AWAY-FROM-REACTOR STORAGE OF SPENT NUCLEAR FUEL: FACTORS AFFECTING DEMAND

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PREFACE

This report presents the results of an analysis of factors affecting the demand for U.S. government-provided away-from-reactor (AFR) storage of spent nuclear fuel. The purpose of the analysis is to assist policymakers in predicting more accurately the demand for government AFR storage relative to the demand for other storage options.

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- o K. A. Solomon, *Nuclear Reactor Spent Fuel Valuation: Procedure, Applications, and Analysis*, R-2239-DOE, February 1978.
- o K. A. Solomon and M. B. Triplett, *Valuation of Nuclear Reactor Spent Fuel Using the HP67/97 Programmable Calculator*, N-1176-DOE, April 1979.

The present report is addressed to groups--including, especially, DOE and the Interagency Review Group on Nuclear Waste Management (IRG)--concerned with nuclear spent fuel management.

SUMMARY

Spent nuclear fuel, resulting from nuclear power generation by domestic and foreign utilities, and the military, may either be stored temporarily (interim storage), reprocessed for further power generation, or disposed of permanently. The only option presently open, however, is interim storage, because of current U.S. policy against reprocessing and the current unavailability of repositories for ultimate disposal. Accordingly, this report focuses on the demand for interim storage. Among the options available for satisfying this demand are on-site storage by utilities, private away-from-reactor (AFR) storage facilities, and government AFRs.

This report analyzes factors that affect the magnitude and timing of demand for government AFRs, relative to the demand for other storage options, to assist policymakers in predicting this demand more accurately.

Accurate prediction has important economic and policy implications for utilities, ratepayers, and the government. Underestimation will lead to insufficient AFR storage capacity and may jeopardize the operations of utilities that do not have adequate on-site storage capabilities. They could even have to shut down their nuclear reactors temporarily, because each of the options for expanding storage capacity has lead times that range from months to years, depending on regulatory and legislative delays. Overestimation will promote the building of too much AFR capacity too early, thereby imposing an unnecessary burden on the ratepayers or taxpayers or both, who must bear a larger share of costs than they would have to if costs were spread over more users and over a longer period of time.

Unfortunately, predicting AFR demand is subject to great uncertainty, particularly with regard to future demand for nuclear energy, to costs, and to political and regulatory policies. For that reason, past predictions of AFR demand range widely and often appear to conflict. This report helps to explain the apparent conflicts among

existing demand predictions by demonstrating their sensitivity to changes in key assumptions.

Specifically, the report analyzes factors affecting the demand for government AFR storage facilities; illustrates why demand estimates may vary; and identifies actions that may be undertaken by groups, within and outside the government, to influence the level and timing of demands.

The analysis led to the following conclusions regarding demand and recommendations for policies and actions.

CONCLUSIONS REGARDING DEMAND

The following factors affect the demand for government AFR storage:

- o Regulatory treatment of the fee for government AFR services
- o The demand for nuclear energy
- o Decisions regarding the future of plutonium reprocessing and breeder reactor programs in the United States
- o On-site storage expansion
- o Timing and availability of government AFRs
- o The extent to which transshipment of spent fuel from one utility to another is permitted
- o The availability of shipping casks
- o The extent of foreign demand for AFRs
- o How and by whom the AFR storage facilities are financed

Predicted demand for government AFRs may vary dramatically, depending on what assumptions are made about each of the above factors. For example, under assumptions based on maximum demand, five AFRs (with capacity for 5000 metric tons of heavy metal (MTHM)) would be required by 1993, whereas under assumptions based on minimum demand, less than one AFR of that size would be adequate.

To narrow the wide range in predicted demand requires reducing the uncertainty about the demand factors identified above. Certain

groups may, by their policies and actions, reduce this uncertainty. In the near term (over the next five years), the groups most likely to be able to do so are the utilities, the Nuclear Regulatory Commission (NRC), the Environmental Protection Agency (EPA), and the state public utility commissions (PUCs), because their actions and policies will determine how much on-site expansion takes place. In the long run (more than five years), Congress and DOE are likely to be more influential than other groups in reducing uncertainty, because their actions will determine the size and availability of AFRs--Congress through enabling legislation for funding, and DOE through disbursement of the funds.

RECOMMENDED POLICIES AND ACTIONS

The demand for government AFRs will be highly uncertain as long as U.S. policies toward reprocessing and development of breeder reactors remain unclear. Nevertheless, specific actions such as the following may be taken now to reduce the uncertainty:

The Department of Energy (DOE) could:

- o Set criteria and requirements for accepting spent fuel (e.g., cooling period, advance delivery schedules, level of on-site expansion, efforts to transship fuel, and other considerations);
- o Specify the fee structure more clearly, with regard to the arrangements and timing of fee collection and with regard to whether the fee for storage will be combined with or separate from the fee for disposal;
- o Sponsor research and development on shipping casks to render all casks physically interchangeable and compatible with handling equipment; and
- o Establish definitive criteria in conjunction with the State Department for accepting foreign spent fuel.

The Nuclear Regulatory Commission (NRC) could:

- o Issue regulations for on-site storage expansions and transshipments of spent fuel; and
- o Issue regulations for shipping-cask design criteria.

The Environmental Protection Agency (EPA) and the Department of Transportation (DOT) could:

- o Set environmental and transportation standards for on-site expansion, transfer of spent fuel, and operation of AFRs.

State public utility commissions (PUCs) and other regulatory agencies could:

- o Determine the amount and speed with which utilities will be allowed to recover the costs of AFR fees, and
- o Set clear rules for on-site storage expansion, transshipment, or storage of spent fuel generated in other states.

Utilities could:

- o Make more definitive plans to transship spent fuel or to expand their own on-site capacities, and
- o Participate in private decentralized (regional) AFRs.

Congress could:

- o Authorize legislative authority and funding for an AFR.

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ABBREVIATIONS

AFR = Away-from-reactor storage facility for interim storage of
nuclear reactor spent fuel

DOE = Department of Energy

DOT = Department of Transportation

EPA = Environmental Protection Agency

GWe = Gigawatts of electric energy

IRG = Interagency Review Group

LMFBR = Liquid metal fast breeder reactor

MTHM = Metric tons of heavy metal (spent fuel)

NERC = National Electric Reliability Council

NRDC = National Resource Defense Council

NRC = Nuclear Regulatory Commission

OMB = Office of Management and Budget

PDV = Present discounted value

PUCs = State Public Utilities Commissions

WIPP = Waste Isolation Pilot Plant

Chapter 1

INTRODUCTION

OVERVIEW

This report develops a conceptual framework for analyzing the demand for government away-from-reactor (AFR) spent fuel storage facilities. The report then applies this framework to generate a representative range of possible demand levels, in order to demonstrate the sensitivity of demand predictions to changes in assumptions about several key factors. Because great uncertainty surrounds such key factors as the future costs of interim storage, demand for nuclear energy, and regulatory and political policies, it is extremely difficult to predict future demand. Consequently, wide variation is to be found in reported estimates of when and how much government AFR storage capacity will be demanded by domestic and foreign sources.

In this report, we attempt to narrow the range of demand predictions. Our approach is to identify and analyze factors affecting demand; explain why, and illustrate by how much, various demand estimates differ; and identify actions that groups within and outside the government can take to influence the level and timing of demand, so as to enable more accurate predictions of AFR demand.

POLICY EVOLUTION

To understand the Department of Energy's current nuclear spent-fuel policy, it is important to examine how and why the concept of a government AFR storage program evolved.

Until three to four years ago, most utilities operating nuclear power plants (hereafter called nuclear utilities) intended to reprocess their spent nuclear fuel and recycle unused plutonium and uranium. On April 7, 1977, however, President Carter announced that the United States would defer all commercial reprocessing of spent nuclear fuel indefinitely and would encourage other countries to do

the same. This action eliminated (or at least postponed) the option for marketing the fuel and meant that utilities had to store more spent fuel than they had originally planned when providing for their own on-site storage capacity.

This reprocessing deferral has resulted in an increasing requirement for spent fuel storage capacity. For example, spent fuel at existing and planned reactors in the United States has been projected to continue accumulating at the rate indicated in Table 1.1. On October 18, 1977, prompted by limited and decreasing on-site storage capacity at reactors, the Department of Energy (DOE) announced a new spent fuel policy which under certain conditions would permit DOE to take title to and store spent fuel for a one-time storage and/or disposal fee. This offer was extended to both domestic utilities and foreign governments.

Methodologies to aid in determining the federal charge to utilities for spent fuel storage were developed independently by The Rand Corporation,¹ TRW Energy Systems,² and Pacific Northwest Laboratories.³ A preliminary estimate of the federal fee was released by DOE in July 1978.⁴ The fee for combined AFR storage and disposal services ranged from \$250 to \$300 per kilogram (kg) of spent fuel, and the fee for AFR storage only, ranged from \$150 to \$250 per kg. Reaction to the DOE estimated fee and fee methodology, as reported by the Interagency Review Group (IRG) was generally favorable.⁵ The major debate

¹K. A. Solomon, *Nuclear Reactor Spent Fuel Valuation: Procedure, Application, and Analysis*, The Rand Corporation, R-2239-DOE, February 1978.

²*Economics of National Waste Terminal Storage: Spent Fuel Pricing Study*, TRW Report Y/OWI/SUB-78/42512/2, May 1978.

³M. K. White et al., *Sensitivity of the Federal Fee for Managing Spent Fuel to Financial and Logistical Variations*, Battelle-PNL Report PNL-2637/UC-70, June 1978.

⁴*Preliminary Estimates of the Charge for Spent Fuel Storage and Disposal Services*, Department of Energy Report DOE/ET-0055, July 1978.

⁵*Report to the President by the Interagency Review Group on Nuclear Waste Management*, U.S. Government Report TID-28817, July 1978.

Table 1.1

SCHEDULE OF NUCLEAR GENERATING CAPACITY AND SPENT
FUEL DISCHARGES, ANNUAL AND CUMULATED

Year	GWe Capacity of Reactors Discharging Spent Fuel	Spent Fuel Discharged (MTHM) ^a	
		Annual	Cumulated
1976	38	820	2,500
1977	43	940	3,400
1978	53	1110	4,500
1979	60	1260	5,800
1980	68	1410	7,200
1981	74	1660	8,900
1982	96	1950	11,000
1983	101	2110	13,000
1984	105	2260	15,000
1985	105	2340	18,000
1986	105	2340	20,000
1987	105	2250	22,000
1988	150	3210	25,000
1989	167	3560	29,000
1990	186	3960	33,000
1991	205	4360	37,000
1992	223	4740	42,000
1993	244	5210	47,000
1994	265	5660	53,000
1995	285	6090	59,000
1996	307	6520	65,000
1997	328	6940	72,000
1998	347	7310	80,000
1999	366	7630	87,000
2000	383	7920	95,000

SOURCE: U.S. Nuclear Regulatory Commission,
*Generic Environmental Impact Statement on Handling
and Storage of Spent Light Water Power Reactor Fuel*,
NUREG-0404, March 1978.

NOTE: Data through 1985 are from individualized
reactor characteristics at 0.6 plant factor; for
years 1986-2000, data are based on 0.7 plant factor.

^aMTHM = metric tons heavy metal. An additional
360 MTHM was stored at the Nuclear Fuel Services
plant in West Valley, New York, and at the General
Electric plant in Morris, Illinois.

concerned when the fee should be made final with no subsequent adjustments.

Following the July 1978 Report, several other policy-relevant events occurred. In November 1978, the Spent Fuel Project Office was established at the Savannah River (DOE) Field Office. In December 1978, draft Generic Environmental Impact Statements on both domestic⁶ and foreign fuels⁷ were issued.

In January 1979, DOE proposed legislation before Congress to implement its announced spent fuel policy. The legislation stipulates that the government will take title to domestic and foreign spent fuel upon receipt of a one-time fee for storage and disposal, and that a revolving fund will be established to finance the AFR program. After holding hearings on the proposed legislation, however, the House Commerce Subcommittee on Energy and Power in early April 1979 rejected DOE's request to establish a revolving fund for spent fuel management. Instead, the Committee amended the authorization bill to allow \$30 million for the program and requested further studies on the need for a government AFR Program.

The lack of clearly defined criteria for acceptance of spent fuel, uncertainty about the estimated level and timing of demand for government AFR facilities, and the desirability of financing the program with a revolving fund of the proposed magnitude have caused Congressional concern over the proposed legislation. Critics of the DOE-proposed AFR Program complain that the DOE has not considered these points adequately and that several DOE-sponsored studies concerning the estimated level and timing of demand have some conflicting conclusions.

For example, during 1978 and the first part of 1979, several different estimates of AFR storage requirements were published. Two

⁶Charge for Spent Fuel Storage: Draft Environmental Impact Statement, Department of Energy Report DOE/EIS-0041-D, December 1978.

⁷Draft Environmental Impact Statement on the Storage of Foreign Spent Power Reactor Fuel, Department of Energy Report DOE/EIS-0040-D, December 1978.

studies that clearly conflict are the DOE-sponsored Stoller study⁸ and the National Resource Defense Council (NRDC) study.⁹ Because their assumptions about the extent to which the private sector will provide for its own storage needs differ, they have different views about when the reactors will lose full core reserve space on-site, as shown in Table 1.2. In estimating the loss of full core reserve at individual reactors, the two studies differed by 10 years or more at 5 reactor sites and 7 years or more at 14 reactor sites.

In response to continuing Congressional, utility, and private sector concerns over whether there is a need for a government AFR, and if so, when and of what size, this report develops a conceptual framework for analyzing these concerns. It does so by demonstrating how differences in assumptions about costs, political and regulatory policies, and the behavior of certain interest groups may lead to a wide range of estimates of the demand for government AFRs (see Table 1.2). Having identified certain factors that affect demand, the report then recommends actions that certain groups, including the federal government, Congress, utilities, the private sector, and public interest groups, might take to influence the level and timing of demand.

OUTLINE OF THE STUDY

To develop a conceptual framework for analysis, we begin by examining, in Chap. 2, the range of options available for storing spent nuclear fuel generated by domestic utilities, foreign utilities, and the military.

Due to the present U.S. government policy opposing plutonium reprocessing, and the current unavailability of repositories for ultimate disposal, all spent nuclear fuel must be temporarily stored either on-site or at private, U.S. government, or foreign AFR

⁸*Spent Fuel Storage Requirements--The Need for Away-From-Reactor Storage*, Department of Energy Report DOE/ET-0075, February 1979.

⁹Results of the NRDC survey have been reported in *Nuclear Fuel*, April 2, 1979, pp. 2-4.

Table 1.2
VARYING ESTIMATES OF FUEL STORAGE CAPABILITY

Utility	Estimated Loss Of Full Core Reserve Space Based on:	
	DOE/Stoller Assumptions	NRDC Assumptions
San Onofre	(1978) ^a	1991
Humboldt Bay ^b	(1979) ^a	1986
Brunswick--1	(1980) ^a	1987 (1992) ^c
Brunswick--2	1981	1988 (1992) ^c
Nine Mile Point--1	1981	1991
Diablo Canyon--1	1982	1988
Robinson--2	1982	1992
Diablo Canyon--2	1982	1989
Yankee-Rowe	1982	1995
Hatch--1 and 2	1983	1995
Prairie Island--1 and 2	1983	1992
Zimmer--1	1984	1992
Oyster Creek	1984	1987 (2000) ^c
Fort Calhoun	1984	After 1985
Rancho Seco	1985	1992
Arkansas--1 and 2	1985	1986
Maine Yankee	1985	1992
Susquehanna--1 ^b	1985	1994
Trojan	1985	1985

NOTES: DOE offers "four basic reasons for the differences" between the DOE data and the NRDC data. The NRDC disputes them and offers "one important difference." [*No Need For AFR*, by the National Resource Defense Council, March 1, 1979, Dimitri Rotow.] The four DOE reasons are: (1) In some cases (e.g., Oyster Creek), utility plans have changed since December 31, 1973, DOE estimate; (2) in some cases (e.g., Robinson, San Onofre), reactors lose full core reserve for one or two years but then regain it when another storage basin at a new reactor becomes available; (3) DOE has differing assumptions from those of NRDC; (4) DOE contends that NRDC has internal inconsistencies.

In disputing each of those reasons for why DOE and NRDC estimates differ by so much, the NRDC cites only one reason why they differ: "... the most important difference is that DOE's findings are based on 'current planning.'" If expansion of pools is possible and reasonable, but the utility simply has made no commitment to do so, this capacity would not show up in DOE's analysis. NRDC, on the other hand, asked the utilities what they realistically thought they could accomplish, including what they would do if the Government AFR were not available.

^aThese plants have been able to accommodate the generated spent fuel.

^bReactor is nonoperational.

^cStoller allows for transshipments, by several plants, from one reactor to another. If this assumption is added to the NRDC survey data, the estimated date of loss of full core reserve is extended to the year in parenthesis.

facilities. Figure 1.1(a) shows storage options when cooled spent fuel is reprocessed immediately and recycled. Little on-site storage is needed. However, as Fig. 1.1(b) shows, with delayed or no reprocessing, additional storage options such as expanded on-site storage, a government AFR, or a private AFR are needed. Of course, a permanent disposal facility would alleviate the shortage of on-site space by direct disposal of spent fuel; but currently no such facility exists. If reprocessing resumes after one or more AFRs are operational, the demand for additional AFRs would be reduced.

Chapter 3 focuses on some factors affecting the level and timing of demand for government AFRs, such as the relative cost of expansion at the reactor site compared to the fees for government AFRs, and the varying technical and regulatory requirements that limit on-site storage expansion. Chapter 4 is a detailed examination of how financing options may affect demand for government AFRs. Next, we specify different sets of assumptions for each of the demand parameters in Chap. 5. Our scenarios span a representative range of minimum and maximum demands for government AFRs. We also define a "base" case derived from DOE/ET-0075, *Spent Fuel Storage Requirements--The Need for Away-From-Reactor Storage* (February 1979).

To illustrate the extent to which differences in assumptions about critical parameters can lead to wide ranges in demand estimates, we generate demand estimates for each scenario and evaluate differences.

Finally, in Chap. 6, we identify and evaluate policy tools and actions that various governmental and nongovernmental groups may undertake to effect the realization of each demand scenario defined in Chap. 5. Chapter 7 presents our conclusions and recommendations.

Fig. 1.1 (a) — Spent fuel storage options with immediate reprocessing

Fig. 1.1(b)— Spent fuel storage options with delayed or no reprocessing

Chapter 2

ON-SITE AND AWAY-FROM-REACTOR STORAGE OPTIONS

This chapter enumerates the major storage options both at reactor sites (i.e., on-site) and at AFR centralized facilities, and indicates how they differ in their relative costs, technical characteristics, regulatory requirements, lead times required for regulatory approval and construction, and relative potential for satisfying the expanding demand for storage capacity.

To calculate the comparative unit costs (\$/kg) of the different options, we calculate the present discounted value (PDV) of all capital and operating costs for a particular option and divide by the present discounted value (PDV) of the quantity of stored fuel, measured in kilograms (kg), over the full expected useful lifetime. Expressed in mathematical form:

$$\text{Unit cost (\$/kg)} = \frac{\text{PDV (costs)}}{\text{PDV (kg spent fuel in storage)}} \cdot \quad (2.1)$$

ON-SITE EXPANSION OPTIONS

On-site spent fuel storage expansion options include using existing storage space more effectively by either reracking or using higher concentrations of neutron absorbers in the water, or both; and expanding on-site pool volume.

More Effective Use of Existing Storage Space

Methods for achieving more effective use of existing storage space include:

- o Reracking
 - Filling unused pool areas with existing types of racks or racks of different design.
 - Replacing nonfuel racks with racks that can accept fuel.
 - Replacing old racks with racks of closer spacing.

- o Using a higher concentration of neutron absorbers (e.g., boron in the pool water).
- o Combination of the above.

Storage pool reracking and compaction methods permit increases in storage capacity of from 1.5 to 4 times the original capacity. Recent expansions and current plans suggest an average on-site expansion of 2.5 times the original capacity. The actual figure, however, will depend on certain technical limitations due to criticality considerations (influenced by spacing between assemblies and the concentration of neutron absorbing boron) and total pool heat load. For example, neutron absorption techniques permit use of racks of closer spacing, but the pool temperature must be maintained below 40°C.¹

Regulatory requirements also may determine the extent and rate of storage capacity expansion. For example, the period of design through installation is typically 18 months,² and the NRC must approve each application.³ Few, if any, regulatory constraints have arisen, but legislation pending in Massachusetts would prohibit increases of on-site storage capabilities beyond "the original design specifications."⁴

Cost for modifications to existing facilities typically range from \$1 million to \$2 million (in current dollars). Reported unit costs range from \$5/kg to \$40/kg, depending upon the extent of

¹Marvin M. Miller, *International Management of Spent Fuel Storage: Technical Alternatives and Constraints*, MIT Energy Laboratory, Report No. MIT-EL 78-012, June 1978.

²U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel*, NUREG-0404, March 1978.

³Most currently operating reactors have either completed such changes or have applied to NRC for future expansions.

⁴In January 1979, bill number MA-H2346 was introduced. This bill "would prohibit the expansion of spent fuel storage capacity at commercial nuclear reactors beyond original design specifications," *NRC State Program Report*, February 2, 1979.

modifications to the existing pool. Table 2.1 shows typical costs.

Expansions of On-Site Pool Volume

A second way to increase on-site storage capabilities is to expand pool volume by enlarging the existing pool or by adding an additional pool at the site.

Increasing pool volume is subject to several constraints. For example, cooling requirements pose a technical constraint. For large expansions, the cooling system would require upgrading, which would add significantly to the cost. Furthermore, to enlarge the existing pool, the pool liner must be penetrated. With spent fuel already in place, the NRC would prohibit this activity, and thus this option applies only to new reactors or those under construction. Finally, in view of the costs, technical requirements, additional land and new construction required, state regulations are more likely to constrain this option than the compaction or reracking options.

Table 2.1

EXTENT AND COST OF RECENT STORAGE CAPACITY EXPANSIONS

Reactor	Type	Size (MWe)	Storage Space Assemblies		Increase in MTHM ^a	Total Capital Cost (\$)	Unit Cost (\$/kg)
			Before	After			
Typical	PWR	2(1100)	340	868	238	1,243,000	5.4
Typical	BWR	548	740	1650	173	1,989,000	17.1
Point Beach	PWR	2(497)	208	351	64	2,200,000	35.5
Maine Yankee	PWR	790	318	953	286	1,620,000	9.0
Fort Calhoun	PWR	457	178	614	83	898,700	4.1

SOURCE: NRC, *Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel*, NUREG-0404, March 1978.

^aThe conversion factors for changing from number of fuel assemblies to MTHM are:

MTHM = (no. of fuel assemblies) × 0.19 for boiling water reactors (BWRs);

MTHM = (no. of fuel assemblies) × 0.45 for pressurized water reactors (PWRs).

With regard to costs, the DuPont Savannah River Laboratory (SRL) has compared capital cost estimates for water basin storage and obtained the composite estimate⁵ shown in Fig. 2.1. Using the SRL scaling data for water basin storage, we use Eq. (2.1) to calculate unit costs for on-site expansions, and can then compare these costs with those of a 5000 MTHM AFR, using the same cost model (Table 2.2). As is evident from these data, economies of scale exist for water basin storage because, as the facility size increases, more efficient use is made of the cooling system, material handling and transfer equipment (crane, etc.), and operating personnel.

Note: Figure shows capital cost per unit of capacity; thus, a 5000-MTHM AFR would have a unit capital cost of roughly \$45/Kg HM and a total capital cost of \$225 million.

Fig. 2.1—Capital costs of "Away From Reactor" storage facilities (Savannah River Laboratory, *Storage Cost for Spent Power Reactor Fuel*, DPST-AFR-79-100, January 1979)

⁵ Savannah River Laboratory, *Storage Cost for Spent Power Reactor Fuel*, DPST-AFR-79-100, January 1979.

Table 2.2

ESTIMATED COST OF ON-SITE STORAGE EXPANSIONS
RELATIVE TO A 5000-MTHM AFR

Additional Storage Capacity (MTHM)	Capital Cost (\$ million)	Unit Cost (\$/kg HM) ^a	Additional Annual Discharges Permitted from a 1000-MWe Reactor
200	18	~190	7
400	29	~165	14
1000	60	~130	14 ^b
5000 (AFR)	225	~ 60 ^c	--

SOURCE: Data for the 5000-MTHM AFR are from Savannah River Laboratory, *Storage Cost for Spent Power Reactor Fuel*, DPST-AFR-79-100, January 1979.

^aCapital costs are derived from Fig. 2.1; operating costs are assumed to be \$2 million/year for facilities under 1000 MTHM and \$5 million/year for the 5000-MTHM AFR. All unit costs were calculated with Eq. (2.1), with a discount rate of 8 percent. These unit costs are self-consistent in that one model generated the results, but the magnitude of these estimates may differ from those made by other sources because of different financing assumptions.

^bAnnual discharges into the 1000-MTHM facility are assumed to arrive from *two* 1000-MWe reactors, rather than from a single reactor.

^cWe assume that AFR construction takes three years, with capital costs incurred of 15 percent the first year, 35 percent the second, 40 percent the third, and 10 percent on decommissioning. We also assume that spent fuel arrives uniformly through the first five years of operation.

AWAY-FROM-REACTOR STORAGE OPTIONS

AFR storage options include use of existing and new government and private facilities. Options under consideration include: storage at existing reprocessing facilities, including the Barnwell, West Valley, and Morris plants; a new government facility; a privately owned and operated AFR; and a system of small AFRs servicing utility regions.

Storage at Existing Reprocessing Facilities

Several reprocessing facilities with spent fuel storage basins could be enlarged to provide AFR storage. Spent fuel is currently stored at the Nuclear Fuel Services (NFS) plant in West Valley, New York, and at GE's Morris, Illinois plant. Allied-General Nuclear Service's (AGNS) reprocessing plant in Barnwell, South Carolina, could also store spent fuel after some modification.

Both the West Valley and Morris plants could receive spent fuel under emergency circumstances, but any substantial contribution to the nation's storage capabilities would require expansion and upgrading of the existing facilities. Legal actions could prohibit use of the Morris plant as a federal AFR,⁶ however, and DOE is currently negotiating with the State of New York concerning the disposition of radioactive wastes stored at West Valley. One suggested approach is for DOE to take charge of the waste in return for use of West Valley as an AFR. Opposition from environmental groups is expected, however. Expansion of the Barnwell plant is not favored by South Carolina's governor at this time. This attitude reflects the sentiment that each state should handle its own nuclear waste.⁷

Table 2.3 shows the estimated cost, potential contribution, and schedules for upgrading existing facilities.

Although storage at existing reprocessing facilities may be the only way to meet AFR demand in the next five years (assuming all on-site expansions have been completed), DOE cannot implement this option instantaneously. Site selection must first await completion of the NEPA (National Environmental Policy Act) process. Next, a final generic environmental impact statement (EIS) must be

⁶In April 1979, Illinois Attorney General William Scott filed suit to prohibit the use of GE's Morris plant as a federal AFR (*Nucleonics Week*, April 19, 1979, p. 9). In addition, the Illinois Senate introduced a bill banning the storage of out-of-state spent fuel (*Nucleonics Week*, May 17, 1979, p. 9).

⁷*Nucleonics Week*, "A Major Waste Management Bill," December 13, 1977, pp. 8-9.

Table 2.3

ESTIMATED COST AND SCHEDULE FOR UPGRADING EXISTING FACILITIES

Facility	Existing Capacity MTHM	Current Use MTHM	1st Expansion			2d Expansion		
			Capacity	Schedule Months	Cost (\$M)	Capacity	Schedule Months	Cost (\$M)
Barnwell	400	0	1100	30	16	5000	51	110
GE Morris	750	300	1800	36	NA ^a	4800	60	125
NFS/West Valley	260	200	900	18	NA	NA	NA	NA

SOURCE: *Energy Daily*, "The Dilemma Over Spent Fuel," February 1, 1979, pp. 4-6.

NA = Not available.

completed and must be followed by a site-specific EIS. Consequently, the construction schedules in Table 2.3 depend upon completion of the requisite hearings and EISs.

Storage at a New Government Facility

As an alternative to using existing facilities, another option is to build a new government facility.

To realize economies of scale (recall Fig. 2.1), storage capacity of a new facility would range from 5000 MTHM to 10,000 MTHM. The AFR would have an annual receiving rate of 2000 to 3000 MTHM.

DOE estimates the capital cost of a 5000-MTHM AFR at \$290 million.⁸ Assuming operating costs of \$5 million per year leads to an average unit cost of \$77/kg of heavy metal. (See Table 2.2 for additional assumptions upon which this estimate is based.)

The process of site selection and approval could be a formidable barrier to this option. With an AFR in place, there are reasons in favor of locating a repository--that is, a facility for ultimate disposal--at the same site. For example, co-location of an AFR and a repository would save much of the current cost of

⁸*Energy Daily*, "The Dilemma Over Spent Fuel," February 1, 1979, pp. 4-6. This capital cost estimate is higher than that reported by the Savannah River Laboratory, and consequently leads to a higher unit cost, \$70/kg HM versus \$60/kg HM.

transporting spent fuel from reactor to AFR and AFR to repository. Furthermore, co-location may help to counter the arguments of some intervenor groups who wish to permit transportation of spent fuel only from the reactor to a licensed repository, because they view transportation to an AFR as an unnecessary risk. Such fears could inhibit state concurrence in AFR siting. Moreover, the view that each state or region should provide its own nuclear waste storage and disposal has grown in popularity and would further inhibit the siting of one centralized AFR.

Storage at a Privately Owned AFR

Another option, as an alternative to a new government facility, is to provide storage at a privately owned AFR. For example, TVA has proposed a 4500-MTHM water basin storage facility at an estimated capital cost of \$300 million.⁹ Using our prior assumptions, this capital cost estimate leads to a unit cost of \$88/kg HM.¹⁰

Theoretically, the capital costs of a privately owned facility should not differ substantially from those of a government facility, as described in the previous section. However, differences in the cost of capital and other financial parameters would lead to a slightly higher actual storage charge for private AFRs.

Storage at Small Distributed AFRs

Alternatively, instead of a single, large, privately owned AFR, there could be a system of small AFRs, with storage capacities in the range of 1000 to 2000 MTHM, servicing geographic or National Electric Reliability Council (NERC) regions.¹¹ Existing or planned multiunit nuclear sites could supply locations for distributed AFRs. However,

⁹ Ibid.

¹⁰ For the purpose of comparison, this estimate was derived in a fashion identical to that used for the government AFR (see footnotes to Table 2.1).

¹¹ Savannah River Laboratory.

most of the requirements faced by on-site expansions and large AFRs would apply to distributed AFRs.

With regard to relative costs, in a study of the distributed AFR storage concept for DOE's Savannah River Operations Office, SRL showed distributed AFRs to be more expensive than large national AFRs by a factor of at least 1.5, depending on assumptions of foreign participation.

OPTIONS FOR ULTIMATE DISPOSAL OF SPENT FUEL

The accumulation of spent fuel generates a demand not only for interim storage, but also for ultimate disposal. Even though approximately 95 percent of the radioactivity of spent fuel decays after about 10 years of storage, the remaining radioactivity must be contained for nearly 1000 years before decaying to a level not threatening to humans. At this time, however, there is still uncertainty about the relative costs, technical characteristics, regulatory requirements, and potential capacities of repositories for the ultimate disposal of nuclear spent fuel. There is even uncertainty about the ultimate form of the disposed materials (e.g., whether spent fuel rods, waste encased in glass or the like) and the ultimate geologic medium (such as salt mines, seabed, and so on).

Current repository designs call for capacities of from 30,000 MTHM to 50,000 MTHM, depending upon certain technical factors.¹² Given potential logistics problems with an initial repository that may limit its receiving rate,¹³ the need for AFR storage may continue even after the first repository becomes operational. For the first repository,¹⁴ DOE is considering two alternative approaches. Under

¹²The selected geologic medium will have a maximum heat load that will limit the density of stored material and thus the overall capacity of a given site. Initial repositories will operate so as to maintain retrievability of the waste for some number of years. This period will in turn influence the permissible heat load.

¹³T. B. Cochran and A. R. Tamplin, *Nuclear Waste: Too Much Too Soon*, Natural Resources Defense Council, May 1, 1978.

¹⁴U.S. Department of Energy, "The Nuclear Waste Management Strategy for the Department of Energy--Draft," May 21, 1979.

the first, DOE would review existing site investigations and select one in 1982. Construction could be completed by 1988, with initial operation between 1988 and 1992. Under the second alternative, DOE would decide on the first repository site only after investigating a broader range of geologic environments, e.g., seabed disposal, in which case initial operation would not begin before 1992 and possibly not until 1995. Delays beyond this schedule do not seem unlikely and would further reduce the potential contribution of a repository in the timeframe of this study.

Siting of a repository is likely to be a long and arduous process. Recent experience with the Waste Isolation Pilot Plant (WIPP) in New Mexico has aroused skepticism concerning both the technical and political feasibility of nuclear waste disposal.

In view of the great uncertainty about options for ultimate disposal of spent fuel, this report focuses primarily on the options for interim storage, recognizing, however, that the demand for interim storage may be increased and intensified by delays in the availability of repositories for disposal.

With the major storage options identified, Chap. 3 examines certain factors that favor government AFRs over other storage options.

Chapter 3

FACTORS AFFECTING THE DEMAND FOR GOVERNMENT AFR STORAGE

This chapter explores the decisionmaking process of potential domestic, foreign, and military customers in choosing between government AFR storage facilities and the other storage options enumerated in Chap. 2. Our analysis of the factors affecting demand is based on an investigation of numerous private and government studies, journal and newspaper articles, Congressional testimony, and interviews with representatives of the nuclear industry, the utilities, the government, the Congress, and state public utility commissions. These sources offer a wide range of opinion regarding specific factors and their relative importance. For the purpose of analysis, however, we summarize this information by classifying the most consistently identified factors into several general categories. Furthermore, we consider separately the demand by domestic, foreign, and military sectors, in view of fundamental differences in their political constraints and choices.

DEMAND BY DOMESTIC UTILITIES

Before discussing factors that are likely to affect AFR demand by domestic utilities, we need to explain that not all utilities can be expected to exhibit identical demand behavior.

For example, a utility's demand for government AFR storage and disposal services may be expected to differ depending on whether the utility is publicly or privately owned and operated. Ownership matters because public and private utilities are subject to different kinds of taxation (e.g., a private utility must pay federal, state and local taxes, whereas a public utility pays no federal taxes), which may affect how much revenue must be raised for full cost recovery of AFR fees.

Another condition that may distinguish the behavior of particular groups of utilities is whether or not their state regulatory commissions are aggressive and cost-conscious. Some state regulators may

regard the relative costs of on-site expansion versus AFR fees as more important than other factors in considering regulatory approval. Accordingly, there may be a higher expectation of full and timely cost recovery if the state regulatory commission is cost-conscious and aggressive, and there may be greater opportunities for expediting regulatory reviews and licensing procedures.

Also, utilities that already depend heavily on nuclear power may exhibit different demand behavior from that of utilities that depend only minimally or not at all on nuclear power. Utilities contemplating new or additional investments in nuclear reactors may be subject to more stringent regulations to provide full, on-site, lifetime storage capacity. Utilities that already depend heavily on nuclear power may have a more urgent demand for off-site storage, especially if they have already taken steps to maximize on-site expansion, such as compaction.

Because of these differences among utilities in ownership, stringency of state regulation, and degree of dependency on nuclear energy, we may expect differences in the level and timing of their demand for government AFR facilities. In particular, we may expect them to assign greater or lesser importance to various demand factors. These demand factors may be grouped into the seven major categories described below.

Factors Affecting Domestic Demand

The Magnitude, Structure, and Regulatory Treatment of the Fee.

Demand may vary with the magnitude of the fee depending on how much the utility is willing to pay for a given amount of storage capacity at a certain time. If the fee is high relative to the costs of the alternative storage options in Chap. 2, such as on-site expansion or small private distributed AFRs, demand for government AFRs will be reduced. For example, DOE estimates of the fee range from \$250 to \$300 per kilogram (kg) for AFR storage and disposal, and from \$150 to \$250 per kg for AFR storage only. These fees are based on average (full) costs, including a proportion of historical sunk costs, research and development, and current fixed costs. The fee estimates

also include average transportation costs from utility to AFR. Further, the fee may be proportionately higher for some utilities if it is differentiated according to the quality (intensity) of the spent fuel or the timing and urgency of the utility's demand (e.g., whether or not government AFR storage constitutes the utility's last resort or whether other storage options are available). Such price discrimination will discourage demand by utilities facing the higher fees.

Demand will also be affected by the structure of the fee and its regulatory treatment. For example, if the fee is a one-time fixed charge, not subject to change for at least a minimum specified period, it would reduce uncertainty regarding price. The utility's state regulatory commission might then be more likely to grant faster and more complete cost recovery through rate increases (e.g., by allowing rapid amortization and the establishment of tax-exempt advance reserve accounts for future full cost recovery). In turn, that will increase a utility's willingness to pay the fee.

In contrast, a fee that includes a risk (or contingency) premium in case of unanticipated cost increases, accidents, or failures of storage and disposal facilities, and which therefore requires utilities to share the liability for risk, will discourage demand.

Another consideration that will affect both the level and timing of demand is whether the fee combines both storage and disposal or applies to disposal only. Separating the storage decision from the disposal decision allows a utility greater flexibility in choosing among near-term interim storage options, for which costs and constraints are more certain than they are for ultimate disposal. It also allows the utility more flexibility in choosing how long to store spent fuel on-site before paying the fee for ultimate disposal, in contrast with the case of a combined fee that requires a utility to pay for disposal at the same time it pays for interim storage.

Total Expected Demand for Nuclear Energy. The quantity and timing of a utility's demand for storage and disposal facilities derive from its expectations about the level and rate of future demand for nuclear energy. Its plans for generating nuclear power to meet a share of the

total demand will determine the rate at which it expects to accumulate spent fuel.

Political Decisions Regarding Reprocessing and the Breeder Program. Demand will vary depending on whether or not a utility expects the government to reverse its decision about reprocessing (i.e., resuming operations), within the near future (e.g., the next 10 years), and to accelerate the breeder reactor program. In particular, demand will be dampened if the utility believes it can "sell" spent nuclear fuel, in the future, at a price that will at least cover interim on-site storage costs; or "buy back" provisions from government AFRs are such that, in the future, it would cost the utilities more to buy back their spent fuel than they could recover by reprocessing.

On-site Expansion. Demand for government AFR storage will be influenced by whether a utility expects to be able to provide sufficient on-site storage capacity (over the lifetime of the reactor) and to satisfy certain future regulatory standards (regarding health and safety, environmental protection, and nonproliferation) with its existing or planned on-site storage capabilities. To the extent that the utility expects to face shortages of on-site capacity and to encounter costly regulatory delays or regulatory and legislative restrictions against major on-site expansions (such as the construction of new pools), then its demand for government AFR storage may increase accordingly.

Timing of Availability of Government AFR Storage Facilities and Repositories. Uncertainty regarding possible delays in the availability of government AFR storage facilities and repositories will reduce utility demand if utilities expect to run out of on-site storage capacity before government facilities are available (in which case they might be motivated to undertake a large-scale, on-site expansion program of their own or invest in a private AFR facility).

Furthermore, demand will be influenced by the acceptance criteria that DOE specifies for deliveries of spent fuel, which may restrict the access or timing of access by certain utilities. For example, if DOE specifies a long cooling time prior to delivery

(e.g., 5 to 10 years or more), during which time the utility expects to run out of on-site storage capacity, it may decide to go ahead and invest in its own major on-site expansion effort, large enough to provide for current *and* future needs (especially if by doing so it can capture economies of scale), thereby reducing future demand for government AFR storage. Other acceptance criteria may affect demand by assigning highest or exclusive delivery priorities to those utilities that are expected to run out of on-site storage capacity first (i.e., "last resort" cases). In this case, demand by utilities considered of lower priority will be reduced.

Extent to which Transshipment of Spent Fuel Is Allowed. Demand for government AFR storage will slacken if transshipment of spent fuel is permitted from one reactor to another within utilities and from one utility to another. In either case, approval is required by NRC, EPA, and DOT, and may also be required by state public utility commissions (PUCs) and other state agencies, including state legislatures, if transshipments involve the transfer of spent fuel from one state to another.

Availability of Shipping Casks. The extent to which shipping casks are not available in sufficient quantities at the desired time, and are not physically interchangeable or compatible with handling equipment, may reduce the demand for government AFR storage and increase utilities' incentives for undertaking major on-site expansions.

DEMAND BY FOREIGN UTILITIES

We would expect foreign utilities' demand for U.S.-supported AFRs to be affected by at least three factors.¹

¹These factors have been adapted from U.S. Department of Energy, *Spent Fuel Storage Requirements: The Need for AFR Storage*, DOE/ET-0075, February 1979. For additional detail on storage of foreign spent fuel, see: U.S. Department of Energy, "Draft Environmental Impact Statement, Storage of Foreign Spent Power Reactor Fuel," Report DOE/EIS-0040-D, December 1978.

Returns from Countries in Sensitive Regions

Acceptance of spent fuel from countries in areas where international tensions are high may be decided on a case-by-case basis. In some countries there may be a potential for violent conflict, or the nuclear program itself is a source of tension. Spent fuel may also come from countries that have agreements with the United States for peaceful use of nuclear power, and from selected countries without such agreements. Because conditions in these countries can change rapidly over time, they cannot be reliably forecast.

Inadequate Foreign Storage Capabilities

On-site reactor storage basins are filling up at foreign reactors. To provide a nonproliferation benefit, transfer would be offered to countries that have no immediate alternative. The intent would be to avoid commercial reprocessing, whether as a direct or indirect consequence of continued policies. Generally, transfers from small, nonnuclear weapon states would be included.

This category of countries resembles the preceding one, but also includes:

- o Cases in which reprocessing is likely to be a probable alternative to storing fuel in the United States.
- o Cases in which U.S. acceptance would be offered under terms that would encourage the sending country to develop alternatives to national reprocessing, including investigation of multinational or national storage facilities.
- o A larger number of cases in which adherence to the Non-proliferation Treaty or similar actions might be encouraged.

Fuel Assurance Contracts

The United States must approve transfers of spent fuel of U.S. origin purchased under fuel assurance contracts. The contractors

thereby provide an additional mechanism for recovering spent fuel from foreign countries. For estimates of demand under this category, we assume that transfers are included in the prior categories.

The estimates of foreign spent fuel deliveries in Table 3.1 were obtained through detailed studies of individual countries. However, eventual participation may differ from these estimates for many reasons that will be explained below.

One reason is a foreign country's decision to participate in any spent fuel storage program depends in part on its cost relative to alternative actions, e.g., reprocessing. Thus, if a country has the opportunity to sell its spent fuel for reprocessing (either domestically or in a third country), then it may choose not to transfer its spent fuel to the United States--for a fee.

If it were in the interest of the United States (e.g., for non-proliferation or political reasons) to encourage transfers from certain foreign countries, the United States might be willing to negotiate a fee for spent fuel to compare favorably with the value of foreign reprocessing and thereby increase foreign demand.

Another reason for uncertainty about the eventual level of foreign demand is that perhaps one-half of all foreign spent fuel potentially available for U.S. storage was generated in heavy water reactors (HWRs). Because criticality² is not a concern in storing HWR spent fuel, it requires only one-fourth of the capacity required to store an equivalent amount of other spent fuel.

Finally, international arrangements for spent fuel storage are currently under consideration; if they are concluded, most if not all spent fuel otherwise destined for U.S. storage would be diverted.

MILITARY DEMAND

Military nuclear wastes have been generated since World War II as a by-product of fissile material production for U.S. weapon programs.

²Criticality can be described as an unsafe situation resulting from too dense a compaction of fissionable material, leading to an uncontrollable neutron generation which, if unchecked, could lead to material meltdown with a large release of radionuclides.

Table 3.1

ESTIMATES OF FOREIGN SPENT FUEL DELIVERED TO
THE UNITED STATES: THREE SCENARIOS

(In total MTHM)

FY	Countries in Sensitive Regions (Option 1)		Nonproliferation Benefits			
			Low Option (Option 2)		High Option (Option 3)	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
1983	110	110	220	220	541	540
1984	50	160	125	340	417	960
1985	65	225	95	435	443	1400
1986	70	295	140	575	620	2020
1987	80	375	115	690	540	2560
1988	90	465	195	885	440	3000
1989	95	560	210	1095	480	3480
1990	110	670	220	1320	530	4010
1991	115	785	230	1550	600	4610
1992	120	905	240	1795	660	5270
1993	130	1035	250	2045	750	6020
1994	135	1170	265	2310	830	6850
1995	145	1315	285	2595	900	7750
1996	150	1465	305	2900	970	8720
1997	160	1625	330	3230	1080	9800
1998	170	1795	350	3580	1170	10970
1999	180	1970	375	3955	1260	12230
2000	190	2160	400	4355	1350	13580

SOURCE: U.S. Department of Energy, *Spent Fuel Storage Requirements: The Need for AFR Storage*, DOE/ET-0075, February 1979.

The waste is in the form of high-level and low-level liquid wastes stored at the Hanford Reservation, the Savannah River Laboratory, and the Idaho National Engineering Laboratory. Spent fuel rods exist but are likely to be reprocessed. Military demand for DOE AFR storage space is therefore expected to be minimal, but demand for disposal services is another matter. Clearly, all military waste must be permanently disposed. Disposal requirements for military waste differ from those for commercial spent fuel because of differences in form, content, and activity level.

AFR costs could be reduced by siting a DOE AFR at an existing military reservation, to the extent that administration, security, monitoring, and transportation services could be shared.

Chapter 4

THE EFFECT ON DEMAND OF ALTERNATIVE FINANCING ARRANGEMENTS FOR GOVERNMENT AFR'S

In this chapter, we first discuss the financing characteristics that may affect the demand for government AFR storage facilities. Next, we identify five major financing alternatives and briefly describe their demand characteristics. Finally, we suggest how each of these financing alternatives is likely to affect the demand for government AFRs.

FINANCING CHARACTERISTICS THAT MAY AFFECT DEMAND

The method of financing AFR storage and disposal facilities may affect the demand for them, depending on who pays whom, how much, when, and for what. For example, demand depends on whether facilities are publicly or privately controlled, whether financing is based on U.S. Treasury rates or private capital market rates, whether fees are collected early, at the time of power generation, or later, at the time of delivery, and whether fees include *both* storage and disposal or disposal only.

Below, we group the financing characteristics into seven categories and explain how each may influence demand.

Decisionmaking Control

Demand for AFR storage and disposal services may depend on whether the government, the utilities, or private firms exercise primary control over decisions about the size and scheduling of facilities, fees, and acceptance criteria. To the extent that a utility perceives that it has limited or no power over such decisions, it may accordingly reduce its demand.

Distribution of the Cost Burden

Each method of financing allocates cost burdens among different

groups, over time. For example, cost burdens are allocated between the government (taxpayers) and the utilities (ratepayers), and between current and future generations of taxpayers and ratepayers. Furthermore, in the short run the cost burden may be allocated disproportionately among utilities, according to the feasibility and relative costs of their opportunities for on-site expansion. The extent to which a given financing method allocates costs directly to those who benefit, instead of requiring one group to subsidize another, may influence demand, particularly if the group that is bearing the cost burden perceives that it is subsidizing another group.

Separate or Combined Fees

Whether or not the financing (and fee) for disposal is linked to the financing (and fee) for storage may influence demand by utilities, particularly those utilities whose on-site storage expansion opportunities are cheaper than the (combined) fee for AFR storage and disposal. In other words, a combined fee may not adequately reflect the preferences of a utility that has strong demand for disposal services, but low demand for AFR storage services.

Time of Collection

Because the timing of collection affects the cash-flow of the group that is financing the services, as well as the group that is buying them, it may be expected to influence demand. For example, if fees are collected early (e.g., at the time of power generation), the group buying the services faces a possible negative cash flow, which may reduce its demand. If fees are collected later (e.g., at the time of spent fuel delivery), the financing group is likely to experience a negative cash flow and the group buying services, allowed to defer payments, may therefore have increased demand.

Cost Recovery by Utilities

The speed with which utilities are allowed to recover AFR storage and disposal costs (fee payments) from customers, and the extent

to which they are allowed to incorporate their share of the financing costs of different options in their regulated rate base, are likely to influence the attractiveness of different financing options and, accordingly, their relative demand for AFR services. For example, if one option allows utilities to incorporate financing expenses in their rate base, but another allows them to account such expenses only as "operating costs," then they may favor the former--which allows them to earn a rate of return on their share of the capital investment.¹ Furthermore, if a financing option allows utilities to pass through their share of the costs more completely and rapidly and with greater certainty than alternative options, then utilities will have a greater demand to participate directly in such an option.

Financing Source

Financing costs will be affected by whether capital is borrowed from the U.S. Treasury at low-interest government rates or from private capital markets at high-interest rates. To the extent that the higher costs of financing from private capital markets are reflected in higher fees, under different financing alternatives, demand will accordingly be reduced.

Degree of Flexibility and Reversibility

In view of the great uncertainty about future costs, demand, national security considerations, and political and regulatory policies, financing options that allow some flexibility of choice among utilities, over time, may influence demand. For example, options that offer separate fees for storage and disposal and for disposal only allow the utility greater flexibility in the event of changes in the relative costs of on-site storage expansion, reprocessing

¹Electric utilities are subject to rate-of-return regulation, according to which they are allowed to expense "operating costs" on a dollar-for-dollar basis, but are allowed to earn a "fair rate of return" on any capital investments included in their rate base. For inclusion in the rate base, an expenditure must be considered "used or useful" in providing services.

decisions, regulatory policies affecting on-site expansion, and demand. Furthermore, options that allow for future buy-back of spent fuel, if desired (i.e., reversibility), may increase utilities' willingness to participate. If there is too much flexibility and uncertainty, however--for example, concerning the future rate structure and level in the event of cost increases or political and regulatory changes--then utilities may accordingly reduce their demand because planning is difficult under such uncertainty.

MAJOR FINANCING ALTERNATIVES

Among the financing alternatives for providing AFR storage facilities are: complete government financing through Congressional appropriations; domestic private sector financing through a Congressionally authorized government revolving fund; complete private sector financing; foreign and private sector financing; and government responsibility for financing and ownership of nuclear fuel throughout the nuclear fuel cycle, allowing for lease of the fuel to the private sector for a fee based on full cost recovery.

Congressional Appropriations

Under the option of Congressional appropriations, the DOE assumes complete financing responsibility for AFR storage facilities. Control over decisions is exercised by the executive and the legislative branches, as follows.

First, the DOE must prepare a budget request to be reviewed by the Office of Management and Budget (OMB) in the Executive Office of the President. The budget request must specify the total amount of funds necessary ("budget authority") as well as the pattern of expenditure for disbursement of the funds over the entire length of the program ("budget outlays").

If OMB approves the request, it is included in DOE's annual federal budget and submitted to Congress for review and approval.

If Congress approves, OMB will apportion federal funds on a quarter-by-quarter basis. Any changes in the outlay schedule or amount will be subject to executive and legislative branch approval,

and both branches will continue to exercise oversight authority regarding the apportionment of funds for specific AFR projects. The flexibility of the program is therefore limited by the strict requirements for government approval, over time.

Since the government borrows funds from the U.S. Treasury to finance the program initially, before fees are collected, current taxpayers and future ratepayers share the cost burden. Fees may either be combined for storage and disposal or may be collected separately for disposal only. They may be collected either at the time of power generation or fuel discharge, or later at the time of delivery to the AFR facility or repository. Since the government is the owner and provides the capital investment, utilities will most likely be allowed to expense the fees only as operating costs (dollar for dollar) rather than incorporate the fees in their rate base (to earn a return).

Revolving Fund

The government can establish a revolving fund that allows it to finance AFR storage and disposal facilities through private sector contributions, consisting of prepayments of a combined fee for AFR storage *and* disposal services. Control over decisions is exercised by the executive and legislative branches through oversight authority regarding the activities of the fund, and initially by the enactment of enabling legislation to establish the fund and to collect contributions from the private sector. To the extent that private sector contributions are not sufficient to cover costs, the fund is authorized to borrow from the U.S. Treasury at private capital market rates (Triple A rates), but *not* at low-interest government rates.

Under this option, ratepayers, not taxpayers, assume the cost burden. Because fees are likely to be prepaid, or paid early (e.g., at power generation), when they can contribute to the initial capital investment and construction costs, utilities may be allowed to include the fee payments in their rate bases (as a share of the capital investment) and therefore earn a return.

Private Sector and Utility Funding

If the government decides not to assume funding responsibility for AFR storage and disposal facilities, either because of budgetary constraints, conflicting public policy objectives, Congressional opposition, or evidence of private sector willingness and capability for independent funding, then one or several private firms and utilities may attempt to raise capital in the private capital markets to fund private AFRs for storage or disposal or both. In this case, the executive and legislative branches would *not* exercise either budgetary or oversight authority regarding the size, timing, and cost of the facilities; however, federal, state, and local regulatory agencies would still have some control over the determination of siting and acceptance criteria.

Under this option, there could be separate fees for storage and disposal or for disposal only. Ratepayers would bear the cost burden and fees would probably be prepaid or collected early (e.g., at the time of power generation--to help finance the initial investment and construction). Accordingly, utilities might be allowed to incorporate fee payments in their rate bases.

Private Sector, Utility, and Foreign Sector Financing

As an alternative to exclusive U.S. private sector and utility financing, one or more U.S. firms and utilities may join with one or more foreign firms or foreign government agencies to raise capital in the private U.S. or international capital markets. As a condition for financial participation, it is possible that some foreign partners might expect to use the U.S. facilities for storage and disposal of their own domestic spent fuel. The U.S. executive and legislative branches would *not* be able to exercise budgetary or oversight authority over such privately funded ventures, but regulatory bodies might exercise some control over siting and the determination of acceptance criteria, especially in the case of foreign spent fuel.

As with the option of U.S. private sector financing, ratepayers (domestic and foreign)² would bear the cost burden, and fees would likely be prepaid or collected early--to help finance initial investment and construction--allowing for possible inclusion of fee payments in utilities' rate bases.

Leasing of Nuclear Fuel by the Government

The U.S. Government could retain *exclusive* ownership of nuclear fuel throughout the fuel cycle. Leased fuel would be provided by the government for a fee (for combined storage and disposal) based on full-cost recovery and would be subject to change, depending on changes in costs, demand, and political and regulatory policies. Liability and financial risk would be borne entirely by the government, which would exercise primary control over all decisions regarding costs, timing, budgeting, size, and acceptance criteria for AFR facilities.

Both taxpayers and ratepayers would share the cost burden, although initial investment and construction costs would be financed from the U.S. Treasury, since fees would probably be collected late (e.g., at the time of spent fuel delivery). Accordingly, fee payments would probably be "expensed" by utilities (dollar for dollar) rather than being incorporated in their rate bases.

Table 4.1 summarizes the major demand characteristics of each of the above five financing options, according to the categories developed in the first section of this chapter.

LIKELY EFFECT OF MAJOR FINANCING OPTIONS ON DEMAND

We have argued, in general, that the choice of financing options may affect the demand for government AFR services; we will now indicate, in particular, how the five major financing alternatives identified in the section above might affect demand.

²Except in the case of foreign government (taxpayer) contributions.

Table 4.1

CHARACTERISTICS OF MAJOR FINANCING OPTIONS THAT MAY AFFECT DEMAND

Characteristics	Congressional Appropriations	Revolving Fund	Private Sector & Utility Financing	Private Sector, Utility, & Foreign Sector Financing	Leasing of Fuel from the Government
Decisionmaking control	Federal executive & legislative branch control & oversight	Federal executive & legislative control & oversight	Private sector & utility control	Private sector & utility control	Federal executive & legislative control & oversight
Distribution of cost burden	Taxpayers & rate-payers	Ratepayers	Ratepayers	Ratepayers	Taxpayers & rate-payers
Separate or combined fees	Combined	Combined	Separate	Separate	Combined
Time of collection	Probably late (at time of delivery)	Probably early (at time of power generation)	Probably early (at time of power generation)	Probably early (at time of power generation)	Probably late (at time of delivery)
Cost recovery by utilities	Fee payments expensed, not allowed in rate base	Fee may possibly be allowed in rate base	Fee may possibly be allowed in rate base	Fee may possibly be allowed in rate base	Fee payments expensed, not allowed in rate base
Financing source	U.S. Treasury	Private capital markets and U.S. Treasury--at private market rates	Private capital markets	Private & foreign capital markets	U.S. Treasury
Degree of flexibility & reversibility	Limited--due to government budgetary & oversight control	Fairly limited--due to government oversight authority	Fairly flexible	Fairly flexible	Very limited--due to exclusive government ownership of fuel

Table 4.2 presents a *qualitative* ranking of the effect that each demand characteristic--described in the previous two sections and summarized in Table 4.1--might have on the demand of domestic U.S. utilities for government AFR services. The rankings consist of high (H), medium (M), and low (L), representing our qualitative evaluation of the likely strength of the positive demand response--based on reasoning explained below.

Congressional Appropriations

The demand response is likely to be favorably affected by the distribution of the cost burden--because taxpayers bear some of the burden; by the time of collection--because it is likely to be late (at time of delivery), thus allowing utilities to avoid the negative cash flow problems associated with early payments; and by the financing source--because by borrowing at U.S. Treasury rates, the financing costs should be less than by borrowing at private rates.

However, demand is likely to be negatively affected by the oversight and budgetary control of the government--preventing utilities from exerting much influence; by the restriction that fees for storage and disposal be combined--limiting utilities' choices about the size and timing of their own on-site storage expansion plans; by the treatment of fee payments as "operating expenses" rather than as capital investments--thus preventing utilities from including the payments in their rate bases and earning a return; and by limited flexibility and reversibility--owing to the degree of government control over decisionmaking and the restriction of choice from combined fees.

Revolving Fund

The utilities' demand response is likely to be favorably affected under a revolving fund option by the treatment of fee payments as capital investments to be included in the rate base, because utilities may then earn a return. However, demand is likely to be less favorably affected by governmental control over decisionmaking, which restricts utilities' influence; by the financing source--the U.S. Treasury--which may permit easier access than private capital

Table 4.2

LIKELY IMPACT OF ALTERNATIVE FINANCING OPTIONS ON DEMAND

Characteristics	Congressional Appropriations	Revolving Fund	Private Sector & Utility Financing	Private Sector, Utility, & Foreign Sector Financing	Leasing of Fuel from Government
Decisionmaking control	L	L-M	H	H	L
Distribution of cost burden	H	L	L	M	H
Separate or combined fees	L	L	H	H	H
Time of collection	H	L	L	L	H
Cost recovery by utilities	L	H	H	H	L
Financing source	H	L-M	L	L	H
Degree of flexibility & reversibility	L	L-M	H	M	L

NOTE: H = high, M = moderate, L = low.

markets, but will still be more expensive than Congressional appropriations, since the Treasury lends funds at private market rates; and by the limited degree of flexibility and reversibility, which is expected to be greater than under Congressional appropriations but less than under private sector financing.

The demand response is likely to be negatively affected by the distribution of the cost burden, because it is borne entirely by ratepayers instead of being shared with taxpayers; by the restriction of combined fees, which limits choices among on-site expansion opportunities; and by the early collection of fees (probably at the time of power generation), which may create negative cash flow problems for the utilities.

Private Sector Financing

Under private sector financing, the demand response is likely to be positively affected by the greater control over decisionmaking; by the greater range of choice afforded by separate fees for storage or disposal; by the possibility of including fee payments in the rate base, thus earning a return; and by the greater flexibility and reversibility than are possible under government controlled and financed options.

However, demand is likely to be negatively affected by the distribution of the cost burden, which is borne entirely by ratepayers and not shared with taxpayers; by the early collection of fees, which may create negative cash flow problems for some utilities; and by the financing source--private capital markets--which impose higher rates than the U.S. Treasury, for example, under the Congressional appropriations option.

Private Sector, Utility, and Foreign Sector Financing

The demand response under the private sector, utility, and foreign sector financing option is likely to be very similar to that under strictly U.S. private sector and utility financing. However, U.S. utilities' demand may be higher under this option to the extent that the cost burden is shared with foreign ratepayers and taxpayers;

but it may be lower if foreign financial participation imposes restrictions on acceptance criteria, size, timing, location, and types of facilities.

Leasing of Fuel from the Government

Under the government leasing option, utilities would face a very restricted range of choices regarding government AFR storage and disposal facilities, because of the government's exclusive ownership of fuel. Assuming that the fees for storage and disposal are combined, demand would depend largely on a cost comparison between leasing the fuel and continuing to store it on-site, and paying the combined fee for selling it back to the government for storage and disposal. Because the government would always own the fuel, utilities would continue to incur leasing costs as long as they stored it on-site. Consequently, demand would probably be positively affected by AFR storage and disposal fees that were cheaper than cumulative leasing costs. In addition, demand would probably be positively affected by the sharing of the cost burden with taxpayers as well as ratepayers; by the late collection of fees (probably at time of delivery), allowing utilities to avoid the negative cash-flow problems associated with early payments; and by the financing source, the U.S. Treasury, which allows cheaper borrowing rates than under private sector financing (e.g., for on-site expansion or private AFR facilities). Demand may be negatively affected by the loss of control over spent fuel once it is returned to the government; by the treatment of fee payments as operating expenses, instead of capital investments that could be used to earn a return; and by the very restricted flexibility and reversibility once the fuel is delivered to government AFR storage and disposal facilities.

We hasten to emphasize that the demand response of utilities under each of these five financing options is subject to wide speculation, and the rankings in Table 4.2 represent only our qualitative assessment of the likely effects. More evidence and further analysis are necessary to determine more precisely the nature and extent of

the utilities' demand response under these and other possible financing options.

Chapter 5

ESTIMATING A RANGE OF DEMANDS FOR GOVERNMENT AFR'S UNDER VARIOUS ASSUMPTIONS

In this chapter we estimate a range of demands for government AFR services under varying assumptions about costs, pricing policies, future events, financing arrangements, and future regulatory and political policies. In this way we hope to reconcile, or at least to provide insights into, the differences between conflicting demand studies that have been undertaken in the past. (For example, recall the discussion in Chap. 1, and Table 1.2, which illustrate the differences between the Stoller and NRDC demand projections.)

Our assumptions are chosen to represent three scenarios: an "extreme" case of maximum demand for government AFRs storage; a base case derived from current DOE estimates and expected future policies;¹ and an "extreme" case of minimum demand for government AFRs.

We begin by identifying the categories of assumptions that we use in defining the scenarios. Next, we define the scenarios by stating our assumptions explicitly for each category. We then estimate demand for each scenario. Finally, in Chap. 6, we attempt to explain the differences in demand projections under each scenario by identifying the critical parameters that can affect demand and the major groups that can influence the values of those parameters.

CATEGORIES OF ASSUMPTIONS USED TO DEFINE ALTERNATIVE SCENARIOS

To provide a representative range of scenarios, we begin by identifying four major categories of assumptions: demand, supply, pricing and financing, and regulatory and political policy assumptions. Each category includes:

¹U.S. Department of Energy, *Spent Fuel Storage Requirements: The Need for Away-From-Reactor Storage*, DOE/ET-0075, February 1979.

- o *Demand assumptions* about the likely future level and rate of demand for nuclear energy. This demand will determine the level and rate of accumulation of spent fuel (i.e., less or more than current DOE estimates) and the likely level of foreign demand for storage and/or disposal (for emergency returns, inadequate storage availability, and fuel assurance contracts).
- o *Supply assumptions* about on-site expansion capabilities (considering maximum technical capabilities, realistic practical capabilities, and regulatory obstacles and costs); the timing and availability of government AFRs (in view of possible delays in construction and licensing); relative costs (degree of uncertainty about costs of on-site expansion and private AFRs relative to the fee); and transshipments (extent to which intra-utility transfers of spent fuel are allowed) and extent of availability of shipping casks.
- o *Pricing and financing assumptions* about the nature of the fee (whether future changes in costs are to be reflected immediately, automatically and retroactively in the one-time fee, or are to be announced in advance); the regulatory treatment of the fee (extent of cost recovery allowed, rate of amortization allowed, and whether a tax-deductible advance operating account is allowed); whether the fee consists of separate or combined fees for storage and disposal or for disposal only; and whether or not future costs are expected to increase, remain as predicted, or fall. Assumptions are also made about the method and source of financing for government AFRs (government, private, or foreign sector financing).
- o *Regulatory and political policy assumptions* about future decisions about commercial reprocessing and the breeder reactor program (indefinite delays, deferment until specified date, or acceleration)

and possible new regulatory restrictions imposed for future nuclear reactors (requiring adequate on-site provision for lifetime storage needs prior to licensing).

In each category we choose specific assumptions to define the three demand scenarios, which range from an extreme case of maximum demand for government AFRs (Scenario 1) to an extreme case of minimum demand (Scenario 2) to a base case derived from current DOE estimates and expected future policies (Scenario 3).² Table 5.1 describes the specific assumptions we have chosen to define each scenario.

QUANTIFYING THE SCENARIOS

On the basis of the assumptions specified in Table 5.1, we estimate the sensitivity of demand to changes in these assumptions, from one scenario to another, using *Spent Fuel Storage Requirements: The Need for Away-From-Reactor Storage*, DOE/ET-0075, as a base case. That report assessed the sensitivity of AFR demand to fuel burnup, reactor capacity factor, transshipment, discharge capability (e.g., full core reserve), and on-site expansion. For our estimates we begin with the DOE base case but allow only the level of transshipment and on-site expansions to vary as a function of the economic, regulatory, and political assumptions of Table 5.1. In the following sections we describe how the assumptions of Table 5.1 are used to generate AFR demand estimates for each scenario. Figures 5.1 and 5.2 illustrate the resulting demand projections for domestic utilities and for domestic plus foreign sources.

Scenario I: Maximum Demand for Government AFR Storage Assumptions

Scenario I represents conditions under which the domestic and foreign demand for government AFR storage facilities is the greatest. To do so, it is assumed that only one-half of all planned on-site expansions are completed and that the level of foreign demand is

²Ibid.

Table 5.1

NUCLEAR WASTE STORAGE AND DISPOSAL SCENARIOS AND ASSUMPTIONS

Factor	<i>Scenario I</i>	<i>Scenario II</i>	<i>Scenario III</i>
	Maximum demand for government AFR storage and disposal.	Minimum demand for government storage. Maximum private solutions to storage problem, including private AFRs. Government provides for disposal only.	Base case: Limited private initiatives for providing own storage. Large demand for government AFR storage and disposal.
<i>DEMAND ASSUMPTIONS</i>			
Demand for nuclear energy	Higher level and rate of demand than current DOE estimates (so that wastes are accumulating more rapidly than predicted).	Lower level and rate of demand than current DOE estimates (so that wastes are not accumulating as rapidly as predicted).	Current DOE estimates of demand (i.e., Reference Case, from DOE report cited in footnote (a)).
Foreign demand for government AFR storage and disposal ^a	Returns from countries in sensitive regions and from countries with inadequate storage and disposal facilities (countries with both small and medium-sized nuclear power programs)--DOE Option 3.	Returns from countries in sensitive regions only--DOE Option 1.	Returns from countries in sensitive regions and from countries with inadequate storage and disposal facilities (<i>small nuclear power programs only</i>)--DOE Option 2.
<i>SUPPLY ASSUMPTIONS</i>			
On-site utility storage expansion	Minimum expansion. Assumes that regulatory policies of state PUCs, NRC, and FERC make it difficult to expand (assumes only 1/2 of planned expansions are allowed).	Maximum expansion, including major new construction and private AFRs (maximum compaction).	Limited on-site expansion consisting of compacting, reconfiguring, pooling, etc., without major new construction (all planned on-site expansions).
Timing and availability of government AFRs (in view of possible construction delays, supply bottlenecks, licensing problems, etc.)	Little uncertainty about government AFRs, but major uncertainty about on-site expansion.	Major uncertainty about government AFR storage and disposal facility schedule.	Major uncertainty.
Relative costs	Major uncertainty about relative costs of on-site expansion but little uncertainty about government AFR fees.	Major uncertainty about government AFR costs but little uncertainty about costs of on-site expansion and private AFRs.	Major uncertainty about all relative costs, especially about disposal costs.
Transshipments	No transshipments.	All intrautility transshipments.	1/2 of intrautility shipments are made.

For footnotes, see end of table on following page.

Table 5.1--continued

Factor	Scenario I	Scenario II	Scenario III
<i>PRICING AND FINANCIAL ASSUMPTIONS</i>			
Structure of the fee	One-time fixed fee without future changes until a specified date (e.g., beyond 1983).	Initial one-time fixed fee, but possible future increases in fee due to increases in costs, changes in fees to be implemented immediately, automatically, and retroactively.	Initial one-time fixed fee but possible future increases in fees, announced in advance and allowed only at specified intervals (e.g., every year, every six months).
Regulatory treatment of the AFR fee by utilities	Full cost recovery with rapid amortization of expenses, with approval for a tax-deductible advance operating account.	Partial cost recovery with slow amortization of expenses and restriction against a tax-deductible advance operating account.	Full cost recovery with relatively slow amortization and allowance for a tax-deductible advance operating account.
Combined fee for storage and disposal or separate fee for disposal only	Combined fee--so that utilities will have an incentive not to incur the double cost of providing their own storage in addition to paying the government for storage--as a condition for receiving disposal services.	Separate fee for disposal only, so that utilities may choose private AFRs for storage.	Optional. Utilities may choose either combined or separate fees.
Financing method	Congressional appropriations	Private sector and utility planning	Revolving fund
Financing source	U.S. Treasury	Private capital markets	Private capital markets and U.S. Treasury--at private market rates
<i>REGULATORY AND POLITICAL POLICY ASSUMPTIONS</i>			
Political decisions regarding commercial reprocessing and the breeder program	Government defers any decisions regarding reprocessing until 1990s. Announces that there will be no breeder reactor until 2000, if then.	Government indicates willingness to reconsider reprocessing decision and to consider accelerated development of the breeder reactor (with demonstration plant in early 1990s).	Government indicates that it will continue to oppose reprocessing indefinitely (probably forever) and that there will be no breeder reactor until after 2000, if then.
Regulations regarding new nuclear facilities (i.e., planned or approved but not yet constructed)	New reactors may gain faster and more favorable regulatory treatment if they contract initially for storage in government AFR.	All new reactors are required to provide for their own lifetime storage needs.	Mixed, state by state.

^a Assumptions for foreign demand are based on three options identified in U.S. Department of Energy, *Spent Fuel Storage Requirements: The Need for Away-From-Reactor Storage*, DOE/ET-0075, February 1979.

Fig. 5.1—AFR demand estimates for domestic participation

equal to DOE Option 3 (see Table 3.1). Assuming that only one-half of planned on-site expansions are completed suggests two circumstances:

- o DOE relaxes spent fuel storage acceptance criteria to permit utilities that have not reracked to use the AFR;
- o Legislative opposition constrains on-site expansion of storage capabilities in many states.

If states were to oppose on-site expansion, they would probably also oppose transshipment of spent fuel to relieve storage problems. We assume, however, that the added effect of no transshipment is insignificant in combination with the level of expansions allowed. To verify this, the Stoller DISFUL Model would have to be used.

Fig. 5.2—AFR demand estimates for domestic and foreign participation

Scenario II: Minimum Demand for AFR

Scenario II represents conditions under which the domestic and foreign demand for AFR storage is minimized owing to utilities taking maximum responsibility for their own storage needs and to restrictions on the acceptance of foreign fuel. For domestic utilities, the DOE base case is used with some distributed private AFRs (1000 to 2000 MTHM) built to service NERC regions (or large utilities or consortia). Foreign demand is based on DOE Option 1 (see Table 3.1), which involves transfers from countries in sensitive regions.

We assume the DOE base case as a starting point because the maximum on-site expansion would be uneconomic relative to distributed AFRs (recall the discussion of relative costs in Chap. 2). Although we cannot estimate the demand from this option in detail without a model such as DISFUL, we assume that distributed AFRs would not be available before at least 1985, after which time demand for a central

facility would fall drastically. A private facility would be unlikely to handle foreign fuel. We allow for the possibility of a resumption of reprocessing. Although we do not know how much this might reduce the total demand for storage, we believe that it will increase the demand for on-site storage or storage at private AFRs relative to government AFRs, because of the utilities' greater access to and control over their spent fuel under these options.

Scenario III: Base Case

In Scenario III we alter the DOE base case by assuming that only one-half of all intrautility transshipments take place. Foreign demand is set by DOE Option 2 (see Table 3.1)--involving acceptance of foreign fuel from sensitive regions and from countries where there are immediate storage problems--and nonproliferation benefits to be realized.

For domestic AFR demand, DOE's base case provides the starting point. However, whereas DOE assumes transshipments would occur between reactors owned by the same utility, shipping cask availability and state legislation could hamper these measures. Consequently, we assume that only one-half of the intrautility transshipments occur.

As is evident from Figs. 5.1 and 5.2, estimated demand under the three scenarios ranges very dramatically from less than 2500 MTHM to more than 20,000 MTHM by 1993 (an eight-fold difference) for domestic participation, and from less than 5000 MTHM to more than 25,000 MTHM by 1993 (a five-fold difference) for both domestic and foreign participation. This implies that the number of government AFRs (of size 5000 MTHM) required to satisfy demand ranges from five under Scenario I to only one under Scenario II. If we assume that the capital costs of each AFR are approximately \$225 million in 1979 dollars, that operating costs are \$5 million/year, and that, under Scenario I, AFRs are built in 1981, 1983, 1985, 1987, and 1989 and under Scenario II, one AFR is built in 1983, then the present discounted value of the difference in total costs (discounted at a rate of 8 percent) in 1979 dollars, is \$690 million (that is, \$890 million for Scenario I minus \$200 million

for Scenario II).³ This amount may appear small compared with the cumulative billions of dollars of capital investment in the nuclear industry (e.g., the current estimated capital cost of constructing a single 1000 megawatt nuclear power plant exceeds one billion dollars). However, this amount appears quite sizeable when considered in terms of the transfer of dollars between the private and government sector. Depending on how and how quickly the transfer is accomplished (recall the discussion of alternate financing methods in Chap. 4), the difference in the magnitude and timing of government capital expenditures under Scenarios I or II could have noticeably different impacts on capital markets, cash flows within utilities, and the distribution of storage costs between taxpayers and ratepayers.

Having identified the differences in predicted demand among our three scenarios, we explore in Chap. 6 some of the reasons for these differences.

³These scenario cost comparisons reflect the AFR costs to the government and do not reflect total storage costs, including private storage costs, which also vary across scenarios, and transportation costs. For a more complete comparison with total storage costs, see Savannah River Laboratory, *Storage Cost for Spent Power Reactor Fuel*, DPST-AFR-79-100, January 1979.

Chapter 6

EXPLAINING THE DIFFERENCE IN DEMAND PROJECTIONS

To the extent possible, this chapter explains the difference in AFR demand projections between scenarios, and in doing so, highlights the policy options that DOE and other agencies may take to support or constrain realization of each scenario. We begin by identifying the important assumptions, or critical parameters, that can affect the magnitude, intensity, and timing of demand for government AFRs. We then identify those government agencies and other groups that can affect the values of these critical parameters. Finally, we identify actions that DOE would have to undertake to achieve each scenario, and highlight policies and activities of other agencies or groups that could either support or oppose DOE's actions.

CRITICAL PARAMETERS AND ASSUMPTIONS

Among the numerous assumptions specified in Table 5.1, nine are of critical importance in explaining differences in the magnitude, intensity, and timing of demand for government AFRs. These nine critical parameters represent specific examples of the demand factors that we identified in Chaps. 3 and 4. They include:

1. Regulatory treatment of the fee,
2. Total U.S. demand for nuclear energy,
3. The timing and nature of government legislation, regulation, and policies affecting spent fuel reprocessing and the breeder program,
4. The extent of regulations regarding on-site expansion of spent fuel storage pools and the licensing of decentralized, privately and/or utility financed AFRs,
5. Timing and availability of government AFRs and repositories,
6. The extent to which transshipment of spent fuel is

allowed from a reactor that has filled its storage basin to one that has excess storage space,

7. The availability of shipping casks for transshipments and/or transfers to AFRs,
8. Foreign demand for U.S. government operated AFRs, and
9. How and by whom the AFR storage facilities are financed.

Each of these parameters affects the level of demand for government AFRs to varying degrees. Table 6.1 summarizes the extent to which each critical parameter affects AFR demand. We compare the impact on demand for both the short run (through the year 1984) and the long run (through the year 2000). Those critical parameters most influential in affecting AFR demand in the short run are:

- o The extent to which transshipment of spent fuel between reactors is permitted, and
- o The extent to which on-site storage expansion is permitted. (There is increasing sentiment, as demonstrated by state regulatory action, both to limit expansion of on-site storage capacity and to prevent the storage of out-of-state spent fuel.)

In the long run, however, these two parameters are far less influential than are decisions regarding reprocessing and the breeder reactor program, and government AFR availability.

Demand for nuclear energy is not expected to influence AFR demand strongly in either the short or the long run. The reason is that licensing of a new reactor could be made contingent upon its having enough on-site storage to accommodate 40 years of spent fuel. A further contingency could be added that might require excess on-site storage capacity so that nearby reactors could transship spent fuel.

Recognizing that each of the eight parameters affects the level of demand for government AFRs to varying degrees over time, we have defined our three scenarios (outlined in Table 5.1) to represent very

Table 6.1

EXTENT TO WHICH EACH CRITICAL PARAMETER AFFECTS
THE DEMAND FOR GOVERNMENT AFR'S

Critical Parameter	Sensitivity of AFR Demand to Changes in Critical Parameters	
	Short Run (Through 1984)	Long Run (Through 2000)
Regulatory treatment of the fee	Moderate	Moderate
Demand for nuclear energy	Low	Low
Reprocessing and the LMFBR	Low	High
On-site pool expansion	High	High
Government AFR availability	Moderate	High
Transshipment	High	Low
Shipping cask availability	Moderate	Low to moderate
Foreign demand for AFRs	Moderate	Low
How and by whom the AFR facilities are financed	Moderate	Moderate

different assumptions regarding these parameters. Table 6.2 summarizes how each of the three scenarios treats these parameters.

GROUPS WITH POWER TO AFFECT THE VALUES OF CRITICAL PARAMETERS

Table 6.3 compares the extent to which various government agencies and public groups can influence the values of these critical parameters. Comparing Table 6.3 with Table 6.1 indicates how each group could influence AFR demand (as will be explained in the next section below).

The Department of Energy could influence AFR demand by setting standards for accepting spent fuel (e.g., cooling period, level of on-site expansion, efforts to transship fuel) and by setting the fee structure for spent fuel transfers. DOE can influence shipping cask availability through R&D support. In addition, although future decisions about reprocessing and the LMFBR will be made at the White House and in Congress, they are influenced by technical and institutional developments that DOE may undertake. In conjunction with

Table 6.2

ASSUMPTIONS FOR CRITICAL PARAMETERS
OF THE THREE SCENARIOS

Critical Parameter	Scenario I, Maximum AFR Demand	Scenario II, Minimum AFR Demand	Scenario III, Base Case
Regulatory treatment of the fee	Full cost recovery	Partial cost recovery	Full cost recovery
Demand for nuclear energy	Higher than current DOE estimates	Lower than current DOE estimates	Current DOE estimates (see DOE/ET-0075)
Assumptions regarding reprocessing and the LMFBR	Decisions deferred	Strong possibility	No reprocessing in near term
Assumptions regarding on-site pool expansion	Minimum-- only one-half of planned expansion	Maximum-- more than currently planned	Currently planned
Availability of government AFRs	High	Low	Medium
Extent to which transshipment is assumed permitted	None allowed	Maximum	One-half of maximum
Availability of shipping casks	Sufficient	Sufficient	Sufficient
Extent of foreign demand for AFRs	DOE Option 3	DOE Option 1	DOE Option 2
How and by whom the AFR facilities are financed	Congressional appropriation	Private sector and utility financing	Revolving fund

Table 6.3

EXTENT OF INFLUENCE VARIOUS GROUPS HAVE ON CRITICAL PARAMETERS

Group	Critical Parameter							
	Fee Setting and Government AFR Availability	Demand for Nuclear Energy	Reproces- sing and LMFBR	On-Site Expansion	Trans- shipment	Shipping Cask Availability	Foreign Demand for AFRs	Financing Arrangements
DOE	H	M	M	H	M	M	M	H
NRC	H	M	H	H	H	M	L	L
EPA	H	M	M	M	H	L	L	L
State PUCs and other state agencies	H	H	M	H	H	L	L	H
Utilities	L	H	M	M	H	L	L	H
Intervenor groups	M	M	M	M	H	L	L	L
Congress	H	M	H	L	L	L	M	H
State Department	L	L	L	L	L	L	H	L
Department of Transportation	L	L	L	L	H	L	L	L
Private nuclear industry	L	M	M	M	L	H	L	H

NOTE: H = high, M = moderate, L = low.

the State Department, DOE also determines the criteria for accepting foreign spent fuel and thus influences the potential for foreign participation.

The NRC could influence AFR demand and the conduct of spent fuel storage and disposal policies through regulation of facilities and procedures. NRC has direct authority over expansions of on-site storage capacity and transshipment of spent fuel. Through its regulation of shipping cask designs, the Commission influences cask availability, because delays or changes in cask-design criteria impede the production of casks by private industry.

The Environmental Protection Agency (EPA) and the Department of Transportation (DOT) play similar roles to that of the NRC in that their authority to set environmental and transportation standards can affect the capacity to expand on-site storage, transfer spent fuel, and operate AFRs.

State PUCs and other state regulatory agencies affect AFR demand by ruling on the financial disposition within utilities of the one-time fee. Also, some regulatory bodies (including state legislatures) may influence AFR demand by denying on-site storage expansion, transshipments, or storage of spent fuel generated in other states.

Utilities have the most direct effect on AFR demand in the short term through their efforts to transship spent fuel and to expand their on-site capacities, and in the long term by efforts to participate in private decentralized AFRs.

Intervenor groups pressing their causes related to nuclear power can influence any of the critical parameters associated with regulation. They often delay decisions and hence add to uncertainties regarding, for example, on-site expansions, transshipments of spent fuel, and AFR siting.

Congress directly influences the conduct of spent fuel storage policy through its power to approve funding and legislative authority for an AFR. Consequently, the availability of a government AFR is largely a matter for Congress to determine.

THE EXTENT TO WHICH EACH GROUP CAN INFLUENCE AFR DEMAND

By convoluting Tables 6.1 and 6.3, we obtain Table 6.4, which indicates the extent to which government, public, and private groups can influence AFR demand in both the short run and the long run.

In the short run the most influential groups would be the regulatory bodies--NRC, EPA, and state regulatory bodies--because their regulation could immediately affect on-site expansion. Utilities, as well, would clearly be influential in the short run, whereas Congress could have a significant effect in the long run through its funding powers.

By setting criteria for accepting spent fuel (e.g., cooling period, extent of storage expansion) DOE can substantially affect AFR demand in both the short run and the long run.

ACTIONS AND POLICIES THAT SUPPORT OR OPPOSE EACH SCENARIO

Each of the three scenarios discussed Chap. 4 implies a specific spent fuel disposition policy. DOE can pursue each policy by specifying the appropriate fee structure, setting requirements for spent

Table 6.4

EXTENT TO WHICH GOVERNMENT, PUBLIC, AND
PRIVATE GROUPS CAN AFFECT AFR DEMAND

Group	Effect on AFR Demand	
	Short Run (Through 1984)	Long Run (Through 2000)
DOE	H	H
NRC	H	H
EPA	H	H
State PUCs	H	H
Utilities	M	M
Intervenor groups	M	M
Congress	M	M
State Department	L	L
Department of Transportation	L	L
Private industry	M	M

NOTE: H = high, M = moderate, L = low.

fuel acceptance, and providing necessary storage facilities. Other agencies and groups may carry out actions that either support or oppose fulfillment of DOE's policy. Below, we specify the DOE actions associated with conducting each scenario, and in Table 6.5, we summarize the corresponding supporting and opposing actions of various other agencies and groups.

Scenario I represents the maximum demand for government AFR storage and disposal services, with the government taking an active role in relieving domestic storage problems. The scenario assumes an aggressive policy of pursuing foreign spent fuel storage. DOE would conduct this policy contingent upon Congressional support by setting lenient criteria for accepting spent fuel. These criteria may include a short cooling period (e.g., one year), no transshipment, and minimal reracking of storage pools. The fee structure would require the government to absorb the risk of future cost increases.

Scenario II represents the minimum demand for government AFR services by providing incentives for private solutions to storage problems, including private AFRs, but with the government assuming responsibility for disposal services. Any AFR storage capacity provided by the government would be limited to acceptance of foreign spent fuel only on an emergency need basis, and of domestic spent fuel only when insufficient storage space threatens reactor operations. The latter restriction places the burden upon utilities to pursue all possible private solutions to storage problems.

Scenario III assumes a significant government role in interim storage of spent fuel, with limited encouragement of private efforts. Foreign fuel would be accepted during emergencies and from countries with small nuclear power programs experiencing storage problems. To implement this policy, DOE should impose a fee structure that is not subject to drastic changes, accept fuel that has cooled for five years, and require utilities to rerack pools to the extent technically feasible.

Table 6.5

ACTIONS THAT SUPPORT OR OPPOSE DOE'S IMPLEMENTATION OF THREE SCENARIOS

Agency	Supporting Action	Opposing Action
<i>Scenario I</i>		
NRC	Allow shipment of one-year cooled fuel. Restrict transshipments. Restrict pool expansions. Clarify regulations for shipping casks.	Deny licensing to government AFR. Delay regulations on cask design.
State PUCs and regulators	Allow full pass-through of one-time fee to utility customers. Deny expansion of storage pools or transshipments.	Deny full cost pass-through.
Intervenors		Seek to require lifetime storage of spent fuel at each reactor. Seek to allow transportation to repository only.
Congress	Provide full funding for AFR. Pursue foreign participation.	Deny AFR authorization and funding.
Utilities	Early commitment to participate in AFR program. Advance payment of fees.	Delay decision to participate in AFR program.
<i>Scenario II</i>		
NRC	Permit on-site expansion: reracking and volume expansion. Permit transshipments. Require lifetime storage at new reactors.	Restrict pool volume expansions. Restrict transshipments.
State PUCs and regulators	Disallow full pass-through of government fee. Permit on-site expansions.	Restrict on-site expansions, transshipments, or storage of out-of-state spent fuel.
Utilities	Actively pursue on-site expansion and inter- and intrautility storage.	Delay expansion efforts and pursuit of private solutions.
Intervenors	Require lifetime storage of spent fuel at reactors.	Block expansion of pools or transshipments.
Congress	Provide low funding level for modification of existing government storage facilities only.	Decide to pursue large foreign participation.
<i>Scenario III</i>		
NRC	Restrict transshipments. Restrict pool volume expansion. Clarify regulations for cask design.	Delay cask design regulations. Deny government AFR license.
State PUCs and regulators	Allow full pass-through of fee to utility customers. Restrict pool volume expansions. Restrict storage of out-of-state spent fuel.	Disallow full pass-through.
Utilities	Express willingness to participate in AFR program by prepayment of fees.	Actively pursue on-site expansion and private AFRs and refuse to participate in government AFRs.
Intervenors	Block pool expansions and/or transshipments.	Block transportation of spent fuel to AFRs.
Congress	Approve legislative authority and funding for a government AFR.	Deny legislative authority for or withhold full AFR funding.

Chapter 7

FINDINGS AND RECOMMENDATIONS

We find that variation in estimates of demand for government AFR storage facilities can be explained, in large part, by differences in assumptions about critical parameters, including:

- o Regulatory treatment of the fee for government AFR services,
- o The demand for nuclear energy,
- o Political decisions regarding reprocessing and the breeder program,
- o On-site storage expansion,
- o Timing and availability of government AFRs,
- o The extent to which transshipment of spent fuel is permitted,
- o The availability of shipping casks,
- o The extent of foreign demand for AFRs, and
- o How and by whom AFRs are financed.

Depending on what assumptions are made about each of these critical parameters, predicted demand may vary dramatically, as Fig. 7.1 illustrates. The figure shows the number of government AFRs (of 5000-MTHM size) that would be demanded in 1985 and in 1993 under each of the three scenarios defined in Chap. 5. The estimates for 1993 range dramatically from a high of five AFRs under Scenario I to only one AFR in Scenario II.

To minimize the uncertainty about demand for government AFR storage and disposal facilities requires reducing the uncertainty about each of the critical parameters listed immediately above. Certain groups may be influential in reducing this uncertainty by their policies and actions. For example, in the short run (over the next five years) the most influential groups are likely to be the

Fig. 7.1—AFR requirements for each scenario

utilities and the federal and state regulatory bodies--the NRC, EPA, and state PUCs--because their actions and policies can determine how much on-site expansion takes place. In the longer term (more than five years), Congress and DOE are likely to be most influential, because their actions will determine the size and availability of government AFRs--Congress through enabling legislation for funding, and DOE through disbursement of the funds.

In view of the great amount of uncertainty about what actions different groups will take, in addition to uncertainties about future costs and future regulatory, political and foreign policies, it is not possible accurately to predict demand for government AFRs. However, certain groups may reduce uncertainties by taking actions such as the following:

- o The DOE, by setting requirements for accepting spent fuel (e.g., cooling period, level of on-site expansion, efforts to transship fuel), by setting the fee structure, by sponsoring research and development on shipping casks, and by setting criteria in conjunction with the State Department for accepting foreign spent fuel.
- o The Nuclear Regulatory Commission (NRC), by regulating expansions of on-site storage and transshipment of spent fuel and by regulating shipping cask design criteria.
- o The Environmental Protection Agency (EPA) and the Department of Transportation (DOT), by setting environmental and transportation standards which will affect the capability for on-site storage expansion, transfer of spent fuel, and operation of AFRs.
- o State public utility commissions (PUCs) and regulatory agencies, by deciding the amount and the speed by which utilities will be allowed to recover costs of AFR fees, and by restricting on-site storage expansion, transshipments, or storage of spent fuel generated in other states.
- o Utilities, by their efforts to transship spent fuel, to expand their own on-site storage capacities, and to participate in private decentralized (regional) AFRs.
- o Congress, by approving legislative authority and funding for an AFR.