund industry R&D for existing plant issues
Policy issues for decommissioning	
	Revise goals for decommissioning timing and site release
	Reconsider adequacy of decommissioning financing
	Clarify regulatory policies for low-level waste
	Use early retirements as decommissioning case studies

SOURCE: Office of Technology Assessment, 1993.

and occupational risks. Background radiation from other sources will also remain. The NRC has recently undertaken a process to revise residual radioactivity requirements for terminating a license. The NRC could extend this effort to examine alternatives to its current requirement of unrestricted site release. For example, because future exposures depend on land use (e.g., industrial, residential, or agricultural), the NRC could investigate different radiological standards matched to restricted land uses.

Several Federal policy considerations relating to plant safety and economy could potentially result in more timely and better informed plant life and decommissioning decisions. These are listed in table 1-A and are discussed in the three last sections of the chapter. First, the following section provides an overview of the current understanding and management of aging.

UNDERSTANDING AND MANAGING AGING

Experience With Plant Aging

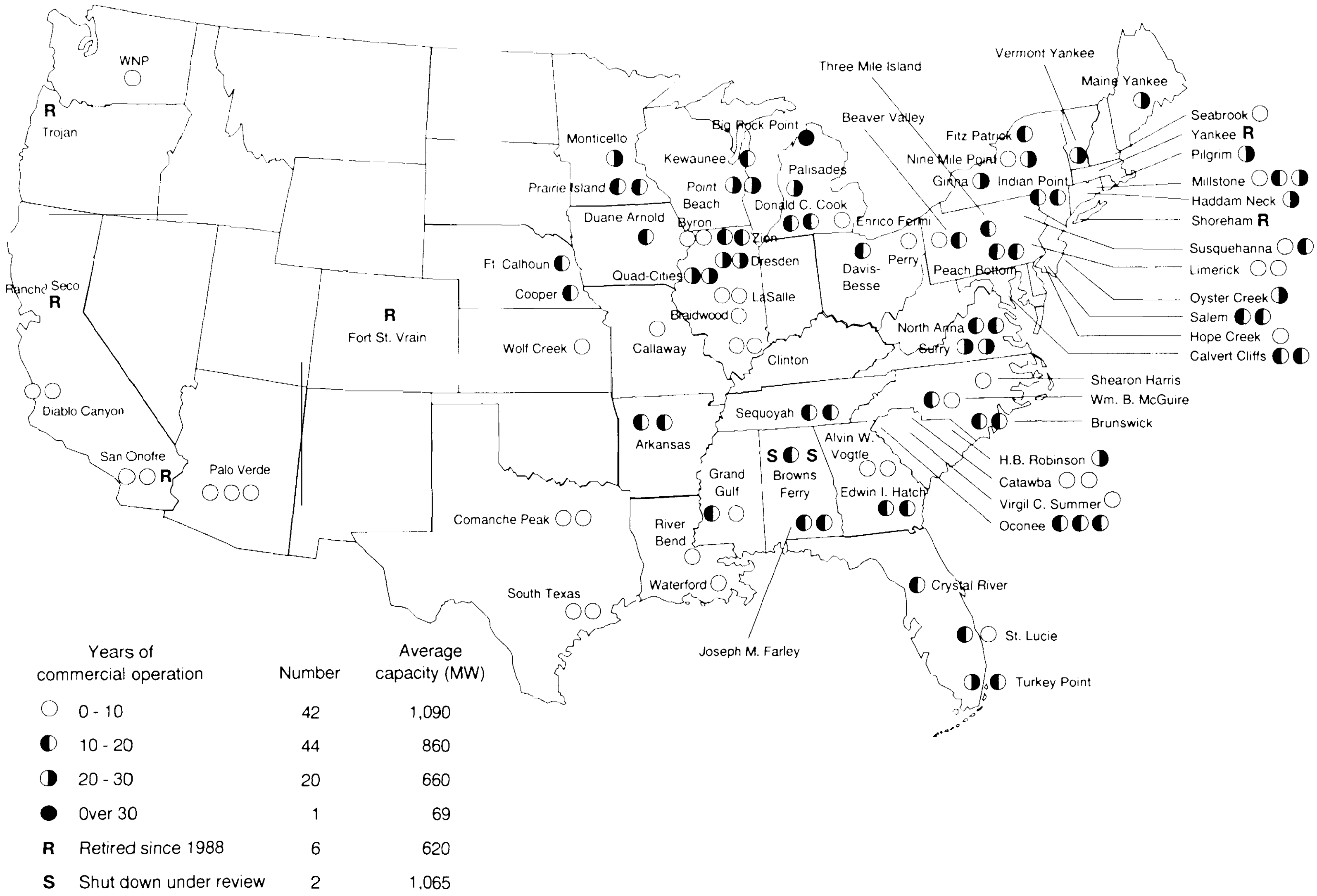
The number and size of nuclear power plants grew rapidly in the 1970s and 1980s. Twenty-five years ago, there were 11 nuclear power plants in the United States with an average capacity of about 180 MW and an average age of 5 years. As of 1993, the average age of the 107 operating U.S. nuclear power plants was about 17 years, with an average capacity of over 900 MW.[2] While there are operating nuclear power plants in all regions of the Nation except the Rocky Mountain States, most of the older units are in the Midwest and along the Atlantic seaboard States (see figure l-l).

The number of plants outside the United States has grown rapidly as well. As of 1992, there were about 300 nuclear power plants in operation in 24 other countries. Although the United States has the largest number of nuclear power plants of any country, nuclear power supplies a larger fraction of total electricity in half of the other countries. Nuclear plants outside the United States tend to be newer, many of which have recently come into service. However, nuclear plant life management issues are being examined in the international community, for example, by the Organization of Economic Cooperation and Development, the International Atomic Energy Agency and by individual countries (see figure 1-2).[3] Worldwide, 22 new nuclear power plants began operation between 1990 and 1992, including one in the United States. During this period a similar number of plants were retired, the majority of which were in Germany and the former Soviet Union.

[2] Of the 11 plants operating 25 years ago, 2 remain in service. These are Big Rock Point, a 69 MW plant in Michigan, and Haddarn Neck (also known as Connecticut Yankee), a 569 MW plant. U.S. Department of Energy, *Nuclear Reactors Built, Being Built, or Planned: 1991*, DOE/OSTI-8200-R55, July *1992,* pp. 1-6, *23, 24.*

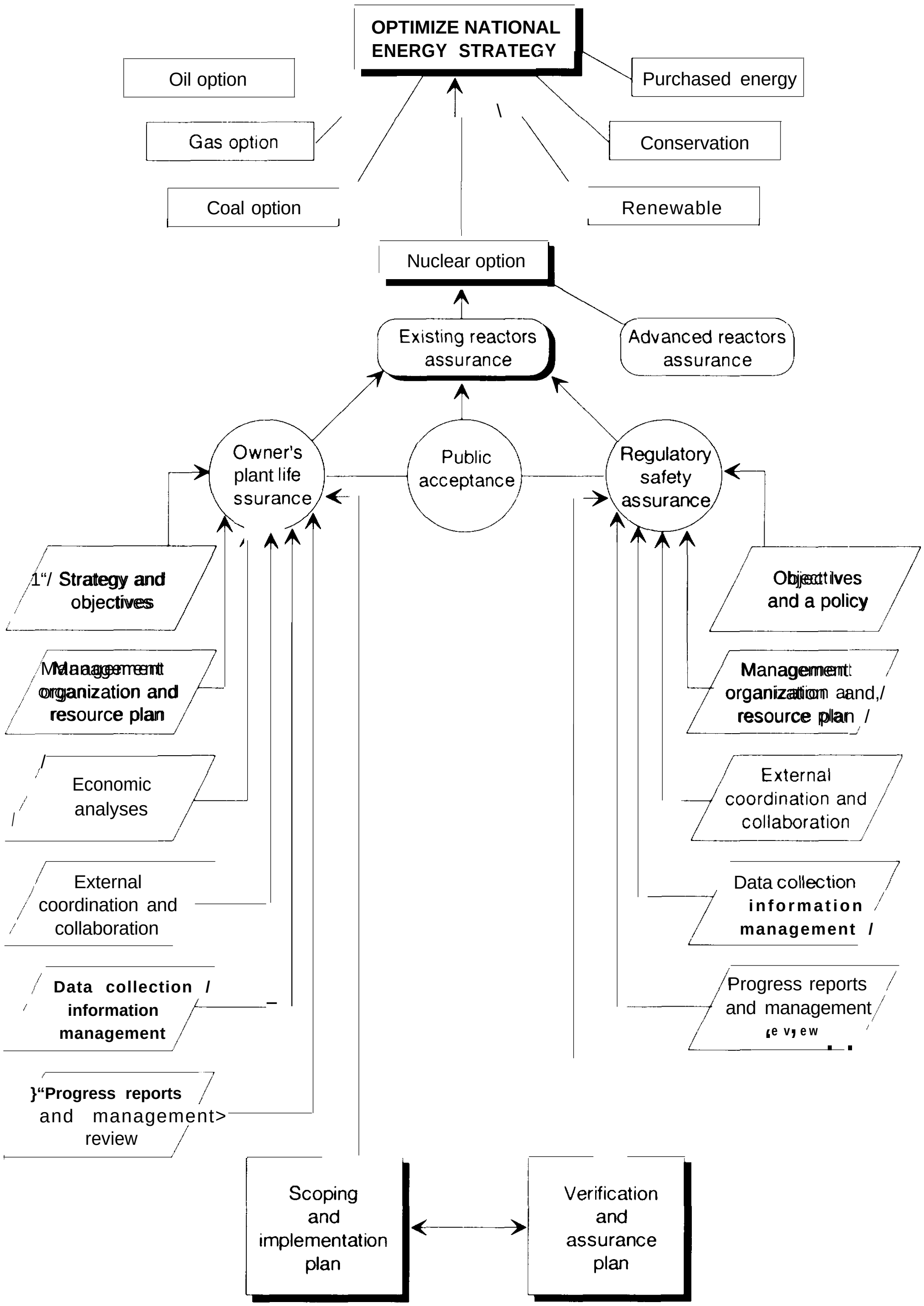
[3] See, e.g., Organization of Economic Cooperation and Development/Nuclear Energy Agency, "Nuclear Power Plant Aging and Life Management: A Model Approach, Current Status, and Country Comparisons, " draft, Nov. 3, 1992.

Figure 1-1—Commercial Nuclear Power Plants in the United States as of July 1993



SOURCE: Adapted from U.S. Nuclear Regulatory Commission, *Information Digest* (Washington, DC: USNRC, 1992).

Figure 1-2—An International Framework for Nuclear Plant Life Management



SOURCE: Organization of Economic Cooperation and Development, Nuclear Power Plant Aging and Life Management: A Model Approach, Current Status, and Country Comparisons, draft, Nov. 3, 1992, p. 6.

Box 1-C–What is Aging Degradation?

Many systems, structures, and components (SSCs) in industrial facilities, including nuclear power plants, are subject to aging degradation. For nuclear power plants, aging degradation is defined as the cumulative degradation that occurs with the passage of time in SSCs that can, if unchecked, lead to a loss of function and an impairment of safety.[1] The basic processes of aging are generally, if imperfectly, understood; continuing experience and research provide ongoing improvements in scientific understanding and ability to predict and address the effects.

Aging degradation can be observed in a variety of changes in physical properties of metals, concrete, and other materials in a power plant. These materials may undergo changes in their dimensions, ductility, fatigue capacity, mechanical or dielectric strength. Aging degradation results from a variety of aging mechanisms, physical or chemical processes such as fatigue, cracking, embrittlement, wear, erosion, corrosion, and oxidation. These aging mechanisms act on SSCs due to a challenging environment with high heat and pressure, radiation, reactive chemicals, and synergistic effects. Some operating practices such as power plant cycling (i.e., changing power output) and equipment testing can also create stress for plant SSCs.

There is a fairly limited set of degradation mechanisms, a large commonality in materials used, and fairly similar operating conditions. However, due to the diversity in plant designs, construction and materials used, operating conditions and histories, and maintenance practices, the specific effects of aging, although similar, are unique for each plant. Even near-twin units at the same site can have substantial differences in the remaining lives of major SSCs, based on subtle design or material differences and operating histories.

Among the major aging degradation issues for long-lived SSCs are:

- reactor pressure vessel embrittlement;
- steam generator tube corrosion and cracking;
- environmental qualification for in-containment cables and other electrical equipment; and
- fatigue, stress corrosion cracking, and other mechanisms that may affect a variety of metal components,

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[1] U.S. Nuclear Regulatory Commission *Nuclear Plant Aging Research (/VP'A/?) Program P/an,* NUREG-1144 Rev. 2 (Washington, DC: June 1991).

Experience with and understanding of aging issues continue to increase (box l-C). In total, the histories of the more than 400 nuclear plants provide several thousand reactor-years of operating experience with aging. However, because of the industry's youth, experience with nuclear power plants in the second half of their 40-year licensed lives is limited. This limited experience with aging can be particularly important for some major long-lived systems, structures, and components (SSCs) such as the reactor pressure vessel (RPV), cables, and containment structure that are intended to function for the full life of a facility.

Absent actual long-term operating experience for long-lived SSCs, understanding of aging issues involves engineering analyses and research, often using techniques to simulate accelerated aging on test materials. Retired plants may also yield lessons about aging by providing naturally aged SSCs for study. However, the diversity among plants and their SSCs prevents simple generalizations about the ultimate effects and management of aging. In contrast, many other components have relatively short lives (e.g., pumps and valves) and are periodically refurbished or replaced. For these shorter lived SSCs, engineering analyses and aging research are supported better by actual operating experience.

Managing Aging Degradation

Effective maintenance programs are crucial to manage aging degradation. Maintenance involves a variety of methods to predictor detect aging degradation and other causes of SSC failure, and to replace or refurbish any affected SSCs. New maintenance technologies include an array of improved hardware and procedures that can benefit the future management of aging degradation. To "ensure the continuing effectiveness of maintenance for the lifetime of nuclear power plants, particularly as plants age," the NRC promulgated a maintenance rule in 1991 to become effective in 1996.[4] The Institute of Nuclear Power Operations (INPO), an industry organization established in 1979 to promote excellence in nuclear power plant operations, had previously developed guidelines for effective maintenance to guide utility practices.[5]

The process to manage aging is elaborate, beginning with plant design and construction, and continuing with maintenance and research. The SSCs that comprise a nuclear plant were designed to have sufficient design margins to meet specified minimum lifetime requirements. However, in the decades since many of today's plants were first designed and built, extensive experience and research have shown that some SSCs degrade more rapidly than had been expected, while others last longer. Major examples of more rapid degradation are RPV embrittlement, steam generator tube degradation, and fatigue and stress corrosion cracking of piping. The NRC currently devotes about 20 percent of its $100 million annual research budget to aging-related projects. The industry also performs extensive aging-related research. For example, since its inception in 1973, the Electric Power Research Institute (EPRI) has devoted about 15 percent of its nuclear research budget (currently over $100 million annually) to understand, detect, and mitigate degradation of nuclear power plant components.[6]

Based on research and experience, design standards have changed considerably since today's oldest plants began operating. To assure the adequacy of older designs in the light of new technical information, the NRC and the industry have conducted extensive reviews (most notably through the NRC's Systematic Evaluation Program of the late 1970s) and continue to do so. Two current examples of particular attention are the NRC's efforts to examine environmental qualification of electrical equipment (EQ) and fatigue as generic safety issues. Factors such as fatigue, EQ, and embrittlement are more prominent for older plants, not so much because they have aged more, but because older plant designs and materials were based on less complete understanding of aging degradation than newer plants. Thus, younger plants may be presented with fewer challenges as they age. For those plants affected, the costs of addressing these issues may be substantial.

AGING AND SAFETY

Under normal operating conditions, nuclear power plants cause limited and generally unmeasurable public health impacts. However, as evidenced by probabilistic risk assessments and occasional alarming operating events, existing nuclear power plants also pose a small risk of catastrophic accidents in which public injury or fatality could result. Absent effective aging management as discussed above, aging degradation increases the probability that any SSC will fail to

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[4] 10 CFR 50.65

[5] In promulgating the rule, the Nuclear Regulatory Commission noted that its recent inspections of maintenance activities found that existing programs were adequate and improving, but there were some areas of weaknesses, and no licensee had formally committed to implement the INPO standards prior to the rule's proposal. 56 Federal Register 31321 (July 10, 1991).

[6] John Carey, Electric Power Research Institute, personal communication January 1993; and Electric Power Research Institute, *Research and Development Plan 1993* (Palo Alto, CA: 1993).

function properly, potentially leading to an accident.[7] Continued effort to manage aging at every plant is thus one important aspect of assuring safety. However, after many years of intensive efforts by the NRC and industry, no insurmountable, industry-wide safety challenges related to aging have been identified, although there are some notable uncertainties that research continues to address. Some aging-related safety issues such as more detailed re-examination of fatigue, EQ, and RPV embrittlement, and implementation of license renewal regulations will have effects on plant lives that are yet to be determined. Aside from plant aging challenges, the NRC and the industry continue to address other risks and uncertainties including the performance of human operators, and containment structures, and the potential impacts of external events such as earthquakes and flooding.

Some have suggested that the safety of older plants is inadequate because those plants were not designed with the same detailed guidance as newer plants and therefore often do not meet the current design standards.[8] It is true that a newly constructed plant identical to older plants could not be licensed under current NRC regulations. However, the NRC notes that it has judged and continues to judge the safety of older plants on an ad hoc and plant-specific basis (e.g., through the Systematic Evaluation Program) rather than against standardized design requirements, and finds that adequate safety currently exists.

Institutional Efforts Determining the Adequate Safety of Aging Management

To assure the adequate protection of public health and safety in the use of nuclear power, the NRC performs a variety of regulatory activities to address aging and other issues under the Atomic Energy Act of 1954 as amended (AEA).[9] Each nuclear power plant has a unique set of NRC requirements established at initial licensing and modified over time to provide, in the judgment of the NRC, a reasonable assurance of adequate safety (box l-D). This set of requirements is called the plant's current licensing basis (CLB).[10] Although the NRC plays a major role in assuring nuclear plant safety, the AEA assigns the primary responsibility for safe operation of a commercial nuclear plant not to the NRC but to the plant operator, or licensee .11 Each licensee is ultimately responsible for the design, operation, and maintenance of its plant, not merely to meet NRC requirements, but to assure safety.

Given the complexity and often plant-specific nature of many technical issues, there are often differing opinions, not only about technical is-

T Nuclear plants are designed with the principle of 'defense in depth,'' involving redundancy and multiple safety systems to mitigate the effects of any single failure. Thus, an accident involves a sequence of failures. One example of redundancy is in electrical supplies for critical safety systems, which include offsite electricity sources, emergency diesel generators, and alternate supplies such as emergency batteries. Another example is the multiple barriers designed to contain radioactive materials at successive locations, including the fuel matrix, fuel cladding, primary coolant circuit boundary, and the containment structure. Age-related degradation in the SSCS can affect each level of defense in depth to varying degrees.

[a] See, e.g., Diane Curran, counsel for the Union of Concerned *Scientists, Hearings Before the Subcommittee on Energy and the Environment of the Committee on Interior and Insular Affairs,* House of Representatives, Nov. 5, 1991, pp. 93-95.

9 Atomic Energy Act of 1954 as amended (AEA), Public Law 83-703,68 Stat. 919. The NRC was established by the Energy Reorganization Act of 1974 as an independent agency of the Federal Government. 42 United States Code Sec. 5841 *et seq.* Its regulatory responsibilities were transferred from the U.S. Atomic Energy Commission.

10 This large body of requirements is contained in a plant's operating license application or Safety Analysis Report; plant specific compliance with Commission regulations noted in 10 CFR Part 50, as well as other parts of Title 10 of the Code of Federal Regulations; Commission orders, license conditions, exemptions and technical specifications; and all written commitments made by the licensee in docketed responses to NRC bulletins and generic letters.

11 42 U.S.C. 2011 *et seq.*

Box 1-D-How Safe Is Safe Enough?

An underlying question in determining the adequacy of aging management is the overall goal for nuclear plant safety: "How safe is safe enough?" Absolute protection, that is, the total absence of risk, is neither possible nor a meaningful goal for nuclear power plants or any other energy source. The *Atomic* Energy *Act* provides little direction in answering the question of how safe is safe enough. Rather, it leaves that responsibility with the NRC under the general charge of assuring adequate protection of the public health and safety.

To address the issue of acceptable risk to the public, the NRC formally set qualitative safety goals for nuclear power plant operation in 1986, after several years of development, as well as quantitative objectives to be used in determining achievement of the goals.[1] For example, the policy states,

> The risk to an average individual in the vicinity of a nuclear power plant of prompt fatalities that might result from reactor accidents should not exceed one-tenth of one percent (0.1 percent) of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed.

The best available information indicates that, if aging is properly managed, the risk of fatalities resulting from nuclear power plant operations in the United States is low relative to NRC's safety objectives.

Although the safety goal policy can provide useful guidance in regulatory activities, it has some notable limitations, perhaps the greatest of which is the practical difficulty of translating the risk-based goals into regulatory practices. There is, however, a growing use of risk-based approaches, for example, in complying with the maintenance rule.[2] Other areas for potential improvement in the safety goal policy include: clarifying consistency with safety goals in other Federal law; establishing a practical correlation with risks of non-nuclear electricity resources; considerating changing demographic characteristics near a plant more fully; discussing the appropriate use of cost-benefit analyses; and more explicitly treating the uncertainty inherent in risk estimation.

1 U.S. Nuclear Regulatory Commission, 51 *Federal Register* 30028 *et seq.*, Aug. 21, 1986. As might* expected, the NRC's safety goals do not vary according to a plant's age.

2 See, e.g., U.S. Nuclear Regulatory Commission, Regulatory Guide 1.160, June 1993; and Yankee Atomic Electric Co., *Applications* of *PRA*, EPRi NP-7315 (Palo Alto, CA: Electric Power Research Institute, May 1991).

sues, but about the appropriate level of technical detail to consider in the regulatory process. In fact, many in the industry maintain that some NRC activities and requirements are unpredictable, costly, and unnecessary to assure an adequate level of public health and safety. Similarly, some nuclear critics maintain that at least some NRC activities are ''contrary to Congress' purpose of assuring that operation of nuclear power plants will not pose an undue risk to the public health and safety."[12] Some observers suggest that the regulatory process itself, including the role of the courts, is overly cumbersome, legalistic, and exacerbates uncertainty.[13] Others suggest that NRC policies have been too restrictive of public input in addressing important safety issues.[14]

12 The Union of Concerned Scientists and the New England Coalition on Nuclear Pollution, testimony on the Proposed License Renewal Rule for Nuclear Power Plants at hearings before the House Subcommittee on Energy and the Environment of the Committee on Interior and Insular Affairs, Nov. 5, 1991.

13 M. W. Golay, "How Prometheus Came to be Bound: Nuclear Regulation in America,'' *Technology Review,* June/July 1980, pp. 29-39. Although the article was written some time ago, most of it remains pertinent today. Michael Golay, personal communication, January 1993.

14 M. Adato, The Union of Concerned Scientists, *Safety Second: The NRC and America's Nuclear Power Plants* (Indianapolis, IN: Indiana University Press, 1987). As one example, under 10 CFR 2.206, while the public may petition the NRC staff to initiate a proceeding, there are no provisions for appealing staff decisions either to the Commission or judicially. However, the Commission has in the past invoked at its discretion the power to review staff decisions upon receiving a petition from a public interest group. See U.S. Nuclear Regulatory Commission ''In the Matter of Yankee Atomic Electric Company," Memorandum and Order, 50.029, July 31, 1991.

Ultimately, although regulatory activities and industry practices for managing aging (and other safety-related issues) are based on detailed technical analyses, the determination of whether those practices provide adequate safety lies with the professional judgment of the NRC. In performing its task, the NRC is often aided by other parties including the nuclear industry, public interest groups, and State agencies. The industry established the Nuclear Management and Resources Council (NUMARC) in 1987 to coordinate interactions with the NRC on industry-wide regulatory issues. The NRC's process of issuing licenses and developing new rules and regulations is largely open, and public input is allowed, as required by the Administrative Procedures Act.[15] There have also been numerous cases of judicial review of NRC licensing and procedural decisions brought by the public and interest groups.

It should be noted that while the NRC and the commercial nuclear power industry have elaborate processes for addressing safety issues including aging, those processes have generally, but not always, performed as effectively as intended. The apparent failure of regulatory and industry processes with regard to the widely used fire retardant Thermo-Lag provides one example outside the area of aging.[16] However, such a failure appears the rare exception.

There are several aging-related examples of regulatory issues for which differing opinions and questions about the appropriate level of technical detail are yet to be resolved. Among them are regulatory activities addressing steam generator microflaws and RPV embrittlement, issues that contributed to recent early retirement decisions at two plants. The owners of the plants, both of whom believed their plants to be safe, opted for retirement, citing in part the uncertain but high costs of meeting NRC requirements that were yet to be determined (see descriptions of the Yankee Rowe and Trojan retirement decisions in box l-A.) Another major regulatory issue related to aging for which implementation and other issues remain to be resolved is license renewal, discussed below.

Aging Safety and License Renewal

As specified in the AEA, commercial nuclear plant operating licenses may not exceed 40 years, but may be renewed on expiration.[17] The fried term was established in the AEA for financial and other nontechnical reasons, although once chosen, it became an assumption in specifying certain plant design features (e.g., the number of thermal cycles occurring, and thus the requirements for fatigue).

During the past few years, the NRC and the commercial nuclear power industry, with funding support from the U.S. Department of Energy (DOE), have devoted considerable effort to the topic of nuclear plant license renewal. Although the NRC promulgated its license renewal rule in 1991,[18] it will be several years before practical implementation guidance is finalized. The NRC's implementation effort includes developing a' Regulatory Guide, ' that instructs applicants in detail on the standard format for technical information, and a' 'Standard Review Plan, ' that instructs the NRC staff in detail on the framework for review-

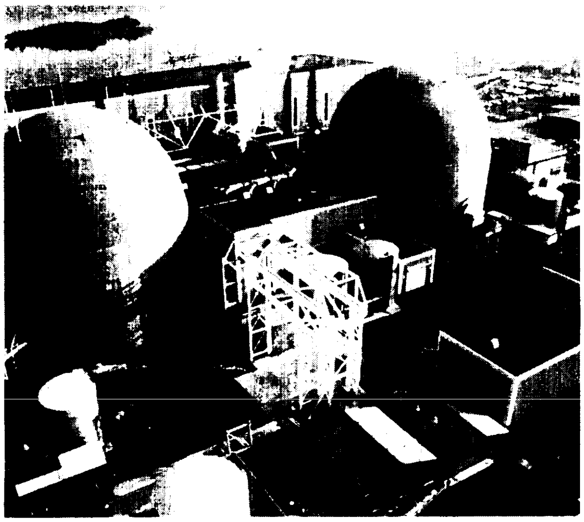
[15] 5 U.S.C. Sec. 551 *et seq.* ''Subchapter II—Administrative Procedures. '

[16] As early as about 10 years ago when Thermo-Lag was certified as a fire retardant, several licensees raised concerns about the material's effectiveness with the NRC. However, the NRC did not act to examine those concerns until the early 1990s, by which time about 84 plants were using Thermo-Lag. Recently, the NRC Inspector General issued a report critical of the NRC's performance in that case, and a grand jury investigation has been initiated by the U.S. Attorney in Maryland.

[17] Of the other countries with large nuclear power programs, none have adopted fixed license terms. The absence of fixed license terms is one of a number of features that distinguishes U.S. nuclear regulatory practices from the international community. Organization for Economic Co-Operation and Development, Nuclear Energy Agency, *Licensing Systems and Inspection of Nuclear Installations 1991* (Paris, France: OECD 1991).

[18] 56 *Federal Register* 64943-64980 (Dec. 13, 1991).

VIRGINIA POWER



Virginia Power replaced the steam generators at its Surry units 1 and 2 (shown here) in 1979 and 1981, respectively. Virginia Power attributes the relatively low cost and rapid completion of the 1993 steam generator replacement at its North Anna unit one in part to the experience gained at Surry.

ing an application. Both of these efforts remain in draft stages, which the NRC expects to finalize after gaining experience from the first few applicants or, "lead plants," working through the process. The NRC has also proposed but not finalized a rule establishing requirements for the environmental review of license renewal applications, as required by the National Environmental Policy Act.[19] Even after the NRC acts on the early license renewal applications, there may be court challenges to the implementation of the rule that would take additional time to resolve.

The inexperience with license renewal regulations is largely explained by the industry's relative youth-with the exception of one small unit, the license of the oldest operating plant will not expire until 2007 (table l-B). Although the licenses of several other younger plants expire sooner, a relatively simple NRC administrative procedure allows those plants to extend their expiration dates by the number of years spent during construction.[20] By 2015, however, license renewal would be required for continued operation of more than 40 other plants, over one-third of those now in operation.

By the end of 1992, early license renewal efforts at the two lead plants had been withdrawn or deferred. Owners of the Yankee Rowe and the Monticello plants originally planned to submit license renewal requests in 1991 as part of a jointly funded multiyear DOE/industry lead plant program. However, Monticello's owners indefinitely deferred their license renewal application in late 1992 citing concern about the interpretation of the NRC's rule, noting that the number of systems to be reviewed had grown from the original 74 to 104 with "no indication of where it might go from there."[21] Also noted as major concerns were operational cost increases and lack of resolution in spent fuel disposal. As noted in box l-A, Yankee Rowe's owners chose early retirement in 1992 for economic reasons, including the cost of addressing NRC concerns about

19 56 *Federal* Register 47016.

20 License terms were initially set based on the start of plant construction rather than the start of operation. However, NRC regulations allow a relatively simple procedure to recover the construction period and thereby extend expiration of the initial operating licenses without license renewal. The difference can be substantial. For example, the license for Unit 1 of the Diablo Canyon plant expires in 200S based on approval of its construction license in 1968, although operation did not begin until 1984 following a series of construction delays. By recovering the construction period in the initial license, Diablo Canyon would require license renewal only in 2024, 16 years beyond the current expiration. For this reason, the year of expiration as currently shown for some licenses is not an accurate reflection of the date at which license renewal would be needed.

21 J. Howard, Chief Executive Officer of Northern States power, cited in "License Renewal Suffers New Blow as NSP Application is 'Deferred'," *Nucleonics Week,* vol 33., No. 46, Nov. 12, 1992, pp. 1, 12, 13. The actual systems to be reviewed are not specified in the license renewal role, and the NRC neither determined nor reviewed NSP's lists of 74 and 104 systems. That is, the actual number of systems to be reviewed remained uncertain at the time NSP deferred its license renewal effort. See also, Northern States Power Co., "Perspectives on the License Renewal Process," Nov. 20, 1992.

Table 1-B—U.S. Commercial Nuclear Power Operating License Expirations Through 2015

Year[a] (Assuming construction recapture)	Year (Under current license, if different)	Name	Generating capacity (MW)
2002	2000	Big Rock Point	67
2007	2007	Haddam Neck	560
2009	2004	Oyster Creek 1	610
	2006	Dresden 2	772
		Ginna	470
		Nine Mile Point 1	615
2010		H.B. Robinson	683
		Millstone 1	654
		Monticello	536
		Point Beach 1	485
2011	2007	Palisades	730
		Dresden 3	773
2012	2007	Turkey Point 3	666
	2008	Maine Yankee	860
		Pilgrim 1	670
		Quad Cities 1	769
		Quad Cities 2	769
		Surry 1	781
		Vermont Yankee	504
2013	2007	Turkey Point 4	666
	2008	Peach Bottom 2	1055
	2008	Fort Calhoun	478
		Indian Point 2	939
		Kewaunee	511
		Oconee 1	846
		Oconee 2	846
		Point Beach 2	485
		Prairie Island 1	503
		Surry 2	781
		Zion 1	1040
		Zion 2	1040
2014	2008	Peach Bottom 3	1035
		Arkansas Nuclear 1	836
		Browns Ferry 2	1065
		Brunswick 2	754
		Calvert Cliffs 1	825
		Cooper	764
		D.C. Cook 1	1020
		Duane Arnold	515
		Edwin 1. Hatch 1	741
		Fitzpatrick	780
		Oconee 3	846
		Prairie Island 2	500
		Three Mile Island 1	808
2015	2009	Indian Point 3	965
		Millstone 2	863

a Year of expiration assuming that the maximum number of years for construction recapture has been added to the current expiration date (i.e., 40 years from start of plant operation).

SOURCE: U.S. Nuclear Regulatory Commission, *Information Digest* 1992 cd., NUREG-1350 (Washington, DC: March 1992) pp. 48, 79-91.

the metallurgical status of the RPV during its review of the plant's license renewal efforts.

In late 1992, a group of five utilities operating seven plants designed by Babcock and Wilcox (the Babcock and Wilcox Owners' Group, BWOG), announced its intentions to pursue a joint effort in developing a license renewal application. Because there are several utilities and power plants represented by the BWOG, costs and experiences of preparing the license renewal applications can be shared, improving the prospects for a successful application. However, the group does not expect to select a plant and submit an application until 1997. Other owners' groups are developing similar programs.

In December 1992, a senior NRC staff management group undertook a review of license renewal issues at the request of the Commission and proposed a revised implementation approach. The staff review concluded that the rule does not need to be changed, and that an efficient process can be implemented. Despite the favorable NRC staff review, however, there still appear to be some problems and uncertainties with the rule and questions about its practical implementation, which are discussed below. The NRC is continuing to address these issues including holding a public workshop.[22]

As promulgated in 1991, the license renewal rule and the accompanying statement of considerations (SOC) appear somewhat inconsistent with other NRC aging efforts. The license renewal rule and SOC require renewal applicants to perform a formal, and potentially far more detailed, demonstration that aging issues are addressed than otherwise applies to existing plants as they age. In particular, the rule and SOC require utilities to perform and file with the NRC for approval an integrated plant assessment (IPA). As described in the SOC, the IPA includes a detailed evaluation of aging degradation for all SSCs directly or indirectly affecting safety. Depending on the level of detail required, this evaluation could be a difficult and costly undertaking. An NRC study estimated the cost to be about $30 million per plant.[23] In contrast, no other NRC regulations require such a formal, detailed evaluation of aging. The recently proposed staff implementation approach would largely bypass this step. Although perhaps appropriate for assuring adequate safety, that staff interpretation strays from the rule's SOC and could expose renewal applications to court challenges.[24]

The rule further requires that licensees obtain regulatory approval of ''effective programs' to address any ''age-related degradation unique to license renewal" (ARDUTLR) that could occur. In contrast, the NRC's maintenance rule, while requiring utilities to have effective maintenance programs, does not require formal regulatory filing and approval of the detailed programs. Further, while the license renewal rule requires that an effective program must maintain the plant's CLB, the maintenance rule allows other objectives, for example, based on risk-significance.

Beyond some inconsistency with other NRC aging requirements, there are other potential problems with the license renewal rule and its eventual implementation. For example, the concept of ARDUTLR as used in the license renewal rule is less useful than it first appears. Although apparently intended to limit the scope of detailed aging examinations and effective programs to

22 u.S. Nuclear Regulatory Commission "Additional Implementation Information for 10 CFR Part 54," "Requirements for Renewal of Operating Licenses for Nuclear Power Plants," " SECY-93-1 13, Apr. 30, 1993; and U.S. Nuclear Regulatory Commission, "Implementation of 10 CFR Part 54, 'Requirements for Renewal of Operating Licenses for Nuclear Power Plants, ' SECY-93-049, Mar. 1, 1993; and 58 Federal Register 42987.

23 U.S. Nuclear Regulatory Commission, *Regulatory Analysis for Final Rule on Nuclear Power Plant License Renewal,* NUREG-1362 (Washington DC: October 1991), table 4.6.

24 Memorandum from William C. Parler, General Counsel, to the U.S. Nuclear Regulatory Commission "License Renewal and SECY 93-049," Mar. 9, 1993, pp. 4,5.

issues not already explicitly addressed in the original license term, according to the NRC staff, there are few if any SSCs that can be readily shown to have no ARDUTLR as defined in the rule. For example, it is difficult to show that even relatively short-lived SSCs under a regular refurbishment or replacement program have no ARDUTLR according to the NRC staff. Regarding long-lived, or life-of-plant SSCs (e.g., containment structures and RPVs), there is little expectation that new aging mechanisms will occur only beyond the original license term. Instead, the rates of degradation and the safety implications are not precisely known, so aging management involves a continuing effort of maintenance and of evaluating operating experience and research.

Federal Policy Considerations; Assuring Adequate Aging Safety

The Federal Government's main responsibility in relation to nuclear power plants is assuring adequate protection of the public health and safety-a responsibility charged primarily to the NRC. Current regulatory and industry efforts to address aging are designed to provide a reasonable assurance of adequate safety. However, there are some aging issues in the safety regulatory process with longer term implications that may benefit from early attention. The safety policy options listed in table 1-A would not necessarily provide for a greater level of safety-rather they could more quickly identify and resolve concerns likely to arise as aging issues continue to be addressed in the coming years, reducing regulatory uncertainty and allowing more timely decision making by the NRC and the industry.

The first two policy options listed specifically address aging issues. The latter two may be important not only for aging but for the broader array of safety regulation as well.

1. Accelerate Ongoing Aging-Related Safety Activities.

Early license renewal efforts suggest that the NRC's existing aging-related safety efforts could be accelerated. According to the NRC staff, early license renewal efforts helped focus needed attention on two aging issues that are of generic importance to the industry during the original license terms of existing plants--EQ and fatigue. The NRC staff has suggested treating both topics as Generic Safety Issues (GSIs), resulting in a more detailed regulatory re-examination for plants during their current licensed lives. Early license renewal activities at one lead plant (Yankee Rowe) also brought additional attention to a third topic of importance to a smaller number of plants, RPV embrittlement.

That license renewal activities brought this additional attention should not be surprising, since the rule places greater importance on formally identifying and managing aging degradation than is required for plants not seeking license renewal. However, any dependence on license renewal activities to address aging challenges that occur during original license terms may be a perverse allocation of efforts, since the plants most affected by aging degradation may also be those least likely to seek license renewal. Such a dependence also leaves unclear how and at what point such focus will be brought absent future license renewal applications.

To help ensure that other aging issues, whether generic or plant-specific, are focused on in a timely fashion absent detailed license renewal efforts, the NRC could pursue a variety of efforts. For example, the NRC could accelerate and intensify the review of topics raised by industry and NRC aging research programs for application to regulatory activities. This could go a long way to supplanting dependence on license renewal activities to identify aging issues needing additional attention. For example, none of the three topics raised in the license renewal activities noted above were new to industry or to the NRC, having been identified previously in research programs. In this review, the NRC could also consider the appropriate level of effort applied to aging in long-lived SSCs versus shorter lived, regularly refurbished or replaced SSCs.

Second, as utilities finalize compliance with the maintenance rule over the next 3 years, the NRC could monitor and report on whether the relatively flexible approach (i.e., without formal filing and regulatory approval of plant-specific maintenance programs, and without an equivalent of the plant-specific integrated plant assessment as originally envisioned for the license renewal rule) adequately identifies and addresses aging degradation. In particular, in reviewing maintenance rule compliance and adequacy, the NRC could assess whether the level of technical detail and analysis of aging issues provided by an IPA (as described in the preamble to the license renewal rule) would provide a substantially greater assurance that aging issues are being identified and addressed in a systematic fashion.

2. **Simplify the License Renewal Rule.**

If ongoing aging management programs are adequate during an original license term, it may be possible to considerably simplify the license renewal rule without affecting safety. The recent NRC staff proposals for implementing the current license renewal rule include several simplifications. However, the staff interpretations allowing for the simplifications are not entirely consistent with the rule's preamble and may thus be subject to considerable regulatory and court challenge. For this reason, the NRC staff has proposed consideration of an additional rulemaking to revise the current rule.

In reopening the license renewal rule, it may be worthwhile for the NRC to consider further simplifications in the rule than those contained in the staff proposal. For example, with adequate, ongoing aging management, it may be appropriate to treat license renewal as a relatively simple administrative procedure. One principal justification for the license renewal rule as promulgated in 1991 is the need to address aging degradation issues that arise during a plant's license renewal term but not in the current license term. However, the practical distinction between ARDUTLR and aging generally is hazy and artificial for both short-and long-lived SSCs. Even for long-lived SSCs, aging management in a current license term may involve revalidation of previous analyses of aging degradation rates and design margins as more operating experience and research are gained. For this reason, it may be better to view aging management as a more continuous process than established in the license renewal rule.

Even assuming the premise that some aging degradation is best viewed as unique to license renewal, it may still be appropriate to simplify the license renewal rule for greater consistency with other NRC aging requirements. Two revisions suggested in the recent NRC staff proposals are: more explicit approval of the use of the maintenance programs required under the maintenance rule; and redefining ARDUTLR in such a way that it focuses on long-lived SSCs and not on short-lived SSCs that are replaced on a time or performance basis.

One potential concern with simplifying license renewal requirements is that it may allow a severely degraded nuclear plant to continue operating beyond its original license term. However, the risk that a simplified license renewal rule would allow should be minimal if other aging management practices are adequate. The two earliest license expirations are set for 2002 and 2007. Any inadequacies in current and planned aging management practices need to be corrected before current licenses expire, rather than relying on license renewal requirements and the ambiguous concept of ARDUTLR.

One consideration in revising the license renewal rule could be whether the estimated $30 million cost per applicant of producing a detailed IPA is the most productive use of funds for addressing aging issues. It may be more productive to devote resources to addressing aging issues affecting plants in their current license terms, or even to safety issues not directly related to aging. For example, both human and containment structure performance in existing plants continues to receive NRC and industry attention, and remain sources of uncertainty in safety assessments.

3. **Revise Public Participation Provisions**

The NRC's regulatory process is largely open, and public participation is allowed. However, by virtue of being a licensing proceeding, the license renewal process for any plant will allow a considerably more extensive public role in examining aging issues than provided during the current license term under existing law. For those doubtful of the adequacy of industry and NRC safety efforts, license renewal will allow an important opportunity to challenge licenses both in the NRC hearing process, and quite possibly through the courts.

To the extent that a greater public role at the time of license renewal would help provide a better assurance of adequate safety with respect to aging, it may be worth examining how that benefit could be gained more generally during a current license term and not linked to a specific regulatory action. In the past, public participation has focused NRC attention on aging safety issues leading to license modifications.[25] Revising some public participation provisions may also help alleviate public concerns about safety.

In particular, under NRC regulations,[26] the public may petition the NRC staff to initiate a proceeding, but there are no provisions for appealing staff decisions either to the Commission or judicially.[27] One approach that has been suggested is to allow judicial review of public petitions to initiate a proceeding to modify, suspend, or revoke a license.[28] A central issue in considering this approach is whether the likely benefits warrant the additional burdens on the court system, the utilities, and the NRC that allowing such review could bring.

An alternate approach that could potentially avoid the cumbersome and confrontational nature of formal hearings is to consider involving critics of the industry and others earlier and more directly in the regulatory process. Providing for more ongoing public participation may also help reduce the uncertainties arising from challenges in the NRC hearing process and the courts. In the past year, noting a longstanding criticism by citizens' groups and some members of Congress with regard to NRC's public petition process, NRC has undertaken an effort, including holding a public workshop, to examine possible revisions to its procedures for treating public petitions.[29] The NRC's enhanced participatory process for establishing site release criteria for decommissioning is one example of a current effort that may be worth expanding to other regulatory areas. Among the approaches that others have suggested include drawing from a broader cross-section of interested and technically competent parties for NRC advisory positions (e.g., the Advisory Com-

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25 See, e.g., Union of Concerned Scientists and the New England Coalition on Nuclear Pollution ''Petition for Emergency Enforcement Action and Request for Public Hearing,' before the U.S. Nuclear Regulatory Commission, June 4, 1991. The aging degradation issue raised in the petition (the effect of embrittlement on the integrity of one plant's RPV) had been previously identified by the NRC staff and was under continued investigation. However, the Chairman of the NRC noted that the petition stimulated the Commission's thorough review of the analyses leading to an NRC order. U.S. Nuclear Regulatory Commission, "In the Matter of Yankee Atomic Electric Company,' Memorandum and Order, 50.029, July 31, 1991; and Statement of Ivan Selin, Chairman, U.S. NRC, before the House Subcommittee on Energy and the Environment of the Committee on Interior and Insular Affairs, Aug. 1, 1991.

26 10 CFR 2.206

27 However, the Commission has in the past invoked, at its discretion, the power to review staff decisions upon receiving a petition from a public interest group. U.S. Nuclear Regulatory Commission, ''In the Matter of Yankee Atomic Electric Company,' Memorandum and Order, 50.029, July 31, 1991.

28 Examples of legislative proposals to ease these restrictions are found in S.1165, 103d Congress; and U.S. House of Representatives Rept. 102-474 Part 8, Report on the Comprehensive National Energy Policy Act, Title I Subtitle C, May 5, 1992.

29 See *Federal Register* 34726 (June 29, 1993).

mittee on Reactor Safeguards), and some form of intervener funding could be used (e.g., to retain industry critics to review and comment on specific aging-related topics).[30] Some in the industry may object strongly to any requirements to fund critics, either directly or through their NRC fees. However, similar options are used to some degree in various regulatory activities of different States. For example, integrated resource planning efforts performed by States and utilities have increasingly involved participation by the public, consumers, and competing generators in part to lessen the contentiousness of adversarial proceedings. As an example of a broadly based advisory group, the Pennsylvania State Low-Level Waste Advisory Commission specifically includes a wide range of members, including local government, environmental, health, engineering, business, academic, and public interest groups.[31]

4. Apply the NRC's Safety Goal Policy to Aging Issues.

While the NRC's aging-related regulatory activities are elaborate, the relationship between those activities and the NRC's safety goals (box 1-D) could be made more clear. For example, the safety goal policy is not mentioned in the license renewal rule, the 32-page Statement of Considerations accompanying the rule,[32] or the NRC's regulatory analysis of the rule.[33] Similarly, the NRC's most recent plan for its Nuclear Plant Aging Research (NPAR) program does not reference the safety goal policy statement in its approximately 170 pages.[34] The NRC has had an ongoing effort to make greater application of the safety goal policy.[35] As part of that effort, the NRC could undertake a more visible and comprehensive effort to ensure that its safety goal policy is appropriately translated into regulatory and research activities related to aging. Further, although a good step forward when it was produced in 1986, the policy itself has some limitations and has not been revised despite considerable advances in the state of the art of risk assessment. Several of the limitations relate to plant aging issues. The NRC could revisit its safety goal policy to ensure that it provides as meaningful a basis as possible for NRC regulatory actions for existing plants.

ECONOMY OF EXISTING PLANTS

The economic prospects for existing nuclear power plants depend not only on the reliability and costs of individual plants but also on the broader economic context of the electric power industry. Uncertainty and change are hallmarks of the electric power industry. Several electric industry trends diminish the long-term economic prospects for existing nuclear plants including: rapid growth in utility industry restructuring and supply competition; low load growth, often resulting in excess capacity; growing utility efforts to tap into a large, low-cost potential for improved energy efficiency; and continuing high availability and low prices for natural gas for electricity generation. At least one trend, incorporating environmental externalities, may improve the prospects, however. In particular, concern over

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30 See, for example, U.S. Congress, Office of Technology Assessment, *Nuclear Power in an Age of Uncertainty*, OTA-E-216 (Washington DC: U.S. Government Printing Office, February 1984), p. 260; and John Kemeny et al., *Report of the President's Commission on the Accident at Three Mile Island* (Washington DC, 1979).

31 Laws of Pennsylvania, Act 1988-2, "An Act providing for low-level radioactive waste disposal," Section 317.

32 56 *Federal Register* 64943-64980 (Dec. 13, 1991).

33 U.S. Nuclear Regulatory Commission, *Regulatory Analysis for Final Rule on Nuclear Power Plant License Renewal*, NUREG-1362 (Washington DC: October 1991).

34 U.S. Nuclear Regulatory Commission *Nuclear Plant Aging Research (NPAR) Program Plan*, NUREG-1144 Rev. 2, (Washington, DC: June 1991).

35 U.S. Nuclear Regulatory Commission, "Interim Guidance on Staff Implementation of the Commission's Safety Goal Policy, SECY-91-270.

global climate change and other environmental challenges related to fossil fuel combustion, if factored into economic analyses, could improve the relative economics of existing nuclear plants considerably (box l-E). Increasingly, these factors are being examined through what are often elaborate planning exercises, called integrated resource planning (IRP).[36]

In addition to change, there is great diversity in electricity market conditions and the value of nuclear power across the country. For example, because excess capacity and fuel costs vary by region, current estimated replacement costs for power are far lower in some areas than in others. Similarly, existing units provided 22 percent of U.S. electricity in 1991, but some regions of the country, primarily along the Atlantic seaboard and parts of the Midwest, are far more dependent on nuclear power (figure 1-1).

All power plants, nuclear and non-nuclear, will eventually be retired. But at what point does it make sense to retire a plant, and what unique issues are raised by nuclear plants? Aging effects on plant economic performance can be important factors affecting the economic attractiveness of existing plants .37 However, other factors can play an equal or greater role in determiningg a plant's economic performance, such as the cost and availability of waste disposa1[38] (box l-F) and the cost of addressing safety issues not related to aging. Decommissioning costs can also be a factor in plant life decisions. For example, one effect of delaying plant retirement is to defer decommissioning, which may be an economic benefit or a burden depending on future cost escalation. Also, delaying plant retirement can allow spreading decommissioning costs over a greater sales volume.

Opinions of the long-term economic prospects for existing nuclear power plants vary greatly. DOE-sponsored studies have estimated that the economic gain from extending operation an additional 20 years could be about $350 billion nationally. [39] Those results are disputed by some who find that nuclear power costs are high and expect they will continue to grow.[40] Some analysts suggest that as many as 25 plants, not necessarily older ones, may be found uneconomic during the next several years.41 Certainly, the growing number of recent early retirements, and others currently being investigated, is an indication that prospects are not as economically attractive as thought even as recently as 1992 when an update to the 1991 the National Energy Strategy was published.[42] Still, costs and other economic conditions vary widely among nuclear

36 See U.S. Congress, Office of Technology Assessment, *Energy Efficiency: Challenges and Opportunities for Electric Utilities*, to be published.

37 As used here, plant economic performance is a combination of the operational costs of a plant, the costs of major refurbishment and other capital additions, and the reliability and output of the plant.

38 Disposal of both spent fuel and low-level waste (LLW) can present economic challenges. However, LLW volumes during plant operation are small, and current disposal costs represent a fraction of one percent of the operational costs of current nuclear plants, Even with the much higher disposal costs anticipated under the interstate compacts, LLW costs will average only about 1 percent of operational costs, The large volumes of LLW resulting from decommissioning, however, present much greater costs relative to that activity, and are discussed below in that context.

39 L. Makovich, L. Forest, and T. Fletcher, "U.S. National and Regional Impacts of Nuclear Plant Life Extension,'' Sandia National Laboratories, SAND87-7136, January 1988.

40 See, e.g., James G. Hewlett, ''The Operating Costs and Longevity of Nuclear Power Plants,' *Energy Policy*, July 1992, pp. 608-622.

41 P.C. Parshley, D.F. Grosser, and D.A. Roulett, Shearson Lehman Brothers, "Should Investors Be Concerned About Rising Nuclear Plant Decommissioning Costs?," *Electric Utilities Commentary*, vol. 3, No. 1, Jan. 6, 1993, p. 1.

42 The discussion of existing nuclear power plants in the National Energy Strategy reports did not acknowledge the prospect '' early retirements. Rather, it emphasized the prospects for license renewal for about two-thirds of existing units. U.S. Department of Energy, *National Energy Strategy: Powerful Ideas for America One Year Later* (Washington, DC: February 1992), pp. 32-36; and U.S. Department of Energy, *National Energy Strategy* (Washington DC: February 1991), pp. 108-116.

Box 1-E–Existing Nuclear Power Plants and Global Climate Change

The potential for global climate change, a growing environmental concern, clouds the long-term prospect for the continued, heavy international reliance on fossil fuels. The public health and environmental harm that some suggest are likely results of climate change maybe far more severe than even pessimistic assumptions of nuclear accidents. While the operation of existing nuclear power plants does not solve the CO_2 problem (a key greenhouse gas), existing nuclear units help act as a bridge to other nonfossil options including greatly improved energy efficiency, advanced nuclear generation, and renewable supplies. For example, if the 613 billion kWh of electricity produced using nuclear power in 1991[1] had instead been fueled by coal, U.S. CO_2 emissions would have been higher by about 160 million metric tons, over 10 percent of energy sector emissions that year.[2] Similarly, if fueled by natural gas in highly efficient combined cycle units, emissions would have been higher by about 70 million metric tons.

Federal and State environmental policy addressing global climate change could greatly improve the relative economic attractiveness of existing nuclear power plants.[3] An increasing number of States are considering environmental and other externalities in new least-cost planning or integrated resource planning efforts.[4] in April, the President announced a commitment to stabilize greenhouse gas emissions at 1990 levels by the year 2000. What future efforts will be taken to meet that objective is yet to be determined.

Although there are no plans to institute a tax on carbon emissions, the potential impact on relative economics are illustrative. For example, consider a hypothetical $100 per ton carbon tax, which one Congressional Budget Office study estimated could potentially reduce U.S. CO_2 emissions by between zero and 25 percent from then current levels over a 10-year periods Such a large tax would translate into nearly $0.03/kWh for coal-fired electric generation, more than the average operational costs at existing nuclear power plants.

The environmental drawbacks of nuclear power are also widely noted. Safely storing, transporting, and disposing nuclear wastes present environmental challenges. So too does the potential for a catastrophic nuclear power plant accident, even though the probability of such an accident is very low. Overall, further examination of the relative environmental impacts of producing electricity by fossil, nuclear, renewable, and other sources may help ensure better informed and more timely decisions about the national energy mix and about individual plant lives.

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1 U.S. Department of Energy, Energy Information Administration, *Electric Power Annual 1991*, DOaEIA-0346(91) (Washington, DC: February 1993), p. 32.

2 Average coal plant carbon emissions are about 0.56 to 0.59 pounds per kWh. Natural gas generation using combined cycle plants produces about 0.26 pounds per kWh. U.S. Congress, Office of Technology Assessment, *Changing by Degrees: Steps to Reduce Greenhouse Gases,* OTA-O-482 (Washington, DC: U.S. Government Printing Office, February 1991), p. 93

3 Other resources, such as renewable energy and energy efficiency measures, do not produce CO_2 emissions and would also have improved economics. Natural gas and petroleum-fired generation produce about half the CO_2 per unit of electricity as does coat and could be affected as well. However, the dominant role of coal, which supplies 55 percent of the Nation's electricity makes it likely that aggressive action to control CO_2 emissions would affect all aspects of the electricity market.

4 See U.S. Congress, Office of Technology Assessment, *Energy Efficiency: Challenges and Opportunities for Electric Utilities, to be* published.

5 U.S. Congress, Congressional Budget Office, *Carbon Charges as* a *Response to Global Warming: The Effects of Taxing Fossil Fuels* (Washington, DC: U.S. Government Printing Office, August 1990).

Box 1-F--Spent Fuel Disposal

The Nuclear Waste Policy Act (NWPA) requires the DOE to begin accepting spent nuclear fuel from commercial power reactors no later than January 31, 1998.[1] DOE's effort to characterize and potentially construct a permanent spent fuel repository at Yucca Mountain, Nevada will be completed no sooner than 2010, under a schedule viewed by many as optimistic.[2] The DOE has also pursued the development of a monitored retrievable storage (MRS) facility for the interim storage of spent fuel and other high-level waste by the year 1998 to meet NWPA requirements.[3] Serious doubts about whether the DOE could meet the 1998 MRS deadline[4] were substantiated by a December 1992 announcement that the DOE seeks to redirect its existing program substantially by focusing on the development of Federal sites for interim storage.[5]

To cover the cost of disposal, utilities pay the DOE Nuclear Waste Fund (NWF) 0.1 cents for each kilowatt-hour of electricity generated in nuclear power plants, an average of about $5 million annually per plant. Of the $8 billion in utility fees and interest collected between 1983 and 1991,$3 billion has been spent[6] with what many have characterized as little progress. Whether the current fees are adequate, insufficient, or excessive to cover actual disposal costs remains to be seen.

Limited on-site spent fuel storage capacity together with the lack of progress in **DOE's programs undermines public confidence in a resolution tot he issue, and could threaten several operating plants with premature closure** in the next fifteen years. For example, Minnesota's Northern States Power (NSP) operates the twin Prairie Island plants having operating licenses expiring in 2011 and 2013, although current spent fuel storage capacity is sufficient only through 1995. To address the shortfall, NSP proposed the installation of a dry storage facility. Out of concern that the dry storage facility would become a de facto permanent repository, however, the Minnesota Public Utilities Commission allowed NSP to construct a smaller facility that would add only seven more years of storage capacity.[7] Further, the facility must be approved by the State Legislature. If unable to operate at the end of that time, this will represent a very large indirect cost of waste disposal.

Several utilities have dry storage facilities in operation or under construction. For example, the Public Service Co. of Colorado (PSC), operator of the retired Fort St. Vrain plant, has constructed a dry storage facility for $23 million and estimates annual operational costs of about $1.5 million.[8] The direct costs to utilities and their customers are not large relative to total plant operational costs, but represent an unanticipated burden on utilities and consumers that have paid for and expect a federally run geologic repository.

1 P.L. 97-425,96 Stat. 2258, Sec. 302(a) (5)(B).

2 Nuclear Waste Technical Review Board, *NWTRB Special Report* (Arlington, VA: March 1993, p. v.

3 U.S. Department of Energy, Office of Civilian Radioactive Waste Management, *Report to Congress on Reassessment of the Civilian Radioactive Waste Management Program,* DOE/RW-0247 (Washington, DC: November 1989), pp. ix-x.

4 See U.S. Congress, General Accounting Office, *Operation of Monitored Retrievable Storage Facility Is Unlikely by 1998,* GAO/RCED-91-194 (Gaithersburg, MD: September 1991).

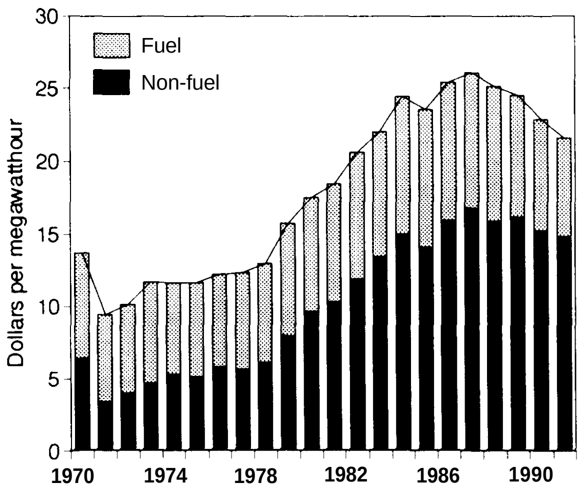
5 James D. Watkins, Secretary, U.S. Department of Energy, letter to J. Bennett Johnston, Chairman, Senate Committee on Energy and Natural Resources, Dec. 17, 1992, See attachment, p. 2.

6 U.S. Department of Energy, *Annual Report to Congress: Office of Civilian Radioactive Waste Management,* DOE/RW-0335P (Washington, DC: March 1992), pp. 54,65.

7 "NSP Gets Reprieve From Minnesota PSC," *The Energy Daily,* vol. 20, No. 124, June 29, 1992, p. 1. See also 57 *federal Register 34319* (Aug. 4, 1992).

8 Michael Niehoff, Public Service Co. of Colorado, personal communication, S@. 23, 1992.

Figure 1-3—Nuclear Power Plant Production Costs 1970-1991 ($1991)



SOURCE: Office of Technology Assessment, adapted from Nuclear Engineering *International*, September 1992, p. 45; nominal dollars adjusted using Consumer Pries Index.

plants appear attractive for the foreseeable future, assuming costs are controlled.

Variability in the effectiveness of nuclear utility management has long been recognized.[43] Continuing evidence of variability can be seen in the wide range of plant economic performance and in the NRC's systematic assessment of licensee performance (SALP) program. The wide range of performance indicates there are opportunities for improved economics at many plants. Efforts to control rising operating and maintenance (O&M) costs include individual utility programs and industry-wide initiatives to address O&M costs by all nuclear utilities. The growing awareness of the potential for early plant retirement and other economic performance incentives may play an important role in motivating utilities to take a variety of steps to reduce cost and improve performance.

Aging Issues in Plant Life Economics

Real nonfuel (O&M) and fuel costs per unit of electricity generated at nuclear power plants are about triple their 1975 levels (figure 1-3). By 1989, average operational expenditures at U.S. nuclear power plants were higher than for an average coal plant for the first time.[44] Dramatic cost increases in the late 1970s and early 1980s, however, were followed by declines in the late 1980s and early 1990s.[45] While economic retirement decisions are based entirely on plant-specific factors rather than industry averages, the general cost trends do indicate the nature of the economic challenge for the industry. If operating cost trends resume their long-term rate of increase, the operation of many existing nuclear power plants will become less economically attractive, possibly favoring early retirement even where replacement capacity is needed.

Much of the historic growth in operating costs was unrelated to plant aging. For example, the experiences gained from the Browns Ferry accident in 1974 and the Three Mile Island accident in 1979 led to costs for revising both equipment and procedures. The rapid growth in average plant staffing, a primary component of O&M costs, does not appear to be age-related. The future rate of cost escalation is speculative. Some future O&M costs related to aging management could be substantial. For example, the NRC estimated the industry's cost of implementing the maintenance rule at over $1 billion (1990 dollars) .46 The NRC further estimated that improved operational per-

43 See U.S. Congress, Office of Technology Assessment, *Nuclear Power in an Age of Uncertainty,* OTA-E-216 (Washington, DC: U.S. Government Printing Office, February 1984), pp. 113-138.

44 U.S. Department of Energy, Energy Information Administration, *Electric Plant Cost and Power Production Expenses 1989* DOE/EIA-0455(89), (Washington, DC: March 1991).

45 U.S. Department of Energy, Energy Information Administration (EIA), *An Analysis of Nuclear Power Plant Operating Costs: A 1991 Update,* DOE/EIA-0547, (Washington, DC: May 28, 1991); and U.S. Department of Energy, EIA, *Electric Plant Cost and Power Production Expenses 1990,* DOE/EIA-0455(90) (Washington, DC: June 1992),

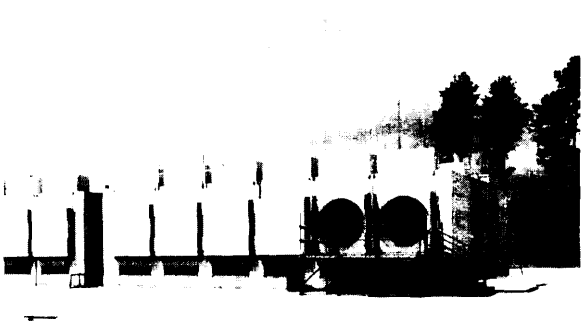
46 56 *Federal Register* 31306 et seq., (July 10, 1991).

formance and availability would result in a saving of just under $1 billion. The NRC's cost estimates were disputed by the industry, which asserted that although the costs of regulatory compliance were substantial, current maintenance practices were already appropriate.

In addition to normal operational expenses, many nuclear power plants have required substantial expenditures on capital additions for major plant refurbishment. Although average capital additions costs have declined from their peak in the mid-1980s,[47] many plants will continue to need them. The types of capital additions undertaken at nuclear power plants are varied, Historically, some have been for NRC-required safety backfits unrelated to aging such as fire and seismic protection. However, many plants face major capital additions costs related to aging degradation. Steam generator replacements, performed at several plants already and under consideration for many more, are a major example, costing $100 to $200 hundred million dollars per plant. It should be noted that some capital additions such as steam generator replacement, while costly, should also improve plant performance. Depending on how the NRC resolves some issues in the coming years, addressing aging-degradation such as EQ, fatigue, and RPV embrittlement may also involve major capital additions for at least some plants.

The high costs and potential for extended outages may effectively turn some major capital additions decisions into plant life decisions. For example, the prospect of large capital additions requirements at two nuclear power plants (Trojan and San Onofre) prompted economic analyses that eventually led to early retirement decisions. Several other plants facing steam generator replacements are also performing detailed economic analyses.

Because capital additions costs may be amortized over the life of a plant, license renewal can affect plant life decisions even before license expiration. For example, if a utility considers license renewal, replacing a faulty steam generator (leading to a remaining life of 40 years or more) may be more attractive economically than shorter lived but less costly repairs such as plugging or sleeving the steam generator tubes or, as in the case of the Trojan plant, early retirement based on the life of the current steam generators. The importance of license renewal in economic life decisions will grow as plants near the end of their licenses. But again, only two plants, including one very small one, will require license renewal for continued operation in the next 15 years.



The independent spent fuel storage installation (ISFSI) for Baltimore Gas and Electric Company's Calvert Cliffs plants is one of several in operation or under development. With delays anticipated in the Federal Government's opening of high-level waste facilities, continued operation of many commercial nuclear power plants may require development of ISFSIs.

■ Institutional Roles in Deciding Economic Plant Lives

Responsibility for the economic performance of existing nuclear power plants lies with the utilities operating them. However, the responsibility for economic decisions regarding nuclear power plant lives, while lying primarily with the

47 U.S. Department of Energy, Energy Information Administration, *An Analysis of Nuclear Power Plant Operating Costs: A 1991 Update*, DOE/EIA-0547, (Washington, DC: May 28, 1991). Capital additions costs (for major retrofits and repairs) have been highly variable.

owning utilities, is generally also a function of the respective State regulators.[48] In addition to regulating retail electric prices, many States also regulate other aspects of utility operations in some detail including IRP decisions related to new capital investment and plant retirement. The direct and indirect economic incentives established by State regulators and the Federal Energy Regulatory Commission (FERC) can also play important roles in plant life decisions. Members of the public, including electricity consumers and other interest groups, often intervene and otherwise participate in economic regulatory processes.

The objectives in nuclear plant life decisions derive from the broader electric power system objectives, including: assuring adequate supplies to meet demand; minimizing the costs of electricity (including, increasingly, environmental costs); equitably treating both electricity consumers and plant owners in the recovery of costs; and, increasingly, responding to intensifying market forces in the electric power industry. Utilities and State regulatory bodies are increasingly developing elaborate regulatory and planning processes for evaluating electricity supplies to meet these objectives.

As is typical in the electric utility industry, there are major uncertainties in the factors determining economic plant lives. For example, in its decision endorsing retirement of Unit One of the San Onofre plant, the California Public Utilities Commission was unable to determine whether or not the plant would be cost-effective in the future.[49] Rather, it found that 'there is substantial evidence on both sides of the cost-effectiveness issue' and that the available analysis may not provide a good indication of future performance.[50] Rather than representing a clearly optimal choice, that and other retirement decisions involved professional judgment and a balancing of the alternative choices and their uncertain outcomes. Because many factors in economic analyses are inherently subjective, some have suggested that certain past State regulatory activities leading to plant retirement reflected an antinuclear bias rather than solid economic analysis.[51] However, while there is certainly potential for bias in any planning process involving the complex and uncertain factors found in the utility industry, past retirement decisions do not provide compelling evidence of regulatory manipulation.

The prospect of early power plant retirement introduces some novel issues.[52] In particular, there is limited precedent in the economic regulation of the electric industry to guide the financial treatment of capital invested, but not yet recovered in rates, following early plant retirement. Similarly, there is little precedent for the treatment of shortfalls in decommissioning funds resulting from early retirement. Of the six recent early retirement decisions, unrecovered capital and decommissioning costs ranged from a few hundred million dollars for most to over $4 billion for one.[53] Consumers bore most or all of the costs in three cases; in one case the utility bore the unrecovered capital costs, and consumers bore decommissioning costs; in the case of a public

413 Most nuclear plants are operated by investor-owned utilities and fall under economic regulation by the Federal Energy Regulatory Commission or State regulators. Five plants are publicly owned (e.g., by a public power authority). Three other operating plants are owned by the Tennessee Wiley Authority (TVA). TVA also has two previously operating units with full power licenses under review (Browns Ferry 1 and 3).

49 In contrast to the Commission's uncertainty about the plant's economics, the California Public Utilities Commission Division of Ratepayer Advocates argued that the plant was demonstrably not cost effective.

so California Public Utilities Commission, *Opinion on SONGS 1 Settlement Agreement,* Decision 92-0S4)36, Aug. 11, 1992.

51 See, *e.g.,* Phillip Bayne, ''Nuclear Power in 1992: A Year-End Review,' remarks to *The Energy Daily's Annual Utility Conference,* Dec. 10, 1992.

52 These issues would be relevant to *any early* plant retirement, not just for nuclear units.

53 The extreme exception is the Shoreham plant, which was retired before commercial operation began.

power district, the owners and the consumers were the same; and as of summer 1993, cost recovery for one plant had not been decided.

Allowing a utility to recover its capital costs in an early retirement is consistent with the traditional regulatory approach in many States where the prudence of the plant investment is determined when the plant becomes operational (e.g., the plant is found to be "used and useful.") Further, not allowing a utility to recover its investment in a plant retired early can create an incentive to keep uneconomic plant in operation. However, the concept of allowing capital recovery in early retirement is not without critics. For example, some in the industry have suggested that allowing favorable terms for capital recovery has been used as an incentive for plant retirement by State regulators biased against nuclear power.[54] Finally, in those retirement cases in which plant performance was poorer and costs were substantially higher than originally anticipated, there may remain a question of whether the utility performed adequately during the operating life of the plant and whether some cost disallowances are warranted.

■ Federal Policy Considerations: Supporting Economic Decisions

Although the Federal Government plays a major role in guiding and supporting State economic regulatory activities for electric utilities,[55] Federal interests and influence over economic life decisions for nuclear plants are largely indirect. However, Federal policies for safety regulation, spent fuel disposal, environmental protection, and research can have substantial impacts on the long-term economy of existing plants. The Federal policies listed in table 1-A could help address several uncertainties related to the economy of plant lives, helping States and nuclear utilities make more timely and better informed decisions.

1. Address Aging-Related Regulatory Safety Issues.

Resolving aging-related regulatory safety issues could greatly reduce uncertainty about the long-term economic attractiveness of existing plants. Each of the policies discussed earlier regarding safety regulation can have substantial impacts on economic attractiveness. For example, accelerating regulatory re-examination of aging issues such as EQ and fatigue as they arise would help clarify long-term capital additions requirements. Clarifying license renewal requirements and demonstrating a workable process will similarly enable utilities and their economic regulators to determine better prospective plant lives, and assess the economics of capital additions.

2. Address Federal Obligations for Nuclear Waste.

DOE's lack of progress in developing both a monitored retrievable storage (MRS) facility and the ultimate repository for spent nuclear fuel have been notable challenges to the economy of existing plants. Many opportunities for, and challenges to, speeding the development of an MRS and the repository have been discussed elsewhere, and are not the topic of this report.[56] Notably, a recent DOE proposal suggested developing specialized casks for storage, transport, and ultimately, disposal; and accepting commercial spent fuel for interim storage at Federal sites.[57] More recently, the Secretary of Energy has suggested that the DOE should assume financial

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54 P. Bayne, "Nuclear Power in 1992: A Year-End Review, " Remarks to *The Energy Daily's Annual Utility Conference,* Dec. 10, *1992.*

55 See, for example, the Federal Power Act (1935), 16 U.S.C. 791a; the Public Utility Regulatory Policies Act of 1978 (P.L. 95-617 PURPA); and the Energy Policy Act of 1992 (P.L. 102-486; EPACT).

56 See, e.g., U.S. Congress, Office of Technology Assessment *Managing the Nation's Commercial High Level Radioactive Waste,* OTA-O-171 (Washington, DC: U.S. Government Printing Office, March 1985); and the National Research Council, 1991.

57 James D. Watkins, Secretary, U.S. Department of Energy, letter to J. Bennett Johnston, Chairman, Senate Committee on Energy and Natural Resources, Dec. 17, 1992. See attachment, p. 2.

U.S. NUCLEAR REGULATORY COMMISSION

The Davis-Besse Nuclear Power Station, operated by Toledo Edison Company, is one of seven operating U.S. nuclear power plants designed by Babcock and Wilcox (B&W). The members of the B&W Owners' Group are working jointly to prepare a license renewal application for one of the B&W plants, to be selected later.

responsibility for spent fuel in 1998 if a final repository is not yet available.[58] Given the importance of spent fuel disposal to continued plant operation, the Federal Government could consider additional options to clarify and fulfill the Federal obligations for disposing spent nuclear fuel, helping utilities and States develop appropriate plans for addressing their spent fuel storage needs and costs.

First, the Federal Government could specify its obligations if the 1998 Nuclear Waste Policy Act (NWPA) deadline to open a high-level waste disposal site is missed. The DOE could be required to take title to the fuel and/or reimburse utilities for the cost of constructing additional storage facilities. Alternatively, the DOE could modify its contractual agreements with utilities by specifying the exact date the agency would assume title to spent commercial fuel. The cost to the Federal Government to reimburse utilities for interim spent fuel storage could be on the order of $20 million to $35 million in today's dollars per dry storage facility, plus operating costs. More than enough, however, has been collected already from utilities to cover the construction of sufficient dry storage at all their sites. At present, the DOE lacks the express authority to reimburse utilities, but this option could bean equitable way to compensate licensees forced to manage waste that they have been paying the Federal Government to dispose of beginning in 1998.

Second, it may be worth considering decoupling MRS construction from the licensing of a geologic repository. Under NWPA as amended, the construction of an MRS is prohibited until a geologic repository is licensed, and only two are allowed.[59] However, delays in repository characterization threaten the viability of the interim MRS disposal option, because they impose an automatic delay on MRS construction. In considering decoupling, it should be noted that the growing number of dry storage facilities owned and operated by utilities already represents the creation of multiple MRS facilities, though each on a smaller scale.

3. Expand Analyses of Nuclear Plant Economics.

The Federal Government has long been a principal source of information on plant costs and performance, and how those relate to the broader electric industry context. Utilities and States are increasingly devoting considerable resources to such economic analyses, and in most cases they are ultimately responsible for economic decisions. However, the large amount of resources at stake in plant life decisions suggests that Federal policymakers have a need for independent assessments of relative costs and performance. There are several areas for improved information collec-

58 "O'Leary Speaks of DOE "Obligation" to Assume Financial Responsibility in '98," *Electric Power Alert*, vol. 3, No. 12, June 9, 1993, pp. 13-14.

59 Nuclear Wrote Policy&t (NWPA) P.L. 100-203, 101 St@. 1330-236, sec. 5021.

tion and analyses. Progress in these areas would provide better information for plant life decisions:

- Improve nuclear plant cost data collected by the Federal Government. As reported by utilities, plant-specific operational costs have been estimated to understate actual costs for nuclear plants by about 30 percent due to definitional problems.[60] Costs such as insurance and NRC fees, for example, are not reported as plant costs, but as utility-wide overhead.
- Identify root causes of historical operational and capital cost increases as a basis for future projections. For example, one Energy Information Administration analysis of nuclear plant operational costs identified research efforts such as detailed regulatory case studies that could help differentiate the effects of changing NRC regulatory requirements from the effects of new technology and information. Similarly, research could be performed to help distinguish between, and project the effects of, plant aging (which should increase costs), and utility experience (which could either increase or decrease costs).
- Identify the causes for the wide variation in costs and performance among the 107 existing nuclear plants. For example, although some of the wide variation in plant staff levels (a large component of operational costs) is due to different plant size and age, much of the reason is unexplained.
- Improve estimates of decommissioning costs and cost escalation rates (see below).
- Continue research into broader electricity market conditions and the application of IRP, particularly considering the implications for existing nuclear plants. Existing avenues for this work are DOE's IRP Program, which was originally established in response to congressional initiatives; and in the development of the DIP that the Energy Policy Act of 1992 requires TVA to perform.[61]

4. **Cofund Industry R&D for Existing Plant Issues.**

Although the industry is developing many new technologies to improve nuclear plant cost and performance, many promising candidates remain only partially pursued. This is true despite the fact that the electric utility power industry is both large (with revenues of about $200 billion annually) and mature. In its 1992 Research&Development Plan, the Electric Power Research Institute (EPRI), identified attractive opportunities in nuclear operational cost control and safety improvements totaling nearly $60 million annually over the plan's 4-year planning horizon. EPRI estimates that only approximately half of that total will be funded.[62] A larger fraction of DOE's R&D effort could be devoted to existing nuclear plant opportunities. For example, a recent National Research Council study recommended a near doubling of such research to $10 million, even while substantially cutting DOE's overall commercial nuclear R&D budget.[63] The national labs may be well-suited to performing some of this work.

AFTER RETIREMENT: DECOMMISSIONING

After a nuclear power plant is retired, NRC regulations require that decommissioning be performed to protect the public and the environment

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60 H.I. Bowers, L.C. Fuller, M.L. Myers, *Cost Estimating Relationships for Nuclear Power Plant Operation and Maintenance*, ORIWI'M-10563, November 1987.

61 P.L. 102-486, Sec. 113.

62 Electric Power Research Institute, *EPRI Research & Development Plan 1992* (Palo Alto, CA: January 1992).

63 National Research Council, *Nuclear Power: Technical a& Institutional Options for the Future* (Washington, DC: National Academy Press, 1992), pp. 13, 175.

from accidental releases of the remaining radioactivity.[64] Decommissioning involves plant decontamination, reactor dismantlement, waste packaging, and finally, transportation of the waste to a disposal facility. Decommissioning does not necessarily involve removal of all radionuclides from a site. Rather it involves removal of sufficient materials such that the resulting level of potential exposure provides adequate protection of public health and safety as determined by regulatory agencies (see below).

Decommissioning experience worldwide is limited thus far to small reactors (less than 250 MW) that generally had short lives and low residual radioactivity. At present, the largest U.S. reactor decommissioned to date has been the small (72 MW) reactor at Shippingport. Larger commercial reactors that are being retired today or in the future, on the other hand, typically will have operated longer and have far higher levels of residual radioactivity.

Although no large commercial reactors have undergone complete decommissioning yet, decommissioning experience with small reactors, and with maintenance activities for operating plants involving decontamination or removal of large SSCs, suggests that the task of decommissioning large commercial nuclear power plants can be accomplished with existing technologies. Advances in technologies, such as chemical decontamination methods and robotics, are being used to perform decommissioning and to reduce further occupational radiation exposures, Many of the conventional technologies used to decommission nuclear power plants are the same ones used to demolish other industrial facilities and buildings, including torches, saws, and controlled explosives. On the other hand, current technologies may require improvements if future residual radioactivity standards, under development at the NRC, are significantly more stringent than current criteria.

Waste disposal (including both spent fuel and LLW) presents a major uncertainty in the prospects for performing commercial nuclear power plant decommissioning. A primary activity of decommissioning is to move radionuclides associated with low-level waste (LLW) from a plant site to a LLW facility. Under the Low-Level Radioactive Waste Policy Amendments Act of 1980, as amended (LLRWPA),[65] responsibility for developing LLW facilities rests with the States, which are encouraged to form interstate compacts. In the early 1970s, six LLW disposal sites were available to commercial nuclear power licensees. Three closed in the 1970s[66] and another (Beatty, Nevada) closed in January 1993. The two sites remaining in operation are in South Carolina (Barnwell) and Washington (Richland), both of which are, or soon will be, restricted to members of their respective compacts. No new LLW disposal sites have been licensed, and legal and other challenges have delayed or terminated construction plans for all currently planned sites .67 In the interim, NRC rules allow, but do not encourage, use of existing plant sites for LLW

64 Complete plant dismantlement and site restoration may intuitively seem like basic elements in ''decommissioning'' any nuclear or non-nuclear facility, but these tasks are not necessary to address the radiological hazard at a nuclear power plant site. As a result, NRC decommissioning rules do not require the dismantlement of nonradiological portions of nuclear power plants nor site restoration although plant owners may perform this other work.

65 P.L. 99-240

66 These three *sites* were in West Valley, *NY* (closed 1975); Maxey Flats, KY (closed 1977); and Sheffield, IL (closed 1978). U.S. Department of Energy, Office of Civilian Radioactive Waste Management, *Integrated Data Base for 1991: U.S. Spent Fuel and Radioactive Waste Inventories, Projections, and Characteristics,* DOE/RW-0006, Rev, 7 (Washington DC: October 1991), p. 118.

67 R.R Zuercher, ''Nebrm~ Officials Going Back to Beginning to Slow LLW Site Progress, " *Nucleonics Week,* vol. 33, No. 21, May21, 1992, pp. 8-9; J. Clarke, "Deadlines Loom But No LLW Sites Open Yet," *The Energy Daily,* vol. *20, No. 204,* Oct. *22,* 1992, pp. 1-2; U.S. Congress, General Accounting Office, *New York's Adherence to Site Selection Procedures is Unclear, GAO/RCED-92-172* (Gaithersburg, MD: August 1992); R.R. Zuercher, ''Illinois Back to Square One on LLW Disposal Facility Siting," *Nucleonics Week,* vol. 33, No. 44, Oct. 29, 1992, pp. 4-5.

storage. Mixed wastes (i.e., chemical hazards that are also LLW) raise special regulatory challenges yet to be fully addressed.

Decommissioning costs will depend on many factors including the approach used (e.g., the length of storage before work begins); the nature and extent of plant radioactivity and other site contamination; local labor rates; waste disposal costs; the number of reactors on a site; and applicable State and Federal occupational and environmental radioactivity standards.

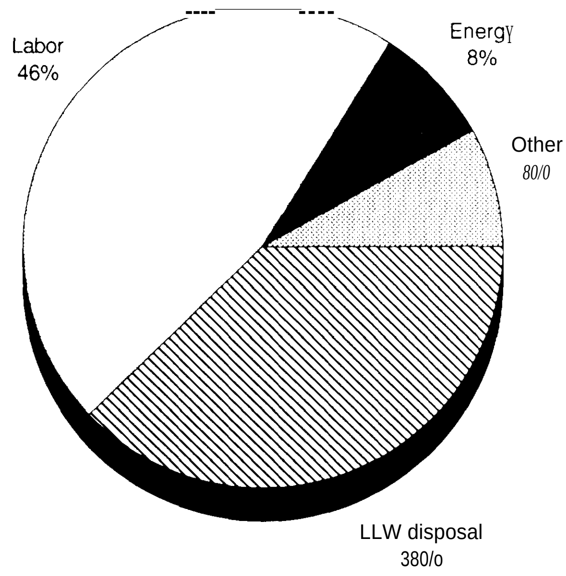
Estimates of decommissioning costs have increased rapidly in the past several years for many plants. Two factors introduce substantial uncertainty in current decommissioning cost estimates: LLW disposal fees and the amount of labor required to perform specific tasks. LLW disposal and labor costs comprise the two largest portions of estimated decommissioning costs (see figure 1-4). LLW disposal costs, currently estimated to comprise about one-third of total decommissioning costs, have been rising several times faster than inflation. The long-term prospects for siting new LLW disposal facilities and their costs remain uncertain.

Also, work difficulty, productivity, and scheduling conditions are difficult to determine reliably in advance of actual decommissioning, suggesting there is no simple and accurate way to determine the reliability of projected labor costs. More experience decommissioning large reactors in the future should reduce uncertainties in labor cost estimation considerably.

■ Standards for Timing and Thoroughness of Decommissioning

As defined by NRC rules, decommissioning involves removing a reactor from service and reducing residual radioactivity to a level that allows a site to be released for unrestricted use, thereby allowing license termination.[68] However,

Figure 1-4-Decommissioning Cost Elements 1,175 MW Pressurized Water Reactor



SOURCE: G.J. Konzek and R.I. Smith, Battelle Pacific Northwest Laboratory, *Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station: Technical Support for Decommissioning Matters Related to Preparation of the Final Decommissioning Rule,* NUREG/CR-0130, Addendum 4 (Washington, DC: U.S. Nuclear Regulatory Commission, July 1988, p. 31.

NRC rules do not prescribe the conditions making a site suitable for unrestricted use. Rather, the determination of 'how clean is clean enough?' is currently made on a site-specific basis using interim NRC guidance criteria frost developed almost two decades ago.[69] These criteria allow a slightly elevated level of radiation relative to pre-existing background conditions. In 1992, the NRC initiated a process to revise the existing criteria and develop more formal standards for final site radiological release. The NRC expects to promulgate a final rule in 1995.

The negative public and political reaction to the 1990 "below regulatory concern" (BRC) policy may indicate potential problems with the

68 10 CFR 50.2

69 U.S. Nuclear Regulatory Commission, Regulatory Guide 1.86 "Termination of Operating Licenses for Nuclear Reactors, " June 1974. Additional guidance was issued in the early 1980s.

current NRC residual radioactivity criteria. Depending on the site, States and the public may have different expectations than the NRC about acceptable levels of residual radioactivity. In many cases, the levels of residual radioactivity implied by current NRC guidance maybe acceptable but, in others, State and public concerns about future land uses at decommissioned sites may overshadow regulatory decisions over the selection of any quantitative standards.

Recognizing that public acceptance will be crucial to the success of the final site release standards, the NRC has taken a novel approach to the rulemaking. Called an "enhanced participatory rulemaking," the NRC has conducted several public workshops prior to its development of a proposed rule.[70] In its rulemaking, the NRC is considering a range of issues, including the appropriate level and distribution of risk over time between both the decommissioned site and the LLW site; the use of costs and benefits in selecting a risk level; and consistency with other Federal laws protecting health and safety. Public comments provided to the NRC have also raised the question of whether allowing restricted land uses at some sites may be a reasonable alternative to the current goal of unrestricted release.

The effect such standards will have on total decommissioning waste volumes, and thus costs, is difficult to determine. However, unless new site release standards are far more stringent than the current requirements (e.g., requiring a return to background levels), the effect on the technical ability to perform decommissioning should be minimal. More stringent standards could alter the amount of material treated as low-level waste. Because LLW disposal is a major portion of decommissioning costs, more stringent standards could result in greatly increased costs.

NRC rules specify the time period over which decommissioning can be performed. The three general types of decommissioning approaches are: immediate plant dismantlement (known as DECON), initial decontamination followed by a storage period and subsequent dismantlement (SAFSTOR), and enclosing and securing a facility for up to 60 years, followed by eventual release of the site (ENTOMB) .71 The major advantage in waiting to decommission a reactor is to allow short-lived radionuclides, which account for most of the residual radioactivity at nuclear power plants, to decay naturally at the site. As the radioactivity diminishes, potential occupational and environmental radiation exposures are reduced. While the total volume of radioactive waste requiring disposal may be relatively unchanged depending on the storage period, the level of radioactivity would be lower.

Of the decommissioning approaches recognized by the NRC, the ENTOMB option, which involves sealing and securing a site after a minimal amount of decontamination and dismantlement, requires the least remediation over the long term. ENTOMB involves costs for site security and monitoring over an extended period. However, monitoring and security costs may not be great if another plant is operated on the same site, which may be likely in many cases since the transmission facilities and other infrastructure at a site make it well-suited for another generating plant.

The NRC considers 60 years a reasonable period to complete decommissioning. However, engineering studies indicate that the ENTOMB option cannot assure sufficient radioactive decay of long-lived radionuclides in the activated reactor vessel and its internal components to allow

70 57 *Federal* Register 58727-58730 (Dec. 11, 1992); and U.S. Nuclear Regulatory Commission, "Briefing on Rulemaking Process for Developing Residual Radioactivity Standards for Decommissioning," Briefing to the Commission (Rockville, MD: Mar. 11, 1992).

71 10 CFR 50.82@)(l). Under special circumstances, the NRC will extend this period to about 100 years. See 53 *Federal* Register 24023 (June 27, 1988).

site release within that time.[72] Uncertainties about the regulatory viability of the ENTOMB approach have made the option unattractive, even though it could be useful in limiting radiation exposures, waste volumes, and total decommissioning costs.

Paying for Decommissioning

To assure that adequate financing is available for decommissioning, the NRC requires utilities to set aside funds over the life of a plant. The funds required in NRC's financial assurance provisions are not intended to be cost estimates. Rather, the NRC has stressed that its decommissioning provisions provide a reasonable approximation of the ***minimum*** costs. Further, the NRC's provisions exclude spent fuel management, even though some storage costs are likely to be incurred until the DOE takes receipt.

Although total decommissioning costs are highly uncertain and are large if viewed as a one-time expense, they are not large relative to total production costs over the entire expected life of a plant. Even at the high end of current estimates, funds set aside for decommissioning are only a few percent of production costs when collected over a few decades of plant operation. However, early retirement or rapidly increasing decommissioning cost estimates toward the end of a plant's life may result in substantial underfunding of decommissioning accounts.

To address funding inadequacy for cases of early retirement, the NRC promulgated a 1992 rule requiring case-by-case determinations of licensee financial conditions.[73] The preamble to the rule stated that the NRC would allow the collection of funds through the original license expiration date, assuming that utility retained an "A" bond rating. For a utility with an early retirement unable to retain an A rating, total funding within 1 year would be required. However, each of the six recent early retirements required funding assurance mechanisms deviating from the NRC guidance in the new rule. Several lacked the required bond ratings, while others intend to accumulate funds beyond the original license term.

Federal Policy Considerations for Decommissioning

Absent license renewal, about three dozen operating nuclear power plants will have to retire in the next 20 years. More immediately, the coming decade may bring several early retirements of large plants, which generally are larger and more contaminated than the plants decommissioned to date. Commercial nuclear power plant decommissioning, therefore, is likely to become a much more visible issue in the next two decades. However, final decommissioning of all but a few very special cases will likely not be performed before early in the next century. Rather, most retired plants will go through at least a several-year waiting period allowing short-lived radioisotopes to decay.

There are several options beyond those currently being pursued that may help address existing gaps in decommissioning policies. Of greatest near-term importance are reconsidering the goals for decommissioning and the adequacy of decommissioning financing, and clarifying policies for LLW disposal.

1. Revise Goals for Decommissioning Timing and Site Release.

The NRC's promulgation of final residual radioactivity standards for site-release, scheduled for completion in 1995, will play an important role in filling a major gap in current decommissioning policy. Such standards will determine the

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72 R.I. Smith, G.J. Konzek, and W.E. Kennedy, Jr., Battelle Pacific Northwest Laboratory, *Technology, Safety and costs of Decommissioning a Reference Pressurized Water Reactor Power Station,* NUREG/CR-0130 (Washington DC: U.S. Nuclear Regulatory Commission, June 1978), vol. 1, pp. V, 4-5 to 4-6.

73 57 *Federal Register* 30383-30387 (July 9, 1992).

ultimate scope and costs of decommissioning work. As part of the rulemaking on site-release standards, alternatives to the single current goal of unrestricted use may be worth developing. In some cases, cleanup to a level suitable for unrestricted use may be neither necessary for public health and safety nor economically desirable, because the expected radiation exposures at a retired power plant site will vary depending on its subsequent use. For example, agricultural activities at released plant sites would introduce different exposure pathways and doses compared to residential use of the same area.[74] Rather than introduce the added occupational risk and economic cost of remediating a site to permit any activity whatsoever (such as farming, for instance), it may be advisable in some cases to remediate to a level allowing restricted use for select activities, such as continued power production, provided that future exposures from those activities will comply with regulatory goals and standards for the protection of public and occupational health and the environment.

Nuclear power plant sites are developed industrial facilities, generally located near water, transport and electrical infrastructure, and some may be well-suited for further power production or other industrial activities, rather than farming or recreational space, for example. Therefore, remediating a site to allow future uses unlikely to occur may not be warranted from a health protection or economic perspective. At the same time, States and the public may accept or prefer restricted land uses or access at some former nuclear facility sites, based on concerns about health and safety from any residual radioactivity on site. To increase the options to perform site cleanups that protect public health and the environment and that are economically feasible, alternatives to unrestricted use may be worth considering, such as restricted use for other industrial purposes.

The NRC could also clarify whether ENTOMB is still a viable decommissioning strategy and, if so, under what conditions. During a 1988 rulemaking, the NRC considered eliminating ENTOMB as a decommissioning option but instead decided to develop more specific guidance on its appropriate uses.[75] No such guidance has been forthcoming. In reexamining ENTOMB as an option, the potential safety benefits (e.g., minimal site work; lower occupational exposures; reduced waste volumes; and deferred and reduced need for permanent LLW sites) and the added challenges (e.g., deferring responsibility to future generations; regulating retired plants as temporary LLW sites) need consideration. Such a review could consider variations of ENTOMB, such as removing the highly radioactive reactor vessel and internal components prior to sealing and securing the plant site. In some cases, ENTOMB maybe a reasonable option to consider based on both safety and economic reasons, and may be acceptable to the public.

Reconsideration of the ENTOMB option is a natural extension of re-examining the concept of unrestricted site release under certain circumstances. In particular, the extended period of site restriction implied by the ENTOMB option suggests that the option may be appropriate in some cases if restricted use becomes an acceptable regulatory outcome of decommissioning.

2. Reconsider Adequacy of Decommissioning Financing.

Early retirements and cost uncertainty both raise questions about the adequacy of current decommissioning fired requirements. Recent site-specific estimates of decommissioning costs are far higher than the NRC's funding requirements.

[74] W.E. Kennedy, Jr., D.L. Strenge, Pacific Northwest Laboratory, *ResidualRadioactive Contamination From Decommissioning: Technical Basis for Translating Contamination Levels to Annual Total Effective Dose Equivalent,* NUREG/CR-5512, vol. 1 (Washington, DC: U.S. Nuclear Regulatory Commission October 1992).

[75] 53 *Federal Register* 24023-24024 (June 27, 1988).

This is true for both plants retired early and those expected to operate for their full licensed lives. The NRC's finding requirements use simple sliding scales that establish the amount of financial assurance for each reactor according to its size. However, size is not the only nor necessarily most important determinant of decommissioning cost. Moreover, utilities are increasingly using site-specific estimates for State and utility economic planning, not the minimum NRC cost figures. This raises the question of whether the usefulness of the NRC figures could be improved by reflecting better the expected-rather than minimum--costs of decommissioning. Although the NRC is performing an update of its original studies, the topic may deserve considerably more attention given the increasing number of plants facing early retirement and decommissioning. Further, the NRC's recent rule addressing financing adequacy for early retirements bears reexamination, particularly in light of the fact that each of the six plants recently retired did not meet the conditions laid out in the rule's preamble.

3. **Clarify Regulatory Policies for Low-level Waste.** Disposal of LLW, including that mixed with hazardous chemicals, rests with States. However, the Federal Government retains responsibility for setting standards for LLW (including mixed waste) facilities. Until more LLW disposal facilities are available, waste may increasingly have to be stored temporarily at plant sites. This practice is allowed, but discouraged, by NRC rules. Given that temporary storage may be unavoidable in the near term, it may be worth reexamining safety regulation of onsite storage of LLW, particularly in the case of decommissioning. Two alternatives for handling LLW in lieu of permanent disposal sites are: deferring decontamination, reactor dismantlement, and waste packaging until a LLW site is available; or performing that work, and storing the packaged wastes at the plant until a LLW site is available.

Mixed waste management remains an incompletely resolved regulatory issue. At present, there are three commercial mixed waste disposal sites (Colorado, Florida, and Utah), but their disposal permits are restricted to select waste groups with low activities.[76] In the future, the DOE may coordinate with States in the development of more mixed waste treatment and disposal capacity,[77] but existing disposal capacity appears insufficient to meet all commercial needs. The NRC is responsible for regulating the radioactive portion of mixed waste under the AEA. The U.S. Environmental Protection Agency (EPA) has direct responsibility or oversight of States in regulating the hazardous chemical portion under the Resource Conservation and Recovery Act of 1976, as amended.[78] Congress could clarify the regulatory responsibilities of the NRC and the EPA.[79] Recent industry efforts to limit mixed waste generation—source reduction, recycling, processing, waste segregation-are notable, but such efforts do not eliminate completely the need for final disposal options.[80]

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[76] J.A. Klein et al., Oak Ridge National Laboratory, *National Profile on Commercially Generated Low-Level Radioactive Mixed Waste*, NUREG/CR-5938 (Washington DC: U.S. Nuclear Regulatory Commission December 1992), pp. 32-35.

[77] U.S. Department of Energy, *Department of Energy Strategy for Development of a National Compliance Plan for DOE Mixed Waste*, predecisional draft (Washington DC: November 1992), pp. 4, 20,24.

[78] P.L. 94-580, Oct. 21, 1976.

[79] For a detailed examination of these LLW policy issues, see U.S. Congress, Office of Technology Assessment, *Partnerships Under Pressure: Managing Commercial Low-Level Radioactive Waste,* OTA-O-426 (Washington, DC: U.S. Government Printing Office, November 1989).

[80] Rogers and Associates Engineering Corp., *The Management of Mixed Low-Level Radioactive Waste in the Nuclear power Industry*, NUMARC/NESP-006 (Washington, DC: Nuclear Management and Resources Council, Inc., January 1990), pp. 5-1 to 5-22.

4. Use Early Retirements as Decommissioning Case Studies.

Finally, current and planned early retirements provide an opportunity to learn more about the adequacy of current decommissioning policies and cost analyses. Even for those plants not opting for immediate dismantlement, actual experience may help reduce much of the uncertainty related to labor costs, the largest cost component of decommissioning.

After a nuclear plant is retired and the fuel has been removed from the reactor, the potential public safety risks decrease greatly. For this reason, NRC policy does not call for retaining the NRC resident inspector during decommissioning as required during plant operation. However, given the lack of experience in large decommissioning projects to date, the NRC could consider allowing utilities to request a resident inspector on site during the first few large decommissioning projects. The costs, borne by the utility, would be small relative to direct decommissioning costs, and may help improve communications between licensees and the NRC, perhaps even leading to a smoother and less expensive process.