REPORT TO THE CONGRESS

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

Considerations For Commercializing The Liquid Metal Fast Breeder Reactor

Energy Research and Development Administration

This report discusses what will be needed for the commercial development of the liquid metal fast breeder reactor--regarded as an essentially inexhaustible source of energy--including the reactor's necessary support facilities.

The report addresses the following questions:

--What will be the principal characteristics of a commercial breeder reactor industry?

--What supporting facilities and industry would be required to bring it into being and thereafter to support it?

--When is a demonstration needed of the required technologies on a scale sufficient to warrant the commitments of those institutions whose support is essential to breeder reactor commercialization?

--What factors are likely to influence the timing and rate of commercial breeder reactor introduction and proliferation?

EMD-77-5

NOV. 29, 1976

COMPTROLLER GENERAL OF THE UNITED STATES
WASHINGTON, D.C. 20548

B-164105

To the President of the Senate and the
Speaker of the House of Representatives

This report presents a picture of the commitment and effort necessary if the liquid metal fast breeder reactor and needed support technologies are ultimately to be commercialized and focuses on the need for coordination of the planning and timing of the separate components required to achieve commercialization.

We made our review pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

We are sending copies of this report to the Director, Office of Management and Budget, and to the Administrator, Energy Research and Development Administration.

Comptroller General
of the United States

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ABBREVIATIONS

CRBR	Clinch River Breeder Reactor
ERDA	Energy Research and Development Administration
FFTF	Fast Flux Test Facility
GAO	General Accounting Office
HPFL	High Performance Fuel Laboratory
HPP	Hot Pilot Plant
LMFBR	liquid metal fast breeder reactor
LWR	light water reactor
MT	metric ton
MWe	megawatt electric
NRC	Nuclear Regulatory Commission
PLBR	Prototype Large Breeder Reactor
R&D	research and development
RD&D	research, development, and demonstration

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COMPTROLLER GENERAL'S REPORT TO THE CONGRESS

CONSIDERATIONS FOR COMMERCIALIZING THE LIQUID METAL FAST BREEDER REACTOR
Energy Research and Development Administration

D I G E S T

The liquid metal fast breeder reactor (LMFBR) has been accorded highest priority among energy supply technologies that hold long-term promise. This ranking is accompanied by the highest Federal outlay to date for any single energy research and development program.

As is well known, the program has generated considerable controversy largely because

--by promising to produce more nuclear fuel than it consumes the LMFBR is the most likely vehicle by which nuclear fission may become an assured energy source into the 21st century;

--key uncertainties about the future of nuclear energy persist with respect to the need for and the economics and safety of LMFBRs; and

--research and development to resolve the uncertainties is an expensive, and often time consuming, matter. (See p. 1.)

A report by GAO identifying critical issues surrounding the LMFBR program in July 1975 concluded that the LMFBR program should be pursued on a schedule that recognizes that the program is still in a research and development stage. Not until some point in the future, GAO concluded--perhaps in 7 to 10 years--does a firm decision need to be made about whether the LMFBR should be a major source of electrical energy in the United States.

Subsequent to that report, the Administrator of the Energy Research and Development Administration determined that a continued strong research effort in the LMFBR program would provide sufficient data by 1986 to enable him to make a determination on the acceptability of widespread commercial deployment of LMFBRs. (See p. 2.)

PURPOSE OF THIS REPORT

In the intervening 7 to 10 years, decisionmakers need to focus attention on the total supporting facilities and industry, or infrastructure, which would be required for a commercial LMFBR industry. The present report discusses what will be needed to commercialize the reactor and necessary support facilities--that is, to proliferate them throughout society. GAO addressed the following questions:

--What will be the principal characteristics of a commercial LMFBR industry?

--What supporting infrastructure would be required to bring it into being and thereafter to support it?

--When is a demonstration needed of the required technologies on a scale sufficient to warrant the commitments of those institutions whose support is essential to LMFBR commercialization?

--What factors are likely to influence the timing and rate of commercial LMFBR introduction and proliferation?

It is not GAO's intent to either advocate or oppose the LMFBR, but to present to the Congress and the Nation an overall picture of the commitment and effort necessary if the LMFBR and needed support technologies are ultimately to be commercialized. (See pp. 2 and 3.)

PRINCIPAL FINDINGS

Successful commercialization of the LMFBR will require not only the development of reactor technology, but three other supporting technologies that comprise the LMFBR fuel cycle. These are

--fuel fabrication,

--plutonium reprocessing, and

--radioactive waste disposal. (See p. 5.)

Major private investment commitments are not likely to be forthcoming until LMFBRs and the three supporting technologies can be demonstrated to be licensable and operable routinely on both the pilot- and prototype-commercial scales.

Until recently, the LMFBR program has placed greatest emphasis on reactor development. The Energy Research and Development Administration does not have plans at present for the scale-up and eventual demonstration of routine performance of fuel fabrication facilities beyond the pilot stage. Only recently have plans been made for a prototype plutonium reprocessing facility. Plans exist for pilot waste disposal facilities which can be expanded to full size to accommodate the requirements of a commercial industry. (See p. 34.)

However, more attention must also be given to the relationship between reactor development and the timing and rate of introduction of the three supporting fuel cycle technologies.

Although not directed toward the LMFBR program, a recent policy decision by the President to delay commercialization of reprocessing activities in the United States until uncertainties are resolved casts doubt as to the future of nuclear fuel reprocessing. This, in GAO's view, adds more doubt as to whether the LMFBR will become a viable energy source because reprocessing is an indispensable prerequisite for LMFBR commercialization. (See pp. 27 and 28.)

Five steps are required to bring a nuclear facility into operation. These include the conceptual and preliminary engineering design, the licensing process in parallel with detailed engineering design, construction, nonnuclear checkout, and a nuclear checkout and test. (See p. 11.)

Bringing a commercial facility into operation is an extremely long process. Based on discussions with Energy Research and Development Administration and Nuclear Regulatory Commission officials and the times suggested by the history of previous experience in building light water reactors, GAO estimates the times required to go from conceptual and preliminary engineering design to operation are

--13 years for a reactor;

--10 years for a fuel fabrication facility;

--12 years for a plutonium reprocessing facility; and

--11 years for a radioactive waste disposal facility.

Investors must make major financial commitments from 8 to 10 years before each facility becomes operational. (See pp. 11 and 12.)

GAO developed three different scenarios for LMFBR commercialization which call for 128 LMFBRs to become operational over different 11-year introduction periods. The introduction periods differ based on assumptions about when major financial commitments by utilities and other private investors to actual operation of commercial facilities may begin. (See pp. 18, 19, and 21.)

In the first scenario, which is based on an Energy Research and Development Administration March 1975 schedule, the 128 reactors become operational by 1998. This scenario is clearly not likely to be met. (See pp. 19 and 24.)

Under GAO's second or Optimistic Scenario, 32 breeder reactors would be operating by year 2001. These findings are not inconsistent with recent Energy Research and Development Administration projections which forecast 30,000 to 60,000 megawatts electric of LMFBR capacity by the year 2000. With commercial reactors of 2,000 megawatts-electric size, this would amount to 30 LMFBRs in the year 2000 for the agency's high forecast. (See pp. 19, 21, and 24.)

Following a decision in the mid- to late-1980s to commercialize the LMFBR, GAO believes that its third, or Conservative Scenario, would be the scenario most likely to be met. By recognizing the amount of time required for development of fuel cycle technologies, this scenario would result in four to six commercial-size LMFBRs in operation by the year 2000. (See pp. 21 and 25.)

The capital costs of commercializing the LMFBR at the level envisioned by the scenarios would be high. GAO estimates that total capital costs would be about $150 billion, measured in 1974 dollars. This includes close to $141 billion for building a prototype and 128 commercial reactors. (See pp. 29 and 30.)

To build the same number and same size plants, capital costs for coal plants and light water reactors would be $95 billion and $128 billion, respectively. The remaining $9 billion in costs for LMFBR commercialization are for building fuel fabrication, plutonium reprocessing, and waste disposal facilities. (See p. 31.)

Public acceptance and institutional adaptation may be more difficult than technical considerations. Any degree of LMFBR commercialization before the end of this century will require the active support of diverse interest groups if the long leadtime decisions and commitments are to be made in time for scale-ups of the required technologies. (See pp. 8 to 10 and 32.)

CONCLUSIONS

If basic uncertainties of safety, safeguards, and environmental effects are resolved early and forthrightly, the start to LMFBR commercialization can be made by the mid-1990s. However, this can be achieved only through an integrated approach of the development of four required technologies:--reactor, fuel fabrication, plutonium reprocessing, and radioactive waste disposal.

The year 1990 may be the earliest by which licensability and routine performance can be demonstrated for <u>all</u> four required technologies. Major private investment commitments are not likely to be forthcoming until both routine performance and licensability of the technologies have been demonstrated.

Additional funding for the LMFBR program is not likely to hasten the initial availability of LMFBR reactor technology. Early development of program plans and increased commitment of resources could accelerate by 1 or 2 years the research, development, and demonstration of the three supporting fuel cycle technologies required for LMFBR commercialization, with a similar effect on the pace of introducing LMFBRs into the Nation's energy system. (See p. 35.)

RECOMMENDATIONS

In the time remaining before a firm decision needs to be made committing the Nation's future to the LMFBR, the Administrator of the Energy Research and Development Administration should act in four areas.

1. Fully develop a management and planning framework which integrates research, development, and demonstration for the four key technologies---reactor, fuel fabrication, plutonium reprocessing, and radioactive waste disposal--needed for a commercial LMFBR industry. Such an approach should relate the required levels of scale-up for each demonstration facility to the same schedule. Integrating the research, development, and demonstration for these technologies is essential, since all technologies must demonstrate routine performance and licensability for the LMFBR to be commercially acceptable on a broad basis.

2. Because of the priority of the LMFBR program and its controversial nature, review--within the integrated management and planning framework--and report annually to the Congress on an integrated basis the status of the development of all technologies needed for an LMFBR industry.

3. In the annual report to the Congress, discuss the implications of the findings on

the relationship of these technologies to other energy research, development, and demonstration programs, in terms of the budgetary cost and other priorities.

4. Develop, where applicable, similar integrated management and planning approaches for other energy research, development, and demonstration programs which have as their goal commercial acceptability. These approaches should consider the total range of technological development and institutional acceptance required to bring about a commercial industrial infrastructure. (See p. 36.)

AGENCY COMMENTS

The Energy Research and Development Administration and the Nuclear Regulatory Commission commented on this report. GAO considered these comments in completing its report and believes there are no residual differences in fact.

In its comments, the Energy Research and Development Administration noted that the report was correct in pointing out that closing the LMFBR fuel cycle expeditiously is a critical determinant to the overall success of the LMFBR program and that internal program reviews had come to the same conclusion.

The Energy Research and Development Administration stated it is undertaking efforts to provide a more integrated approach to each part of the program. The agency further stated that the current LMFBR program plan now takes into account more fully the timing and rate of introduction of commercial fuel cycle facilities, with the goal of commercializing all parts of the LMFBR fuel cycle.

The Energy Research and Development Administration also pointed out that many of the schedules and plans referenced in the report are now out of date but that the major recommendations are still well taken. (See app. III.)

GAO notes that recent program documentation does take into account more fully the LMFBR fuel cycle, in particular fuel fabrication and fuel reprocessing. GAO believes this is a step in the right direction and will closely watch these new planning and implementing activities.

CHAPTER 1

INTRODUCTION

The liquid metal fast breeder reactor (LMFBR), 1/ regarded as an essentially inexhaustible energy source, has been accorded highest priority among energy supply technologies that hold long-term promise. This ranking is accompanied by the highest Federal outlay to date for any single energy research and development (R&D) program: Total LMFBR program funding from fiscal year 1948 through fiscal year 1976 and the transition quarter has been $2.8 billion. The fiscal year 1977 budget submission of $655 million (budget authority) represents a one-third increase over 1976 budget levels.

The LMFBR program has also become one of the most controversial Federal programs.

In July 1975, the General Accounting Office (GAO), in a report entitled "The Liquid Metal Fast Breeder Reactor: Promises and Uncertainties," (OSP-76-1, July 31, 1975) pointed out that the LMFBR program is controversial largely because

--it is the likely vehicle by which nuclear fission may become an assured energy source through the 21st century and beyond;

--key uncertainties persist with respect to the need for and the economics and safety of LMFBRs; and

--research and development to resolve the uncertainties is an expensive, and often time-consuming, matter.

1/LMFBRs can produce more usable fuel (in the form of plutonium) than they consume and can use 60 percent or more of the energy content of uranium. This would thereby extend the useful life of limited available uranium supplies sufficiently to provide electric energy for many hundreds of years.

Liquid metal refers to the liquid sodium used as the coolant to carry off the heat of the reactor fuel. A fast reactor is a reactor in which the chain reaction is sustained primarily by faster neutrons than found in present generation commercial nuclear power reactors.

In this 1975 report we concluded that extreme actions to either expand and accelerate or abandon the program were not warranted. We urged that the LMFBR program be pursued on a schedule that recognizes that the program is still in an R&D stage. We concluded that a firm decision does not need to be made until some point in the future, perhaps in 7 to 10 years, as to the Nation's commitment to the LMFBR as a basic, central station energy source. At that time, additional information should have reduced, eliminated, or at least clarified many current uncertainties, particularly if priority efforts are made to resolve them.

In announcing his findings in December 1975 on the Final Environmental Statement on the LMFBR program, the Administrator of the Energy Research and Development Administration (ERDA) determined that a continued strong research effort in the LMFBR program would provide sufficient data by 1986 to enable him to make a determination on the acceptability of widespread commercial deployment of LMFBRs. He further determined that, to be meaningful, this decision must be made before any commitment to widespread deployment becomes irreversible.

The Administrator emphasized that availability of the necessary decisional information by 1986 requires successful and timely completion of interrelated and parallel efforts in such areas as plant operation, fuel cycle performance, reactor safety, safeguards, health effects, waste management, and uranium resource availability. Delays in any of these efforts will result in delaying the decision date.

PURPOSE OF THIS REPORT

Building on our earlier work on LMFBR, this report analyzes what will be required to commercialize 1/ the reactor and necessary support technologies, assuming all current

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1/Commercialization is the last stage in the process by which a technology fully evolves into an industry. A technology becomes an industry (enters commercialization) when elements of the society decide that the technology, as it currently exists, has been demonstrated sufficiently to warrant the investment to construct the facilities and the infrastructure necessary to proliferate them throughout the society.

uncertainties regarding environmental effects, safety, and safeguards can be satisfactorily resolved. The current status of the LMFBR program is reported, along with a discussion of those technical, financial, scheduling, and institutional factors which must be adequately resolved for successful commercialization.

Our analysis attempts to answer several important questions:

--What will be the principal characteristics of a commercial LMFBR industry? (See ch. 2.)

--What supporting facilities and industry would be required to bring it into being and thereafter to support it? (See ch. 2.)

--When is a demonstration needed of the required technologies on a scale sufficient to warrant the commitments of those institutions whose support is essential to LMFBR commercialization? (See chs. 3 and 4.)

--What factors are likely to influence the timing and rate of commercial LMFBR introduction and proliferation? (See ch. 5.)

It is not our intent to either advocate or oppose the LMFBR, but to present to the Congress and the Nation an overall picture of the commitment and effort necessary if the LMFBR and needed support technologies are ultimately to be commercialized. This report focuses on the need for coordination of the planning and timing of the separate components required to achieve LMFBR commercialization.

CHAPTER 2

CHARACTERISTICS OF A COMMERCIAL LMFBR INDUSTRY

As a condition of its emergence, any electrical energy technology must meet a basic set of criteria. First, total production costs (capital and operating) must be competitive with other electrical energy sources. Production processes and other functional components must be integrated into a smoothly operating system. Finally, the roles of the diverse groups of Government and non-Government entities that will affect commercialization must be clearly defined. These characteristics, as they would pertain to a commercial LMFBR industry, are described below.

ECONOMIC CHARACTERISTICS

The economics of LMFBR is predicated on the assumption that the LMFBR can produce more fuel than it consumes, thereby resulting in lower fuel costs over the life of the plant compared to other major electrical energy sources.

At present, however, capital costs for LMFBR appear to be greater than for light water reactors (LWRs) and coal-fired plants. We estimate the costs of constructing the first few commercial LMFBRs to be about $1.2 billion (in 1974 dollars) for each 2,000 megawatt-electric (MWe) plant. (See table 3, p. 30.) Current capital costs for LWRs and coal-fired plants of the same size are $1 billion (83 percent of LMFBR costs) and $744 million (62 percent of LMFBR costs), respectively, in 1974 dollars. 1/ This initial cost

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1/As we were finalizing this report, ERDA officials told us that their current thinking is that commercial LMFBR plants would be 1,200 to 1,300 MWe in size, rather than 2,000 MWe which they had anticipated earlier. This would, of course, reduce the cost of an individual LMFBR plant but would not affect either the relative cost of the different types of generating plants or the overall cost of a given quantity of generating capacity.

We do not believe that the size of commercial LMFBRs, which may be developed in the 1990s and beyond, can be specified with certainty at this time, so we have presented our analysis still based on the 2,000 MWe plant size. In any event, a change in the size of the commercial LMFBR plant would not significantly affect the conclusions of our study, which is focused on the need for coordination of the planning and timing of the separate components required to achieve LMFBR commercialization.

differential may decline, however, and could eventually disappear as a function of experience and standardization.

Even with higher capital costs, the LMFBR would still retain an economic advantage if its hoped for low fuel costs are attained. Various estimates indicate that competitive capital costs for the LMFBR could range from $60 to $300 a kilowatt more than for LWRs. Nevertheless, the future fuel costs for alternative electrical energy sources are difficult to predict, and the LMFBR experience in the United States over the next few years is not expected to provide firm answers to the cost issue.

FUNCTIONAL COMPONENTS

In addition to the nuclear reactor, a commercial LMFBR industry would be characterized by the routine operation of three other supporting technologies. These supporting technologies which make up the nuclear fuel cycle 1/ are

--fuel fabrication,

--plutonium reprocessing, and

--radioactive waste disposal.

The interrelationship of these facilities is depicted in figure 1 on page 6.

In addition, an LMFBR industry would feature facilities to transport new and spent fuel between the reactors, fabrication plants and reprocessing plants, and to convey waste products to disposal sites.

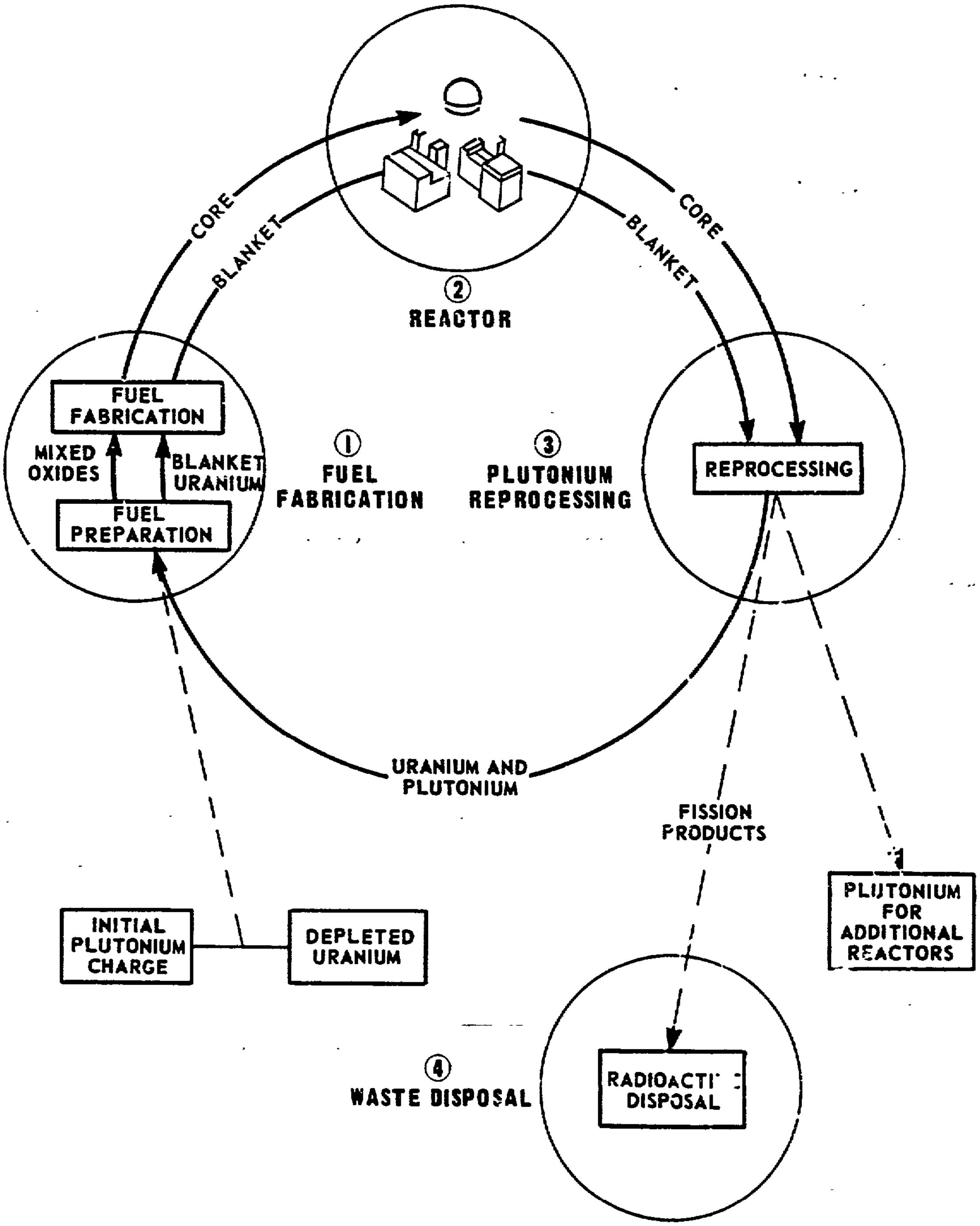
Fuel fabrication

Fuel fabrication facilities will be needed to prepare mixed oxide fuel (10 percent plutonium oxide--90 percent uranium oxide) for LMFBR cores and to prepare uranium for the periodic replacement of blanket material surrounding the reactor core. No commercial-scale capability for fabricating mixed uranium and plutonium oxide fuels is operable today. Low cost mechanized and automated production methods for producing mixed oxide LMFBR fuel in quantities required to meet projected demands must be demonstrated. Current total U.S.-production capacity based on a batch-type,

1/ Appendix I provides a detailed discussion of the LMFBR fuel cycle.

FIGURE 1

FOUR ESSENTIAL COMPONENTS OF THE LMFBR NUCLEAR FUEL CYCLE IN A ROUTINELY FUNCTIONING COMMERCIAL INDUSTRY



nonautomated operation is less than 3 metric tons a year and would not meet future requirements, which we estimate may be as high as 800 metric tons a year in the year 2000. (See p. 43.)

Fuel reprocessing

Plutonium reprocessing facilities would separate waste products and convert the remaining spent fuel into useful uranium and plutonium products. Currently no reprocessing facilities are in operation for either LWRs or LMFBRs. In fact, neither LWR nor LMFBR reprocessing has been successfully demonstrated on a commercial scale. A reprocessing facility for LWRs is currently undergoing licensing review and analysis and might be granted a license in 1978 for reprocessing uranium only.

A viable LWR reprocessing industry is needed as an indispensable prerequisite to LMFBR commercialization. While such an industry would provide technology and experience, the special characteristics of spent LMFBR fuels are such that several aspects of the established reprocessing technology must be significantly modified for LMFBR application. LWR and LMFBR reprocessing facilities are not interchangable. Thus, extensive engineering development and testing of reprocessing technology for LMFBR fuel is required.

It will be critically important to large-scale LMFBR operation to have reprocessing facilities operating on a timely basis. To meet the fuel requirements of the industry, newly bred plutonium must be promptly recycled back into the reactors. If reprocessing facilities are not readily available, spent fuel would accumulate and increasing amounts of plutonium would be captive in unprocessed fuel, possibly resulting in fuel shortages for new or existing reactors.

Waste disposal

Radioactive waste disposal facilities are needed to sequester the radioactive waste products of the nuclear fuel recycle process. Nuclear wastes in the United States are now in temporary storage. These wastes and radioactive waste from LWR and LMFBR recycling facilities will require development of a disposal scheme that will isolate them from man and from other living things for very long time periods--centuries to millenia. These are time scales longer than the lifetime of existing and previous civilizations.

As a result of two recent court decisions relating to how the Nuclear Regulatory Commission (NRC) considers the effect of reprocessing and waste disposal in its reactor licensing process, NRC temporarily halted issuing any new full-power operating licenses, construction permits, or limited work authorizations pending resolution of the issues involved. Although this suspension has been lifted, reprocessing and waste disposal problems could affect the future licensability of all nuclear reactors.

INSTITUTIONAL CHARACTERISTICS

A commercial LMFBR industry will also require a smoothly functioning institutional infrastructure. Many diverse interest groups--both public and private--will play a part. (See fig. 2.)

Although the private sector will be primarily responsible for production and operation, a number of Government bodies will participate in ongoing regulation and review.

Chief among these is NRC, which must insure that a proposed nuclear facility can be constructed and operated without undue risk to the health and safety of the public. The nuclear facility licensing process 1/ requires that applicants submit documentation before permission to construct and operate a nuclear facility is granted. Applicants must demonstrate the adequacy of safety measures, the environmental acceptability of the project and suitability of the site, and that the project does not violate antitrust laws. Once an operating license is issued, NRC inspectors continue to conduct surveillance of personnel, licenses, safety, security safeguards, quality assurance, and other operational programs for the life of the facility.

Although their participation in a commercial LMFBR industry will be intermittent, the President's Energy Resources Council, the Federal Energy Administration, and ERDA can all affect the industry through the development of national programs and policies. ERDA's continued role in research, development, and demonstration (RD&D) for LWR technologies serves as an example.

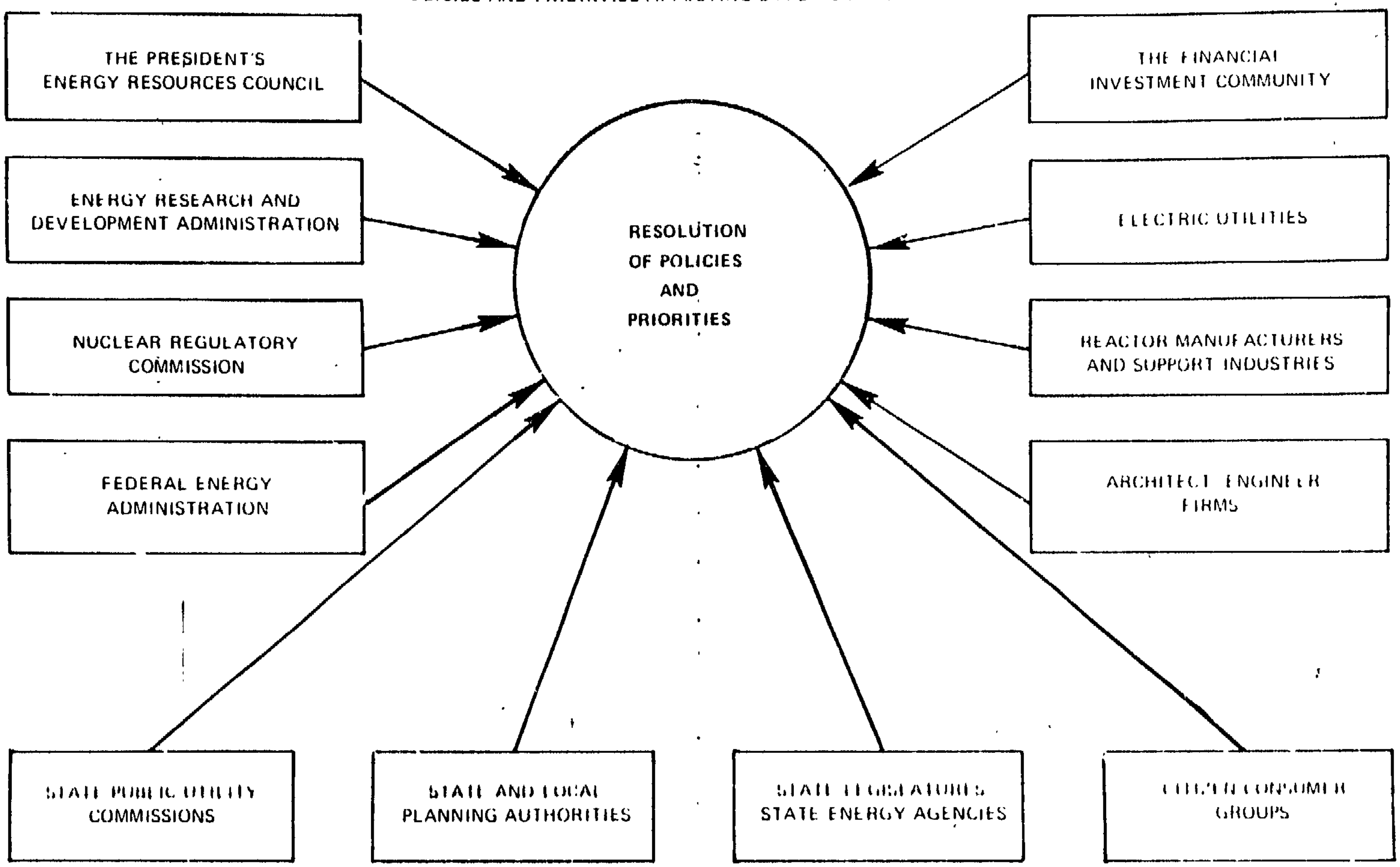
At the State level, public utility commissions are responsible for protecting consumer, producer, and investor interests in their oversight of utility rates and services. Also, State and local planning authorities are often

1/ See appendix II for a detailed description of the licensing process.

FIGURE 2

INSTITUTIONS AFFECTING A COMMERCIAL LMFBR INDUSTRY

THE INTERACTION OF A DIVERSE GROUP OF BOTH GOVERNMENT AND NON GOVERNMENT ENTITIES WILL DETERMINE THE POLICIES AND PRIORITIES AFFECTING LMFBR COMMERCIALIZATION



responsible for insuring that construction of new power-generating facilities conform with land use and other resource development plans.

The major private sector participants in an LMFBR industry will be the electric utility companies, the hardware manufacturers, the financial investment community, and the architectural-engineering firms that are ultimately responsible for integrating the site-specific requirements of an electric utility company with the performance specifications of the hardware. They are also responsible for developing licensing documentation.

In recent years, citzen/consumer groups have become increasingly better informed and have been actively participating in public hearings held by NRC, State public utility commissions, and local planning authorities.

As evidenced by the rapid spread of the nuclear initiative movement, citizen groups can also be expected to exert considerable influence on the future course of nuclear power in this country. Proposals to impose strict controls on future nuclear powerplant development were placed on the ballots in the June 1976 California primary election and in the November 1976 general election in Arizona, Colorado, Montana, Ohio, Oregon, and Washington. Although these proposals were all rejected by the voters, a significant segment of the public supported them and it can be assumed that further attempts of a similar or related nature will occur.

States are also beginning to increase their role in the area of nuclear power. Bills have been introduced in numerous State legislatures which would give the States greater control over the siting of nuclear powerplants and over the transporting of nuclear material in their States. For example, in California, legislation was adopted requiring the State energy commission and legislature to insure that nuclear materials can be adequately reprocessed and stored before nuclear plant siting requests are granted. If these various efforts are successful, State legislatures and energy agencies could acquire an important role in determining the future course of LMFBR commercialization.

Public acceptance and other institutional issues may prove to be more important than technical ones. The early support and resolution of differences among many and diverse interest groups will be essential to commercializing the LMFBR.

CHAPTER 3

SCHEDULE REQUIREMENTS FOR COMMERCIALIZATION

Moving a technology from the research, development, and demonstration stage to a commercial industry is a complex process. Basic questions of economics, technical performance, and licensability must be satisfactorily resolved, and there must be assurances that the reactor and required supporting fuel cycle technologies will be available when needed. Otherwise, utilities and other private investors will not commit themselves to building the technology.

This section looks at the time required to bring an LMFBR and its supporting facilities from conceptual design to initial operation and the status of the ERDA program in the light of these requirements.

BRINGING A NUCLEAR FACILITY INTO OPERATION

Five steps are required to bring a nuclear facility into operation.

--The conceptual and preliminary engineering design.

--The licensing process, in parallel with detailed engineering design.

--Facility construction.

--Nonnuclear checkout ("cold run").

--Nuclear checkout and test.

For the LMFBR, this process applies to each level of facility scale-up for the four required technologies, including the reactor and the three fuel cycle technologies.

The time required for this process is extensive for any nuclear facility; for LMFBR facilities, which are "first-of-a-kind," it will probably be longer. We discussed the time required to bring each principal LMFBR facility on line with ERDA and NRC officials. Cautioning that precise predictions are difficult to make without experience with LMFBRs, various ERDA and NRC officials presented differing estimates of required times. The estimates used here represent a composite of the best estimates of knowledgeable officials at these two agencies, and times suggested by the history of previous experience in constructing LWRs. Our estimates of the amount of time required to bring each of the four required facilities into operation are

--13 years for a reactor,

--10 years for a fuel fabrication facility,

--12 years for a plutonium reprocessing facility, and

--11 years for a radioactive waste disposal facility.

Table 1 provides estimates of the time required for each step involved in bringing the four types of facilities into operation.

Investors in nuclear facilities must make their major financial commitments as the projects move from the preliminary design stage to the licensing process; that it is, at step 2 in table 1 on page 13. As indicated by the estimates in this table, investors will be required to make major commitments from 8 to 10 years before initial operation of a facility.

THE LMFBR PROGRAM

The two major lines of effort in ERDA's LMFBR program are the development of the base technologies and the demonstration of these technologies in operating plants. At the heart of the demonstration plant program is the successive scale-up of facilities, from the current development stage to the eventual size required for commercial operation. Figure 3 on page 14 depicts the four LMFBR technologies and the probable levels of scale-up required for each.

Reactor development

The first successful demonstration of a fast breeder reactor was achieved by the Experimental Breeder Reactor I (EBR-I) in 1951. EBR-I has since been replaced by EBR-II, which continues to operate at the National Reactor Testing Station in Idaho. A 60-MWe LMFBR, the Enrico Fermi Fast Breeder Reactor, stopped operation in 1972.

The step from EBR-II to larger scale plants will be bridged to some extent by the Fast Flux Test Facility (FFTF). This facility is a reactor without an associated electricity generating plant but is equivalent in power to about a 150-MWe plant. Latest estimates for initial operation of FFTF are 1979.

TABLE 1

Estimated Times for Each Step Required to Build A Nuclear Facility

	Reactors	Fuel fabrication (cores only) (note a)	Plutonium reprocessing	Waste disposal
	(months)			
Step 1: Conceptual and preliminary engineering design	30	30	30	30
Step 2: Licensing process in parallel with detailed engineering design	36	35	36	38
Step 3: Construction	63	36	60	36
Step 4: Nonnuclear checkout (cold runs)	12	12	12	12
Step 5: Checkout and test (nuclear)	12	12	12	12
Total (months)	153	125	150	128
Years	13	10	12	11

Assumptions in forming schedule estimates:

Step 1: Based on ERDA's estimates of the time required for conceptual design of the Prototype Large Breeder Reactor (PLBR), the first near-commercial-size LMFBR.

Step 2: Based on LWR experience. This estimate also assumes that there will be no delays arising from intervenors participating in the public hearing process.

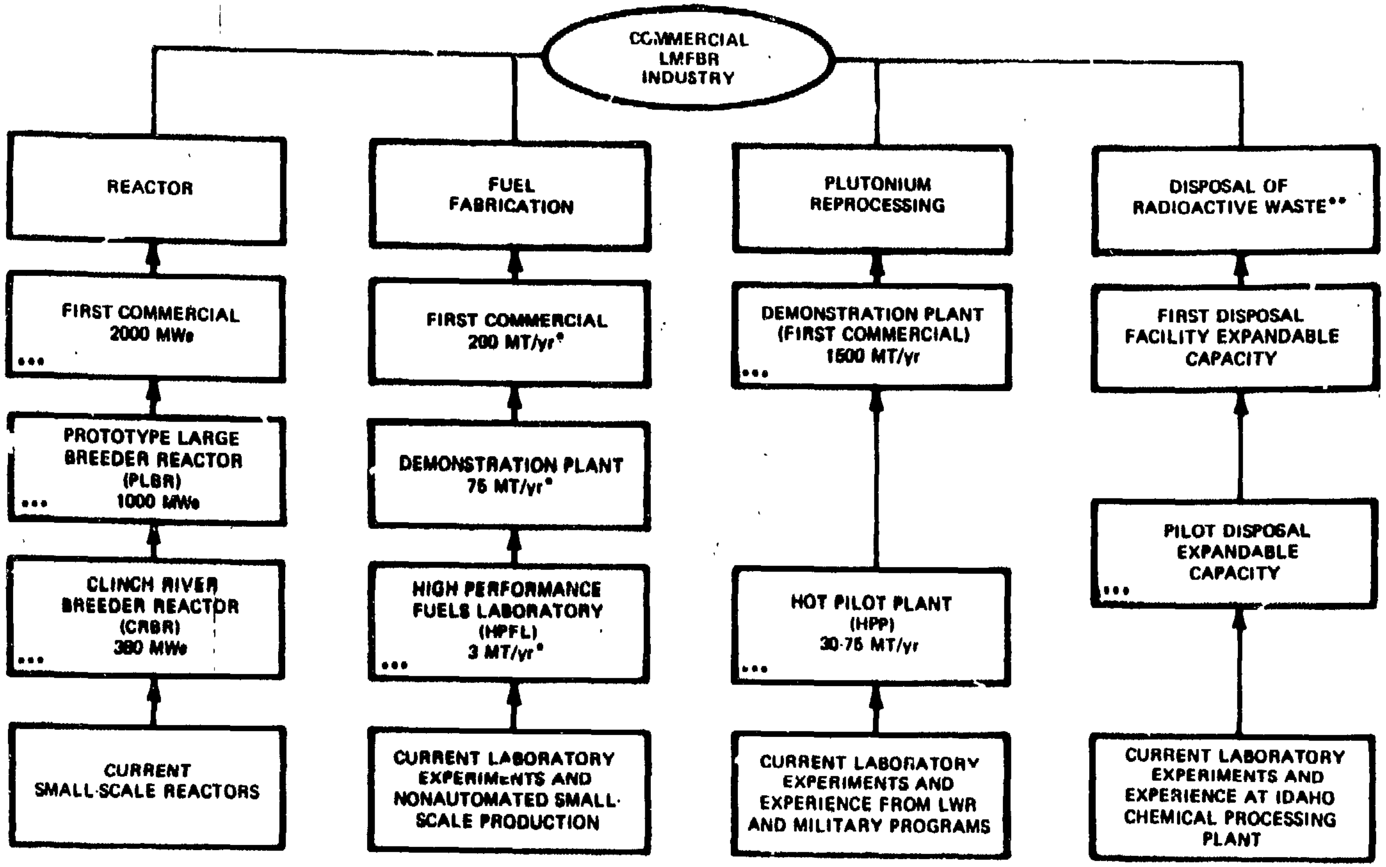
Step 3: Construction time for the reactors is based on LWR experience and ERDA's estimates for the PLBR. For other facilities, estimates are based on discussion with ERDA and NRC officials.

Steps 4 and 5: Based on discussions with ERDA and NRC officials regarding first-of-a-kind nuclear facilities.

a/Blanket fabrication facilities are very similar to existing facilities and would be subject to a licensing procedure much less stringent than procedures for other LMFBR nuclear facilities and could be completed in less schedule time than the 10 years noted above. Only steps 2, 3, and 4 would apply to blanket fabrication facilities and with reduced times--a total of 5 years should be adequate for all three steps.

FIGURE 3

ESSENTIAL TECHNOLOGIES AND THEIR PROBABLE LEVELS OF SCALE-UP



NOTES

* MT/yr = Metric tons per year of throughput capacity for heavy metal which averages 10% plutonium and 90% uranium.

** Disposal facilities for radioactive waste material will be located in remote geological formations such as salt deposits in which additional capacity can be excavated as needed almost indefinitely. Disposal facilities have not been established for any nuclear material. Such facilities will be essentially the same for the waste materials from LMFBR's, LWR's, and all other nuclear facilities.

*** Currently planned facility.

Present ERDA plans for testing and demonstrating reactor technology are focused on two principal facilities:

--The Clinch River Breeder Reactor (CRBR) is intended to serve as the link between the technology development phase and large-scale commercial use. The proposed 380-MWe facility, which is to be built in Tennessee, is now in the early design stage and is undergoing licensing review by NRC. Its latest schedules call for initial criticality 1/ in 1983.

--The Prototype Large Breeder Reactor (PLBR) will represent a near-commercial-size LMFBR. The reactor is expected to be about 1,000 MWe, consisting of commercial-size components. ERDA anticipates that PLBR will be built by a group of utilities with Federal technical support and a partial subsidy. Just how utility support will be obtained and the amount of Federal subsidy required is unclear. The amount of this support could be as high as $1 billion. ERDA now estimates that initial operation of PLBR will be in 1988.

ERDA also envisages that a large breeder reactor, designated "Commercial Breeder Reactor-1" (CBR-1), will begin operations in 1993. Its design would begin in 1983, about 1 year after the construction permit for PLBR is issued. According to ERDA, the designation CBR-1 implies that the plant is the first LMFBR project initiated by reactor vendors and utilities. ERDA expects that successive commercial plants would follow CBR-1, with some possibly receiving Government assistance, but evolving into a solely commercial industry. The amount of Government assistance that might be needed is highly uncertain. ERDA has estimated that such amounts to bring the construction costs of CBR-I and early commercial plants to parity with LWRs could be about $3.6 billion, in 1977 dollars.

Fuel fabrication

The principal test facility for fuel fabrication will be the High Performance Fuel Laboratory (HPFL), which is scheduled to start construction in 1977 with initial operation in 1982. The HPFL will be located at the Hanford Engineering Development Laboratory in Washington. As a test facility

1/The state of a nuclear raactor when it is sustaining a chain reaction.

on a Federal reservation, it will be exempt from NRC licensing requirements, although ERDA intends to develop licensing documentation.

The HPFL will not be a major production facility; it is expected that it will only be able to produce mixed oxide fuel at a rate of about 3 metric tons per year. Nevertheless, no plans exist at present for Government support of larger size fabrication facilities.

Plutonium reprocessing

Current ERDA plans call for a pilot reprocessing facility--the Hot Pilot Plant (HPP)--to become operational in 1988. This plant will be built at Oak Ridge, Tennessee, to be near the CRBR. The HPP is expected to process from 30 to 75 metric tons of heavy metal per year. ERDA anticipates that HPP could provide services for FFTF, CRBR, PLBR, and the first commercial plant.

Just recently, ERDA included in its plans the construction of a large-scale demonstration plant in cooperation with private industry. With an annual capacity of 1,500 metric tons, this plant is expected to meet the reprocessing requirements of about the first 40 commercial reactors. Although the facility is scheduled to begin operation sometime between 1995 and 2000, no plans have yet been made for the extent of industry involvement, the level of Federal support, or the dates by which commitments will be made.

Radioactive waste disposal

Operation of a pilot radioactive waste disposal facility is planned for late 1983, probably at a site to be developed in salt deposits in southeastern New Mexico. These deposits are sufficiently large and deep to later accommodate materials from LWRs, LMFBRs, and all nuclear facilities.

Up to six additional pilot facilities are planned for operation between 1985 and 1991. Plans exist to expand some of these pilot facilities to full-scale facilities to accommodate the requirements of a commercial industry. All waste disposal facilities will be Government-owned.

As part of a comprehensive statement on nuclear policy, the President, on October 28, 1976, directed ERDA to take the necessary actions to speed up the program to demonstrate all components of waste management technology by 1978, and to demonstrate a complete repository by 1985. He also directed that plans for the repository be submitted to NRC for licensing to assure its safety and acceptability.

Radioactive waste management is common to both LWRs and LMFBRs. It is expected that work on disposing LWR waste will contribute to the LMFBR program. The LWR-oriented work in waste management includes both waste processing studies to provide the appropriate form for terminal storage and to provide facilities for such storage. LMFBR reprocessing development may include some specific waste processing studies in preparing suitable waste forms, but the terminal storage function of waste management is expected to be piloted and "commercialized" under the LWR program.

LMFBR PROGRAM IMPLICATIONS

Because of the length of time required to bring a facility into operation, scale-up for each of the four required technologies should ideally proceed at roughly the same pace. While fuel fabrication and reprocessing facilities need not be operating as soon as reactors, they will be required from 1 to 5 years thereafter, respectively. (See app. I.)

Yet as the review of ERDA plans indicates, reactor development is projected through the prototype scale (1988), while fuel fabrication is projected just through the pilot stage (1982). Only recently has ERDA made plans for developing a prototype reprocessing facility (1995-2000).

If private industry is to undertake the scale-up of fuel fabrication facilities, they will most likely want to wait until the technology has been demonstrated at the pilot stage before making investment commitments. Since it takes approximately 10 years from initial design to plant operation, with the HPFL now scheduled for 1982, it might be 1992--4 years after the PLBR begins operation--before a prototype fabrication faciltiy could be licensed, built, and tested. Thus, demonstration of fuel fabrication technology could lag behind reactor development several years.

By the same token, the planned operation of a demonstration reprocessing plant around 1995-2000 places it nearly a decade behind the operation of PLBR, the comparable scale reactor.

Any plans ~~for~~ commercialization must, therefore, take account of the fact that commercial introduction will most likely be paced by fuel cycle technology availability.

CHAPTER 4

ALTERNATIVE FUTURES FOR

COMMERCIALI. _N OF LMFBR TECHNOLOGIES

Several goals for commercial introduction of LMFBRs have been put forward in recent years. Recent ERDA plans have indicated that the LMFBR is regarded as a long-range technology which is not expected to make any major contributions to national energy supply until the beginning of the next century. Recent EPDA projections of total installed LMFBR electric generating capacity in the year 2000 range from about 30,000 MWe (expected forecast) to about 60,000 MWe (high forecast).

But is it possible to achieve either of these forecasts? What, in fact, is realistic? To answer these questions, GAO developed three alternative scenarios for what commercialization might look like and what would be required to achieve it.

Our scenarios employ two basic assumptions. The first is that 128 LMFBRs will become operational over an 11-year introduction period. This is based on the following statement by the Director of ERDA's Division of Reactor Research and Development before the Joint Committee on Atomic Energy on March 11, 1975.

> "The first breeder becomes operational in 1987, and the aggregate capacity doubles annually until about 1990, and every 2 years thereafter until 1998."

Although we believe this growth rate may be unrealistic, it is the only official ERDA statement we found which outlines the timing and rate of commercial LMFBR introduction. As such, it is used here merely as a benchmark against which alternative plans can be assessed. rather than as a reflection of current ERDA plans.

Our second basic assumption is that 8 to 10 years will be required from the time of major financial commitment by utilities and other private investors to actual operation of commercial facilities. Although we believe that most utilities will not make large financial commitments until the United States has gained 2 or 3 years of operating experience in demonstration or prototype plants, we assume in our scenarios that <u>some</u> utilities would be willing to make these commitments to the first few commercial U.S. LMFBRs before this operating experience is achieved. We believe these commitments might be made based on FFTF and CRBR construction and operating experience, general experience gained in the U.S. LMFBR research and development program, and operating experience gained from foreign LMFBRs.

Figure 4 summarizes our scenarios for commercial LMFBR introduction.

ERDA MARCH 1975 SCENARIO

According to this scenario, which is based on the ERDA March 1975 schedule, the first breeder becomes operational in 1987 and proliferation continues until 1998, when 128 LMFBRs are in operation. Implicit in this scenario is the assumption that investors will make commitments on the order of billions of dollars during the 5- to 6-year period--from 1979-1980 to 1986--before the CRBR has demonstrated its reliability under routine operating conditions. Meeting this schedule will also require that 91 LMFBRs be in either the final design and licensing stage or actually under construction by 1987, even before the first prototype breeder reactor is scheduled to begin operation.

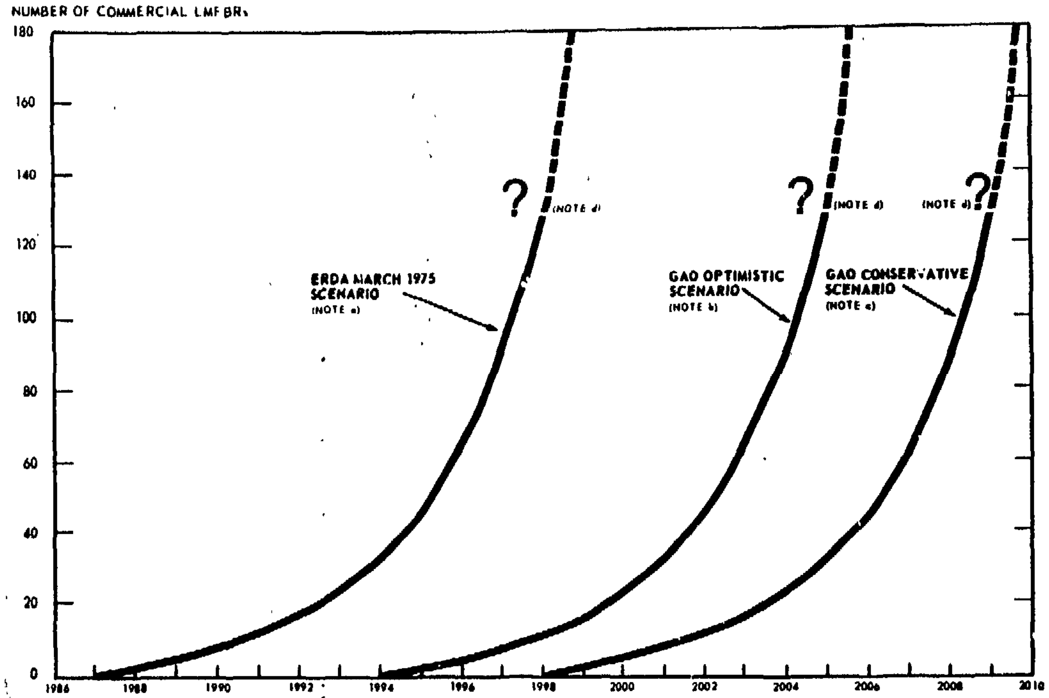
GAO OPTIMISTIC SCENARIO

This scenario also assumes an introductory phase of 11 years, with the same rate of introduction as in the ERDA March 1975 scenario. It assumes that most financial commitments will not be made until 1986 when the ERDA Administrator makes his commercialization decision, about 3 years after initial operation of CRBR. However, the scenario assumes that some utilities will be willing to make commitments to the first few commercial LMFBRs in 1984. We believe these commitments might be made based on FFTF operating experience, CRBR construction experience, general experience gained in the U.S. LMFBR research and development program, and operating experience gained from foreign LMFBRs. The introductory phase therefore spans 1994 to 2005, resulting in 32 LMFBRs in place by 2001. Only 8 to 12 LMFBRs would be committed or in various stages of completion by 1988, when the PLBR is expected to become operational.

This scenario assumes that, by analogy with LWRs, utilities may invest early in preliminary plant designs, site surveys, draft preliminary environmental impact

THREE SCENARIOS FOR COMMERCIAL INTRODUCTION OF LMFBRS

FIGURE 4



ASSUMPTIONS

1 Timely and adequate financing

2 No delays in R D&D program plutonium or other materials fabrication or construction

3 *No technological breakthroughs or double work shifts are required*

4 No delays in public hearings or elsewhere in the licensing process

NOTES

(a) THE ERDA MARCH 1975 SCENARIO is based on the Statement of the ERDA Director of Reactor R&D before the Joint Committee on Atomic Energy March 11 1975 page 11 the first breeder becomes operational in 1987 and the aggregate capacity doubles annually until about 1990 and every two years thereafter until 1998"

(b) THE GAO OPTIMISTIC SCENARIO assumes that, by analogy with LWRs utilities may invest early in preliminary plant designs site surveys draft *preliminary environmental impact statements* and safety analysis reports but will delay making firm contracts and major financial commitments for commercial LMFBRs until the ERDA Administrator makes his commercialization decision which is presently scheduled for 1986 after 3 years of CRBR operating experience GAO believes that this is likely to be the minimum *demonstration period which most utilities will require before they* will commit to buy the first commercial models of a new steam supply system However, the schedule assumes that some utilities will make commitments to the first few commercial LMFBRs beginning in 1984 We believe these commitments might be made based on FFTF operating experience CRBR construction experience *general experience gained in the U S LMFBR* research and development program, and operating experience gained from foreign LMFBRs

The rate of LMFBR introduction is assumed to be the same as in the ERDA March 1975 Scenario

Recent ERDA projections for total installed LMFBR generating capacity in the year 2000 range from about 30 000 MWE (expected forecast') to 60,000 MWE (high forecast) With commercial LMFBRs introduced after 1990 expected to be of 2000 MWE size (WASH 1535 The LMFBR Program Proposed Environmental Impact Statement, 1974, ch 11) this would amount to 30 LMFBRs in the year 2000 for the high forecast This is close to the GAO Optimistic Scenario which reaches 32 LMFBRs in 2001

(c) THE GAO CONSERVATIVE SCENARIO assumes that most *utilities will only make firm contracts and major financial* commitments 2 years after the start of PLBR operation - now estimated for 1988 at the earliest However, the schedule assumes that some utilities will be willing to make commitments to the first few commercial LMFBRs in 1988 We believe these commitments might be made based on FFTF and CRBR operating experience, PLBR construction experience, general experience gained in the U S LMFBR research and development program, and operating experience gained from foreign LMFBRs

The rate of introduction is assumed to be the same as for the two Scenarios considered above

(d) With the introduction of 64 LMFBRs in the final 2 years of each of the three Scenarios LMFBRs would be the predominant type *of new reactor coming into use At that time the total LMFBR* capacity, consisting of 128 plants, would represent a significant portion of total U S electrical generating capacity While more LMFBRs would undoubtedly follow these GAO considers this point to represent the end of the LMFBR commercial introduction period

NOMENCLATURE

CRBR	Clinch River Breeder Reactor
PLBR	Prototype Large Breeder Reactor
LWRs	Light Water Reactors
LMFBRs	Liquid Metal Fast Breeder Reactors
ERDA	Energy Research and Development Administration

statements, and safety analysis reports but that most will delay making firm commitments for commercial LMFBRs until about 3 years after the start of CRBR operation. This is likely to be the minimum demonstration period which most utilities will require before they will commit to buy the first commercial models.

This scenario is not inconsistent with ERDA's recent RD&D plans which anticipate that LMFBR's contribution to national energy supply will be in the long term, or beyond the year 2000.

Recent ERDA projections forecast 30,000 WMe to 60,000 MWe of LMFBR capacity in the year 2000. With commercial-size reactors of 2,000 MWe capacity, the high forecast would amount to 30 LMFBRs in the year 2000. This is close to the GAO Optimistic Scenario which reaches 32 LMFBRs in 2001.

GAO CONSERVATIVE SCENARIO

The rate of introduction is assumed to be the same as the other two scenarios. However, the 11-year introductory phase spans 1998 to 2009, resulting in about four to six LMFBRs in commercial operation by the year 2000.

This estimate for the period of introduction is based on the assumption that most utilities will wait to make firm commitments until 1990. This is 2 years after the PLBR is expected to begin operation--that is, after routine operation and licensability on a near-commercial scale have been clearly demonstrated. However, the schedule assumes that some utilities will be willing to make commitments to the first few commercial LMFBRs in 1988. We believe these commitments might be made based on FFTF and CRBR operating experience, PLBR construction experience, general experience gained in the U.S. LMFBR research and development program, and operating experience gained from foreign LMFBRs.

This scenario also assumes that most utilities will be cautious about making commitments to the LMFBR until successful demonstration of plutonium reprocessing technology by HPP, fuel fabrication technology by HPFL, and waste disposal technology.

SCHEDULES REQUIRED TO MEET THE THREE SCENARIOS

To meet the target dates for commercialization specified by each scenario would require the timely development of the reactor and fuel cycle technologies. To assess the likelihood of achieving the goals of each scenario, we developed a master schedule which ties together the dates by which each required facility, at each level of scale-up, must be operating. This schedule is presented in table 2.

The dates listed under each scenario are all related to that scenario's assumption of when commercial introduction is likely to begin. For example, according to the ERDA March 1975 Scenario, the first commercial breeder powerplant becomes operational in 1987. This implies the first commercial-size core fuel fabrication facility must be in operation by 1988, the first commerical-size plutonium reprocessing facility by 1992, and the first waste disposal facility of a size needed to accommodate a commercial industry by 1989. 1/

The number of required support facilities listed in the table is based on an introductory group of 128 reactors. While this number may ultimately be lowered to conform with ERDA's revised estimate of anticipated LMFBR output, the following sets of relationships will probably always pertain.

--One fuel fabrication plant with an annual capacity of 200 metric tons (MT) can provide reload fuel for 11 2,000 MWe reactors. This assumes that each reactor will use 18 MT of fuel a year.

--One 1,500 MT reprocessing facility can provide services for approximately 40 reactors. This ratio anticipated that each reactor will annually release 38 MT of uranium and plutonium for reprocessing.

Table 2 also contains the dates by which commitments to construct each facility are needed. This analysis assumes that the necessary length of time required from the beginning of the licensing and final design to initial operation (steps 2 through 5 from table 1 on p. 13) are: 10 years for reactors, 8 years for core fuel fabrication facilities, 5 years for blanket material fabrication facilities, 10 years for plutonium reprocessing facilities, and 8 years for radioactive waste disposal facilities.

1/This assumptions in forming the required dates of operation for support facilities are presented in appendix I.

TABLE 2

Three Scenarios for Commercialization:

Required Dates of Operation of LMFBR Technologies

	Capacity	No. of units needed	ERDA March 1975 Scenario: Required Operation	ERDA March 1975 Scenario: Required Commitment	GAO Optimistic Scenario: Required Operation	GAO Optimistic Scenario: Required commitment	GAO Conservative Scenario: Required operation	GAO Conservative Scenario: Required Commitment	ERDA planned operation	ERDA planned commitment
REACTORS										
PLBR	1,000+ MWe	1	1986	1976	1988	1978	1988	1978	1988	1979-80
First commercial	2,000 MWe	1	1987	1977	1994	1984	1998	1988	1993	NP
Additional commercial	2,000 MWe	127	1988-98	1978-88	1995-2005	1985-95	1999-2009	1989-99	NP	NP
FUEL FABRICATION										
Core										
HPFL	3 MT/yr	1	1974	1966	1981	1973	1981	1973	1982	1977
Demo plant	75 MT/yr	1	1981	1973	1988	1980	1992	1984	NP	NP
First commercial	200 MT/yr	1	1988	1980	1995	1987	1999	1991	NP	NP
Second commercial	200 MT/yr	1	1990	1982	1997	1989	2001	1993	NP	NP
Additional commercial	200 MT/yr	12	1992-96	1984-88	1999-2003	1991-95	2003-07	1995-99	NP	NP
Blanket material										
First commercial	400 MT/yr	1	1986	1981	1993	1988	1997	1992	NP	NP
Additional commercial	400 MT/yr	10	1989-96	1984-91	1996-2003	1991-98	2000-07	1995-2000	NP	NP
REPROCESSING										
HPP	30-75 MT/Yr	1	1979	1969	1986	1976	1986	1976	1988	1979
Demo Plant (first commercial)	1,500 MT/yr	1	1992	1982	1999	1989	2003	1993	1995-2000	NP
Second commercial	1,500 MT/yr	1	1997	1987	2004	1994	2008	1998	NP	NP
Third commercial	1,500 MT/yr	1	1999	1989	2006	1996	2010	2000	NP	NP
HIGH-LEVEL RADIOACTIVE WASTE DISPOSAL										
Pilot	152 cu. ft.	1	1984	1976	1991	1983	1991	1983	1983	1979
First waste disposal facility	of high-level waste per reactor per year	1	1989	1986	1996	1993	2000	1997	NP	NP

NOTES: NP = No Plans Mwe - megawatt electric MT = metric ton

RESULTS OF SCENARIO ANALYSIS

A review of the schedule suggests that commercialization could most likely occur on a small scale only by the year 2000.

More specifically, the ERDA March 1975 Scenario is clearly not likely to be met. With the PLBR now scheduled for initial operation in 1988, it is difficult to imagine that commercial reactors will start to come on-line in the preceding year.

Several other milestone dates have also passed, and others have no margin for delay. Most notably, development of fuel fabrication facilities is behind reactor development. The HPFL, which is planned for operation in 1982, would have had to have been operating in 1974 for the ensuing scale-ups to be developed in time for operation of the first commercial fuel fabrication facility by 1988. In addition, a demonstration fuel fabrication facility--for which ERDA currently has no plans--would also have to be in the final design and licensing stage now.

Similarly, the HPP would need to be under construction now for a commercial plutonium reprocessing facility to be operational by 1992. But, as shown in table 2, HPP operation is not even planned until 1988.

As for waste disposal facilities to meet LMFBR needs, a pilot plant should be operating by 1984 for the first disposal facility to be operational by 1989. The first of up to seven pilot plants is scheduled for operation in late 1983 or 1 year before it would be needed under this scenario.

The GAO Optimistic Scenario, which most closely approximates current ERDA projections, could only be met if the RD&D for fuel fabrication and plutonium reprocessing technologies were accelerated and Government participation extended into the early stages of commercial operation.

If utilities are to make large-scale commitments to LMFBRs scheduled for operation in 1994 and later, they will have to be assured by the mid-1980s that fuel fabrication plants will be operating by the dates shown in table 2. Satisfactory operation of the first demonstration plant by that time could probably provide that assurance, but this appears impossible, since such a plant is not even planned and the HPFL is only planned to begin operation in 1982.

These considerations suggest that if the fuel fabrication facilities are to be operating in time for the reactors, a major part of their financing will have to be assumed by the Federal Government for the demonstration and first few commercial-size plants.

Similarly commitments to the construction of the first commercial reprocessing facility have to be made by the late 1980s to have that plant operating by 1999, when needed. If ERDA and private industry decide to make a commitment to build a demonstration reprocessing facility by then, the plant could be in operation on time. But this would leave no slack time in the RD&D schedule for plutonium reprocessing.

Here again, it seems likely that Government participation would be required in the early stages of commercial reprocessing operation to guarantee the availability of fuel cycle facilities when they are needed. This prospect is underscored by the experience of the LWR industry, which still has no complete reprocessing facilities in operation after more than 15 years of operation. 1/ By comparison, this scenario calls for a first full-scale reprocessing plant after only 5 years of LMFBR operation.

Regarding waste disposal facilities, operation of the first of up to seven pilot plants is currently scheduled for 1983, which is well before the 1991 date required to have a disposal facility ready by 1996 when it would be needed to meet LMFBR requirements.

The GAO Conservative Scenario, by recognizing the amount of time required for development of fuel cycle technologies, represents the most likely degree of commercialization to occur by the year 2000.

Under this scenario, commitment to constructing the first demonstration fuel fabrication plant would not have to be made until 1984, 2 years after the HPFL is scheduled to begin operation. Commitments to the first commercial-size reprocessing plant would not have to be made until the early 1990s, which allows leeway for some delays encountered in technical and licensing performance. Commitment for the first waste disposal facility needed to meet LMFBR requirements would not have to be made until 1997.

1/See appendix I for a discussion of plutonium recycling in LWRs.

But even to achieve the level of commercialization envisioned in this scenario would require that RD&D for fuel cycle technologies run on a schedule parallel to reactor development. Thus, if any degree of LMFBR commercialization is to occur before the end of this century, RD&D for fuel cycle technologies, in particular, fuel fabrication, and reprocessing, will have to be accelerated.

CHAPTER 5

CONSTRAINTS ON COMMERCIALIZATION: TECHNICAL, FINANCIAL, SCHEDULING, AND INSTITUTIONAL

While previous chapters have suggested how one might plan for the commercialization of LMFBRs, there nevertheless remains a host of uncertainties which will require resolution if the results of that planning effort are to be successful. Assuming that problems of safety, safeguards, and environmental effects can be reduced or eliminated, there still remain technical, financial, scheduling, and institutional problems which have to be identified.

TECHNICAL UNCERTAINTIES

Plutonium reprocessing

Reprocessing plutonium is vital to the success of LMFBR. According to ERDA, LMFBR will not be viable without it. Yet reprocessing plutonium generated by an LMFBR is an as-yet undemonstrated technology; it has not been developed and demonstrated on even a pilot scale. Although there has been some experience with LWR plutonium reprocessing facilities, these are not interchangeable with LMFBR facilities due to higher concentrations of plutonium in LMFBR fuel.

Furthermore, serious questions regarding the safety, environmental, and safeguard effects of plutonium recycle for LWRs are still being considered by NRC. These questions are expected to be resolved in 1977. Any difficulties experienced in licensing LWR facilities will contribute to a greater sense of caution by private sector investors.

Of potentially greater importance, however, would be a finding by NRC that safety, environmental, or safeguard problems associated with plutonium recycle in LWRs cannot be resolved. Such a decision probably would preclude plutonium reprocessing for the LMFBR, since the safety, environmental, and safeguard problems are essentially the same for both LWRs and LMFBRs.

Although not specifically directed toward LMFBR, the President's recent actions cast doubts as to the future of nuclear fuel reprocessing. This, in our view, also creates doubts as to whether the LMFBR will become a viable energy source because reprocessing is an indispensable prerequisite for LMFBR commercialization. In an October 28, 1976, statement on nuclear policy, the President concluded that "the reprocessing and recycling of plutonium should not proceed unless there is sound reason to conclude that the world community can effectively overcome the associated risks of proliferation."

He further stated that

"the United States should no longer regard reprocessing of nuclear fuel to produce plutonium as a necessary and inevitable step in the nuclear fuel cycle, and that we should pursue reprocessing and recycling in the future only if they are found to be consistent with our international objectives."

The President directed agencies of the executive branch to implement his decision to delay commercialization of reprocessing activities in the United States until uncertainties are resolved. ERDA was directed to (1) change its policies and programs which were based on the assumption that reprocessing would proceed and (2) undertake a reprocessing and recycling evaluation program consistent with meeting our international objectives of strengthening nonproliferation measures.

Scale-up

Scale-up of LMFBR technologies from the current engineering scale development level with individual components to the eventual commercial-size facilities entails large uncertainties.

Design studies, mathematical simulations, and tests of parts of the larger system may aid in predicting large-scale performance, but they cannot be certain of anticipating changes that arise because of the scale change.

Each scale-up increment subjects materials and designs to significantly different conditions. Failure at any of the levels by any of the four types of facilities can potentially jeopardize the development of the entire industry, since each increment of each facility is vital to commercial success.

Alternative plant concepts

The development of alternative plant concepts has been virtually eliminated from the LMFBR program. High technology RD&D programs have become increasingly costly. To reduce overall costs, the LMFBR program was substantially revised in 1974 by eliminating plans for multiple demonstration plants. Thus, it will not contain an important aspect which the LWR program opted for--the provisions of several developmental models of different types, the pressurized water reactor, and the boiling water reactor.

The advantage of developing alternative concepts is that it allows a larger sample of operating experience, as well as offering some insurance against the possibility that a single failure in one version of the product will not necessarily disrupt or even terminate the program.

The LMFBR program has only two developmental models: The CRBR and the PLBR, both of which are loop-type reactors. Delays for any reason in either of these two facilities can potentially jeopardize private sector commitments to LMFBR commercialization until the difficulties are clearly resolved.

Doubling time

In the long run doubling time 1/ is a principal factor which will determine the economics of widespread LMFBR commercialization. Reliable and precise estimates of doubling time require actual operating experience of both reactors and reprocessing facilities. ERDA expects that, by the late 1980s, the experience gained by CRBR and HPP will furnish fairly reliable estimates of doubling times for initial LMFBR fuels. In the long run shorter doubling times are expected to be achieved with advanced fuels, which are to be tested beginning in the 1980s, with reliable estimates of doubling time available in the 1990s.

FINANCIAL UNCERTAINTIES

Each of our three scenarios call for 128 2,000 MWe LMFBRs becoming operational over an 11-year period. We estimate that the total capital costs for these plants and supporting facilities would be high--about $150 billion, meassured in 1974 dollars. This includes about $141 billion for building the PLBR and 128 commercial reactors. Remaining costs for LMFBR commercialization would include about $3.4 billion for fuel fabrication facilities, about $4.5 billion for plutonium reprocessing plants, and about $1 billion for radioactive waste disposal facilities. (See table 3.)

1/The time required for a breeder reactor to produce as much fissionable material (plutonium) as the amount normally contained in its core, plus the amount tied up in its fuel cycle, and thus be able to support the operation of an additional reactor of the same kind.

TABLE 3

Costs of Commercializing the LMFBR

	Capacity	No. of units needed	Cost per unit (millions)	Total cost (billions)
REACTORS				
PLBR	1,000+MWe	1	$2,000	$ 2.00
First Commercial	2,000+MWe	1	1,200	1.20
Addn'l Commercial	2,000+MWe.	127	At decreasing rate for 15 years when cost will be $1 billion	137.60
				$140.80
FUEL FABRICATION				
Core				
HPFL	3 MT/yr	1	60	$ .06
Demo Plant	75 MT/yr	1	75	.08
First Commercial	200 MT/yr	1	200	.20
Second Commercial	200 MT/yr	1	200	.20
Addn'l Commercial	200 MT/yr	12	200	2.40
Blanket Material				
First Commercial	400 MT/yr	1	10	.01
Addn'l Commercial	400 MT/yr	10	10	.10
Transportation				
13 special security trailer per reactor year;		1,664	.20	.33
one tractor is needed per four trailers		416	.045	.02
				$3.40
REPROCESSING PLANTS				
HPP	30-75 MT/yr	1	300	$ .30
First Commercial	1,500 MT/yr	1	750	.75
Second Commercial	1,500 MT/yr	1	750	.75
Third Commercial	1,500 MT/yr	1	750	.75
Transportation Shielded Security	1 MT of heavy metal per car; 10 cars per reactors per year	1,290	1.5	1.92
				$4.47
HIGH-LEVEL RADIOACTIVE WASTE DISPOSAL FACILITIES				
Pilot	152 cubic feet of high level waste per reactor per year;	1	100	$ .10
First Waste Disposal Facility		3	100	.30
Canisters	6.25 cubic feet of waste per canister	10,385	.055	.57
				$ .97
			Total	$149.64

ASSUMPTIONS

1. Costs for PLBR are the same as ERDA's estimate of CRBR costs (Reference statement of Thomas A. Nemzek, Director of Reactor Research and Development, ERDA, before the Joint Committee on Atomic Energy, ERDA Authorization Hearings for FY 1977, February 4, 1976.)

2. Costs for commercial LMFBR's are based on capital costs for LWR's ~~with~~ an assumed cost differential of $100 per kilowatt in the first year of LMFBR commercial introduction, decreasing linearly to zero over 15 years.

3. All other costs are based on best estimates of ERDA officials.

NOTES

1. All costs are in 1974 dollars.

2. The cost for the reactors, fabrication plants and reprocessing plants are capitalization costs. Some of the costs for waste disposal may be considered operating expenses, although the canister costs are intended to amortize the costs of a waste disposal facility.

Mwe = megawatt electric
MT = metric ton

Comparable capital costs for building the same number and same size coal plants and LWRs would be about $95 billion and about $128 billion, respectively. 1/ As discussed on pages 4 and 5, the LMFBR could retain an economic advantage because it promises comparatively lower operating costs due to its ability to produce more fuel than it consumes.

The cost of commercial introduction may pose a formidable barrier to electric utilities for a number of reasons. Investors are analyzing capital intensiveness more closely as a measure of risk, return on investment, and corporate profit in the larger context of alternative means of providing the same services to the public, as well as alternative opportunities for investment.

Furthermore, bond ratings of electric utilities are declining. Between 1965 and 1974, 21 utilities were upgraded while at least 59 were downgraded, in part, because the utilities have not been allowed by their regulatory bodies to include all their costs in their rate base. Downgrading increases difficulty in attracting investment capital, especially on favorable terms.

SCHEDULING UNCERTAINTIES

Successful commercialization at the least cost requires a series of carefully planned activities integrated over at least 10 and perhaps as many as 25 years. However, scheduling these activities poses a number of problems because:

--The information on which to base a realistic schedule is imprecise. For example, while electricity growth has slowed recently, it may be some time before current economic and social indicators can be understood well enough to serve as reliable bases for estimating future electricity needs.

--The nuclear facility licensing process requires planning and cooperation more comprehensive and definitive than has even been required before. For a "first-of-a-kind" facility, it is difficult to predict with precision how long this process will take.

1/Total LWR capital cost is $1 billion (1974 dollars) for each 2,000 MWe plant, including interest during construction. Capital cost for each 2,000 MWe coal-fired plant (with SO2 control) is $744 million, also including interest during construction.

Appendix II contains a discussion of the nuclear facility licensing process.

--Delays in closing the LWR fuel cycle hold significant implications for the timely commercialization of the LMFBR. Essentially all the fuel ever used in LWRs is still in storage at reactor sites. Additional storage facilities are critically needed. However, nuclear opponents may use the public hearing mechanism that is a part of the licensing process to challenge further construction.

--The uncertain availability of uranium supplies has, in part, been responsible for numerous cancellations, deferrals, and lack of orders for LWRs in 1975.

As of January 1976, the average price of uranium that was under contract for 1980 delivery was about $14 per pound. By mid-1976 the market price had climbed to $40 or more per pound for 1980 delivery. Increased mining and milling costs, along with rising demands, could drive future prices even higher.

Present enrichment facilities will be limited in capacity to supplying fuel for LWRs constructed by 1984. Although Federal legislation to develop a private enrichment industry has been proposed, LWRs coming on line after 1984 presently have no assurance of obtaining fuel.

INSTITUTIONAL UNCERTAINTIES

The institutional considerations for commercializing the LMFBR are essentially the same for commercializing any new energy technology, with the exception of the licensing requirement. Establishing an ongoing LMFBR industry would require the adaptation of existing institutional mechanisms and the creation of some new ones.

To accomplish this, however, a diversity of interests must be reconciled and resolved. Since successful commercialization is contingent upon the establishment of an integrated timetable for all necessary technologies, the timely support of these diverse interests at all levels of scale-up is essential.

The difficulties that this will pose may be more formidable than resolving technical problems. The number of groups with some responsibility for energy policymaking at the Federal level alone serves to illustrate:

--A December 1975 tally of the congressional committees with energy policymaking responsibility revealed that 33 committees, 65 subcomittees, and one panel claim some jurisdication over ERDA. Four committees serve a legislative, oversight or appropriations role to the LMFBR program, while 29 other committees and subcommittees share an interest in the development of energy technologies.

--According to the most recent ERDA plan, 29 different Federal agencies share responsibility for recommending comprehensive national energy policy.

Within the private sector, important concerns must be addressed:

--Electric utilities will want assurance of a fuel supply and reliability of operational performance for the life of the facility, typically 30 to 40 years.

--With increasing competition for capital, the financial investment community will require confidence that LMFBR is a demonstrated and licensable technology.

--Hardware manufacturers need assurances that the market for a new product is sufficient to justify the investment required to produce it.

--Citizen groups have let it be known that concerns about the safety of nuclear powerplants must be satisfactorily addressed before public confidence and acceptance can be gained.

--State public utility commissions will require sufficient assurance of the need for the LMFBR facility and for both capital and operating costs to minimize uncertainties affecting rates charged to consumers over the life of the facilities.

Clarifying the roles that each must play in effecting the commercialization of LMFBR--and indeed in determining whether it is to occur--will be a major aspect of planning for a commercial LMFBR industry in the United States.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

A July 1975 GAO report concluded that the LMFBR program should be recognized as a research and development program that has yet to demonstrate that commercial-size LMFBRs can be operated economically, reliably, and safely. Not until some point in the future, that report continued, need a firm decision be made about whether LMFBR will be a major source of electrical energy in the United States. Subsequent to the report, the ERDA Administrator determined that a continued strong research effort would provide sufficient data by 1986 to enable him to make a determination on the acceptability of widespread commercial deployment of LMFBRs.

In the intervening years, however, decisionmakers need to focus attention on the total infrastructure required for a commercial LMFBR industry. Management and planning efforts are needed to bring about an orderly transition from research and development to commercialization of LMFBR technology.

Since commercialization implies that the Federal Government will not be the consumer and operator of the products of its own RD&D program for LMFBR, private sector support is essential. Obtaining private sector support will be difficult, however, because of current uncertainties centering on future demand for electricity, the ultimate cost of power from commercial LMFBR powerplants, availability of capital, and the entire future of the nuclear option.

If this support is to be earned, utilities and other private investors will need assurance that LMFBR and all necessary support technologies are capable of reliable and economic performance and are licensable.

For a routinely functioning LMFBR industry, these support technologies would include fuel fabrication, plutonium reprocessing, and radioactive waste disposal. Until recently, the LMFBR program, however, has placed greatest emphasis on reactor development. No plans currently exist for Government participation in the demonstration of fuel fabrication facilities beyond the pilot stage. Only recently have plans been made for Government support of a large-scale reprocessing facility. Plans exist for pilot waste disposal facilities which can be expanded to full scale to accommodate the requirements of a commercial industry.

Because of the long leadtime decisions inherent in commercialization, investors will also need to know well in advance of commitments when they can expect all required technologies to be available for commercial implementation.

Three different scenarios for commercialization were developed to provide some perspective to these issues. We recognize other scenarios are possible. However, we believe our analysis provides a reasonable picture of what could be expected with respect to LMFBR commercialization. On the basis of this analysis, we believe the following general conclusions are warranted.

--If basic uncertainties of safety, safeguards, and environmental effects are resolved early and forthrightly, the start of commercialization of LMFBR by the mid-1990s is feasible. This can be achieved, however, only through an integrated approach to the development of four required technologies: reactor, fuel fabrication, plutonium reprocessing, and radioactive waste disposal.

--1990 may be the earliest time by which licensability and routine performance can be demonstrated for all four required technologies. Major private investment commitments are not likely to be forthcoming until both routine performance and licensability have been demonstrated.

--The GAO Conservative Scenario, by recognizing the amount of time required for development of fuel cycle technologies, represents the most likely degree of commercialization to occur by the year 2000, with four to six LMFBRs in commercial operation. This scenario assumes that most utilities will be cautious about making commitments to LMFBRs until after a near-commercial scale LMFBR has been operated and licensed and until successful demonstration of plutonium reprocessing technology, fuel fabrication technology, and waste disposal technology.

--Additional funding for the LMFBR program is not likely to hasten the initial commercial availability of LMFBR reactor technology. However, early development of program plans and increased commitment of resources could accelerate by 1 or 2 years the research, development, and demonstration of the three supporting fuel cycle technologies required for LMFBR commercialization, with a similar effect on the pace of introducing LMFBRs into the Nation's energy system.

RECOMMENDATIONS

In the decade remaining before a firm decision needs to be made about the Nation's future commitment to LMFBR as a central station power source, we recommend that the Administrator of ERDA take the following actions:

--Fully develop a management and planning framework which integrates the RD&D for the four key technologies--reactor, fuel fabrication, plutonium reprocessing, and radioactive waste disposal--needed for a commercial LMFBR industry. Such an approach should relate the required levels of scale-up for each demonstration facility to the same schedule. Integrating the RD&D for these technologies is essential, since all technologies must demonstrate routine performance for LMFBR to be commercially acceptable on a broad basis.

--Because of the priority of the LMFBR program and its controversial nature, review--within the integrated management and planning framework--and report annually to the Congress on an integrated basis the status of the development of all technologies needed for an LMFBR industry.

--In the annual report to the Congress, discuss the implications of the findings on the relationship of these technologies to other energy RD&D programs, in terms of the budgetary cost and other priorities.

--Develop, where applicable, similar integrated management and planning approaches for other energy RD&D programs which have as their goal commercial acceptability. These approaches should consider the total range of technological development and institutional acceptance required to bring about a commercial industrial infrastructure.

AGENCY COMMENTS

ERDA and NRC commented on this report. We considered their comments in completing this report. We believe there are no residual differences in fact.

In its comments, ERDA noted that the report was correct in pointing out that closing the LMFBR fuel cycle expeditiously is a critical determinant to the overall success of the LMFBR program and that internal program reviews had come to the same conclusion. ERDA stated it is undertaking efforts to provide a more integrated approach to each part of the program. ERDA further stated that the current LMFBR program plan now takes into account more fully the timing and rate of introduction of commercial fuel cycle facilities, with the goal of commercializing all parts of the LMFBR fuel cycle.

ERDA also pointed out that many of the schedules and plans referenced in the report are now out of date but that the major recommendations are still well taken. (See app. III.)

We note that recent program documentation does take into account more fully the LMFBR fuel cycle, in particular fuel fabrication and fuel reprocessing. We believe this is a step in the right direction and will closely watch these new planning and implementing activities.

THE LMFBR FUEL CYCLE

BACKGROUND

In the introductory years of operation, the plutonium to fuel LMFBRs is expected to come from the recycle of spent fuel from light water reactors. The experience of the LWR industry in plutonium recycle therefore holds important implications for an LMFBR industry.

Plutonium recycling for light water reactors

Plutonium recycling could reduce the fuel requirements of the LWR industry by 25 to 30 percent, thereby decreasing the need for uranium mining and milling and for uranium enrichment, a process that consumes extremely large amounts of electricity. Since the nuclear electric industry began in 1960, however, only one civilian LWR fuel reprocessing plant has been in operation. That plant, Nuclear Fuel Services (NFS) of West Valley, New York, was closed for remodeling after only a few years of intermittent operation. A second civilian plant, built by General Electric at Morris, Illinois, was never able to start operating properly and has now been abandoned, with some of its facilities converted for storage of unprocessed spent fuel. A third installation for reprocessing uranium only from LWRs is being built by Allied-General Nuclear Services (AGNS) in Barnwell, South Carolina. Another reprocessing plant has also been proposed by the Exxon Nuclear Company on a site near Oak Ridge, Tennessee. At present, no complete reprocessing installations are operating in the United States.

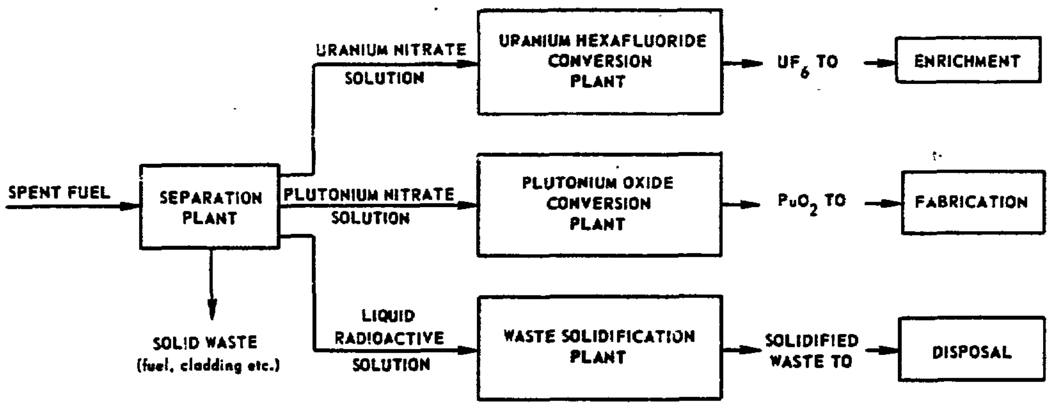
The LWR industry did not anticipate this lack of reprocessing facilities and the ensuing need for storage of large amounts of unprocessed and highly radioactive spent fuel. In some cases, powerplants have been faced with shutdowns because remaining space in storage basins is needed for emergency removal of fuel from the reactor. Constructing additional spent fuel storage capacity, which also requires NRC licensing, results in additional costs for LWR power, instead of the anticipated credits accruing from the value of plutonium in spent fuel.

Government participation in commercial fuel reprocessing was not thought necessary in the early 1960s, when it was assumed that industry would successfully develop reprocessing facilities as they became necessary. Recognizing the current problems of the industry, ERDA has now established the LWR Fuel Cycle Branch in the recently reorganized Division of

Nuclear Fuel Cycle and Production to assist in commercializing of LWR fuel reprocessing.

The diagram below represents the required configuration of facilities for reprocessing spent fuel.

SPENT FUEL REPROCESSING



The installation which most closely approximates this is the AGNS plant. That installation has a fuel separation plant and a uranium hexaflouride plant ready for licensing. The design of an LWR plutonium reprocessing facility to be collocated with the uranium reprocessing facility at Barnwell is about 30 percent complete.

NRC officials told us that the earliest date by which existing AGNS facilties could be licensed to operate is mid-1978. NRC officials also estimate that the NFS installation could be licensed to resume reprocessing operations by 1979 at the earliest. 1/

But even if LWR fuel reprocessing begins operation at the earliest date now considered likely, further questions on safety, safeguards, and environmental effects must be resolved before the plutonium from that fuel could be recycled.

In August 1974 the Atomic Energy Commission (AEC)(predecessor to NRC) issued a draft Generic Environmental Statement on Mixed-Oxide Fuel (GESMO). After receiving extensive comments on the draft, NRC directed its staff to prepare a

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1/In September 1976 Nuclear Fuel Services announced it was no longer reprocessing spent reactor fuel and was abandoning its West Valley reprocessing plant.

partial final GESMO on health, safety, and environmental matters. This document was issued on August 31, 1976. NRC staff members were also asked to prepare a supplemental environmental statement and to propose interim regulations for safeguards to prevent improper plutonium diversion. This is a very serious matter, since plutonium, unlike the slightly enriched uranium used as LWR fuel, can be made into nuclear weapons. A draft environmental statement on safeguard matters, supplementing the final statement on health, safety, and environmental matters, is scheduled to be issued for public comment at the end of November 1976.

Proposed regulations authorizing the use of mixed-oxide fuel in LWRs have been issued. However, a final decision on whether to implement the rules will not be made until issuance of the final safeguards supplement to GESMO, currently scheduled for early 1977. Uncertainty about this decision has apparently restrained the industry from building or even designing plutonium conversion plants. It would, therefore, be some years after the GESMO decision before any commercial plutonium recycling could occur.

MATERIALS AND FACILITIES REQUIRED FOR THE LMFBR FUEL CYCLE

Plutonium requirements and supply

Each commercial-size (2,000 MWe) LMFBR will have a core containing 40 metric tons (MT) of heavy metal (uranium and plutonium), of which 4 MT, or 10 percent, will be plutonium. 1/ This will be surrounded by a blanket of some 80 MT of uranium.

Fabrication of fuel for each new core would begin 2 years in advance of reactor operation, requiring 800 kilograms (0.8 MT) of plutonium in the first year and the remaining 3.2 MT in the year before the reactor begins operation. In each year of reactor operation, some core fuel and blanket material will be removed and sent for reprocessing. The replacement core fuel each year would amount to 18 MT of heavy metal, including 1.8 MT of plutonium; 20 MT of uranium blanket would also be replaced annually.

If one takes as a basis the timing and rate of commercial LMFBR introduction envisioned by the GAO Optimistic Scenario, the amount of plutonium required each year for

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1/ Quantities of material in reactors were derived by averaging estimates submitted to ERDA by two potential commercial manufacturers.

commerical LMFBR operation can readily be determined. (Although three scenarios were developed for this report, the GAO Optimistic Scenario is singled out here because it closely parallels current ERDA projections. Of course, this same analysis can be applied to any alternative scenario simply by substituting the start date for introduction and making all other necessary time adjustments.)

Table I-1, lines d through g, itemizes the quantities of plutonium required to fuel the 128 reactors anticipated over the period of commercial introduction specified in the GAO Optimistic Scenario. The total amount of plutonium required each year, adding that in reactors to the amount proceeding through fabrication plants is shown in line h of the table. Line i shows the amounts of plutonium expected to be available from LWR recycle to meet LMFBR requirements. 1/

Comparing the amounts of plutonium shown in lines h and i reveals that the LMFBR plutonium requirements in the introductory years can be met with plutonium recycled from LWRs--if all required LMFBR fuel cycle facilities are operating by the time they are needed.

For example, line h shows that, in the year 2000 when 24 LMFBRs will be operating, a total of 175.2 MT of plutonium will be required, of which 96 MT will be required for reactors (line d) and 79.2 MT for fuel fabrication. Line i shows that 370.2 MT of plutonium will be available from LWRs to meet this requirement.

Fuel fabrication

LMFBR fuel, a mixed-oxide of about 10 percent plutonium oxide and 90 percent uranium-oxide, has been manufactured commercially on a small scale for the Fast Flux Test Facility in two small plants with capacities of a few metric tons of

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1/In a February 1975 update of WASH-1139 (74), ERDA projected the future of the nuclear electric industry to the year 2000 under four different sets of growth assumptions. The "Moderate Growth-Low" projections in that report also correspond to the rate of overall nuclear electric growth envisioned in ERDA's Intensive Electrification Scenario (ERDA-48). On the basis of these projections, line i reflects the difference between the total amounts of plutonium to be produced in LWRs, less that to be recycled to LWRs and other uses.

APPENDIX I

TABLE I-1

PLUTONIUM FOR COMMERCIAL LMFBRS (Introductory Period)-REQUIREMENTS AND UTILIZATION

GAO OPTIMISTIC SCENARIO

NOTE

Note a) These figures will be larger in the event a major LMFBR industry is introduced and continues to grow. Since this table only treats the introductory period of the industry it has been cut off at the level of 128 plants of 2000 MWe capacity each

YEAR	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
a) New LMFBRs Starting Operation					1	1	2	4	4	4	8	8	13	19	27	37	0*	0*
b) LMFBRs Previously Operating						1	2	4	8	12	16	24	32	45	64	91	128	128*
c) Total LMFBRs in Operation					1	2	4	8	12	16	24	32	45	64	91	128	128*	128*
PLUTONIUM REQUIRED FOR LMFBRs (Metric Tonnes)																		
d) Pu in reactors					4	8	16	32	48	64	96	128	180	256	364	512	512*	512*
e) Pu Being Fabricated for New Reactors			0.8	4.0	4.8	9.6	16	16	19.2	32	36	56.8	82.4	116	118.4*	0*	0*	0*
f) Pu in Process for Fuel Reloading					1.8	1.6	7.2	14.4	21.6	28.8	41.2	57.6	81	115.2	163.8	230.4	230.4*	230.4*
g) Pu in Fabrication (e + f)			0.8	4.0	6.6	11.2	23.2	30.4	40.8	60.8	77.2	114.4	163.4	231.2	282.2*	230.4*	230.4*	230.4*
h) Total Pu Required (d + g)			0.8	4.0	10.6	21.2	39.2	62.4	88.8	124.8	175.2	242.4	343.4	487.2	646.2*	742.4*	742.4*	742.4*
i) Cumulative Pu available for LMFBRs From LWRs	23.2	29.5	38.6	49.3	67.2	94.1	131.0	178.7	235.0	298.1	370.2	445	525	610	700	795	895	1000
PLUTONIUM BREEDING AND SPENT FUEL																		
j) Pu Released Annually in Spent Fuel						2.2	4.4	8.8	17.6	26.4	35.2	52.8	70.4	99	140.8	200.2	281.6	281.6*
k) Cumulative Pu in Spent Fuel If No Large Reprocessing								4.4	17.6	39.4	70.2	118.6	184.6	279.2	415.6	611.4	888.6	1166.8*
m) Excess Pu Bred Annually						4	.8	1.6	3.2	4.8	6.4	9.6	12.8	18	26.6	36.4	51.2	51.2*
n) Cumulative Excess Pu Bred (sum of m)						4	1.2	2.8	6.0	10.8	17.2	26.8	39.6	57.6	83.2	119.6	170.8	222*

SOURCES AND ASSUMPTIONS

a)-c) NEW LMFBRs STARTING. Based on the *GAO Optimistic Scenario* final design and licensing process (Nuclear Facility Implementation Process Step 2) for first commercial LMFBRs begins in 1984, the first year of CRBR operation. The first plant begins operation in 1994. The *rate* of introduction is based on the *ERDA March 1975 Scenario*. "the first breeder becomes operational in 1987 and the aggregate capacity doubles annually until about 1990 and every two years thereafter until 1998."

d)-h) PLUTONIUM REQUIREMENTS. In units of 1000 kilogram (kg) = 1 metric tonne. Quantities derived by averaging estimates submitted to ORRO ERDA by two potential commercial manufacturers. A 2000 MW(e) plant would have 4000 kg of plutonium in its core which must be available in advance for fabrication, 800 kg two years early and 3200 kg in the year before operation. Reloading to replace spent fuel would occur annually, requiring 1800 kg of Pu which would have to be available in the previous year for fabrication.

i) PLUTONIUM AVAILABILITY. Plutonium generated in light water reactors (LWRs) is expected to serve LMFBRs requirements. ERDA's Office of Planning and Analysis has projected plutonium recovery to the year 2000 under four different sets of growth assumptions of the nuclear electric industry. (February 1976 update of *WASH 1139 (74)*)

The highest rate of overall nuclear electric capacity growth which ERDA considers likely in the event of major national commitment to electricity *(Scenario III Intensive Electrification ERDA 48 vol I* p. B 17, June 1975) corresponds to the assumptions of the second set of projections in the February 1976 update of *WASH 1139 (74)- THE "MODERATE GROWTH (LOW)"* case.

The amounts of plutonium to be produced in LWRs less that to be recycled to LWRs and to other uses, were obtained from the updated *WASH 1139 (74)* projections and subtracted to give line i the cumulative Pu to be available for LMFBRs from LWRs.

Beyond the year 2000 it is assumed that annual additions of available LWR Pu will continued to grow by increments of 5 metric tonnes per year to 75 tonnes in 2001, 85 tonnes in 2003, and 100 tonnes in 2007. These assumed increments are smaller than those for the immediately preceding years.

j)-n) PLUTONIUM BREEDING AND SPENT FUEL. Assumes that 1800 kg of plutonium in new fuel loaded each year in each LMFBR would replace spent fuel (j) containing 2200 kg of Pu for a net of 400 kg of excess Pu bred per reloading (m). This gain is optimistic for early plants but it is a reasonable average since it should be reached with second generation fuels intended to be available after several years of large plant experience.

The total amount of excess Pu bred (line n) would be used in refueling reactors so the actual requirements would be less than shown in line h, since excess bred Pu would serve instead of new supply.

If reprocessing is only carried on in the Hot Pilot Plant (Scheduled for 1985 by ERDA with maximum capacity about 75 metric tonnes/yr. of heavy metal containing about 4.4 tonnes of Pu) then starting in 1997 the amount of Pu above 4.4 tonnes would accumulate in spent fuel (line k).

COMMENTS

1 Line g) FUEL FABRICATION. The amount of plutonium to be fabricated into fuel each year both for reloading of operating reactors and for filling the cores of new reactors is shown in line g). Fabrication plants will have to be available to meet this requirement. The capacity of thruput of a fuel fabrication plant is generally counted on the basis of total heavy metal (uranium plus plutonium) handled per year.

Since standard LMFBR fuel will contain an average of 10 percent Pu and 90 percent U, the plutonium capacity must be multiplied by 5 to obtain the heavy metal capacity. Thus *the required fuel fabrication capacity* will be 132 metric tons year MT yr in 1995, 408 MT yr in 1998, 1634 MT yr in 2002 and more than 2822 MT yr in 2005.

Starting in 2003 the total Pu fuel fabrication capacity required will be larger than that shown in line g; the exact value will depend on the number of additional LMFBRs built after the introductory group shown here.

2 Lines h) k) m) & i) PLUTONIUM REQUIREMENTS AND AVAILABILITY. The plutonium requirements of LMFBRs are expected to be met with the Pu generated in LWRs. Comparison of lines h and i shows that this can be easily achieved through 2003 because the amounts of Pu available from LWRs are larger than the amounts required for the first few dozen LMFBRs. However, as spent fuel discharges increase just after the turn of the century the Pu in spent fuel (line k) would constitute portion of the supply so that, lacking large reprocessing facilities REQUIREMENTS (h + k - n) WOULD EXCEED AVAILABILITY FROM LWRs (i) IN 2004. THIS IS THE YEAR BY WHICH THE FIRST LARGE REPROCESSING PLANT FOR LMFBR FUEL WILL HAVE TO BE OPERATING TO AVOID DELAYS OF LMFBR INTRODUCTION. *ASSURANCES OF AVAILABILITY* of reprocessing will be necessary much earlier (1992 - 1996 time frame) to prevent delays of commitments to construct LMFBRs scheduled for 2000 - 2004 and later. This is quite early in LMFBR commercialization compared to LWR history, where reprocessing is not available 15 years after operation of the first commercial plant.

heavy metal each year. These plants have been supplied with plutonium of relatively low radioactivity, however, and could not operate routinely with the more radioactive reactor grade plutonium. 1/ Even if plutonium recycle facilities were developed for mixed-oxide LWR fuel, the proportion of plutonium in that fuel would be only 5 percent.

The High Performance Fuel Laboratory (HPFL), ERDA's proposed pilot fuel fabrication test facility, is expected to demonstrate high-production, mechanized fuel manufacturing processes which could be used with the more radioactive reactor grade plutonium. The HPFL will not be a major test facility, however, for it is only expected to produce mixed-oxide fuel at a rate of about 3 MT a year of heavy metal.

Fuel fabrication capacity required

Since LMFBR fuel will be one-tenth plutonium, the amount of fuel to be fabricated annually to meet the GAO Optimistic Scenario can be calculated simply as 10 times the amount of plutonium to be made into fuel. The amounts of plutonium to be fabricated annually are listed in line g of table I-1; total fuel requirements are illustrated in figure I-1, with required amounts of plutonium indicated on the left side of the figure and total amounts of heavy metal on the right side.

The fuel fabrication capacity required to meet this scenario is quite substantial, reaching 132 MT a year in 1995, 792 MT a year in 2000, and over 2,800 MT a year by 2004. By comparison, the annual capacity of an LWR fuel fabrication plant is 200 MT.

The dotted line in figure I-1 illustrates the capacity available to meet these requirements if a first demonstration plant of 75 MT a year capacity were followed by a series of plants of the current 200 MT a year size, each introduced

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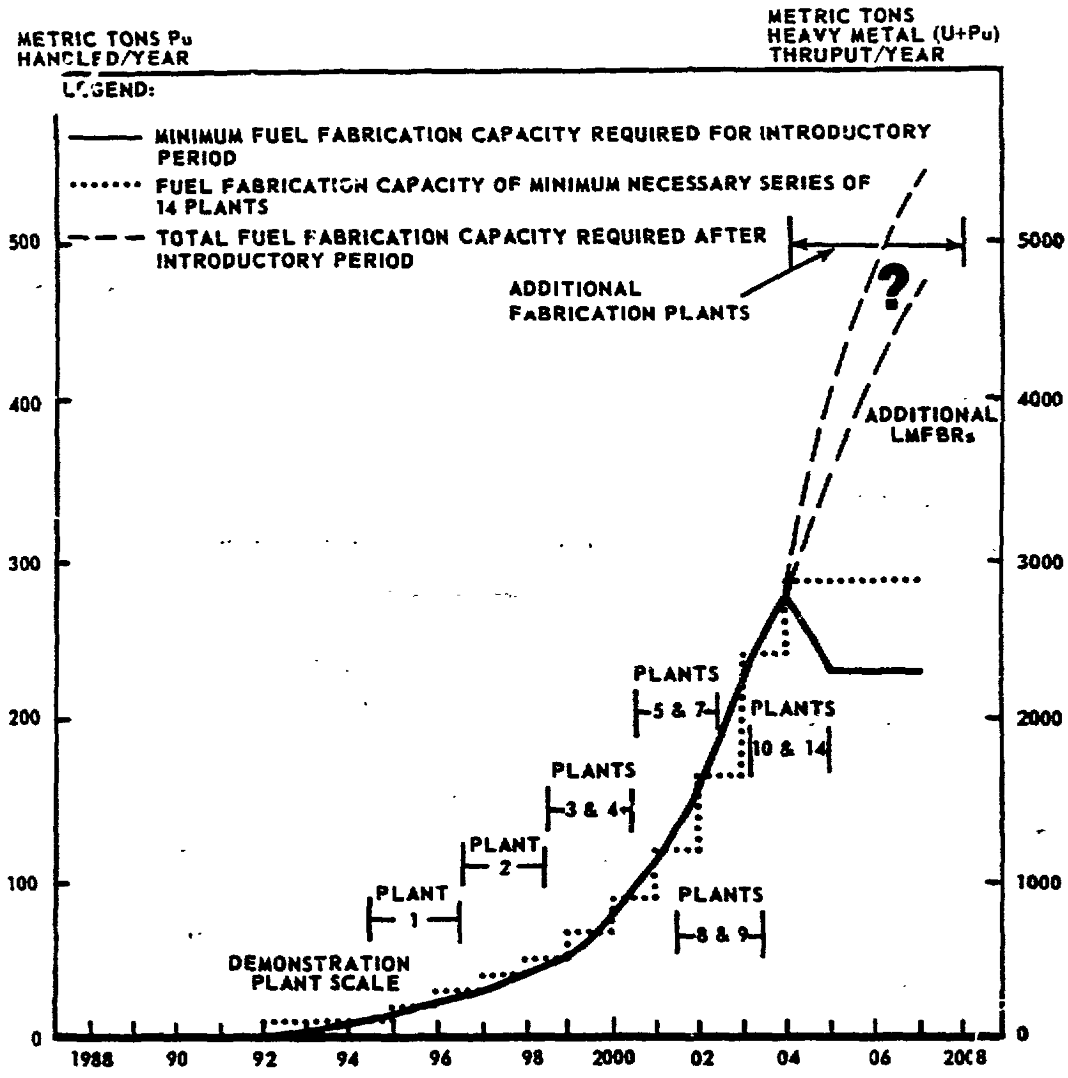
1/When first produced from U-238, plutonium is in the form of Pu-239, an isotope whose radioactivity is not penetrating. However, when this isotope remains in a reactor environment for the usual amount of time, it is transformed first to Pu-240 and then to Pu-241 until an equilibrium is reached. At this equilibrium, some 20 to 25 percent of the plutonium will be present as the Pu-240 isotope, and about 10 percent as the Pu-241 isotope. The higher isotopes give off more penetrating radiation, so that work with this reactor grade plutonium requires more shielding and/or more mechanized processes.

FIGURE I-1
FUEL FABRICATION CAPACITY REQUIRED TO ACHIEVE LMFBR COMMERCIALIZATION
GAO OPTIMISTIC SCENARIO



TIMING AND CAPACITY OF FUEL FABRICATION FACILITIES REQUIRED FOR COMMERCIALIZATION OF LMFBRs; INTRODUCTORY PERIOD AND BEYOND; GAO OPTIMISTIC SCENARIO

THE SOLID CURVE SHOWS THE MINIMUM FUEL FABRICATION THRUPUT WHICH WILL HAVE TO BE AVAILABLE EACH YEAR TO MEET THE FUEL REQUIREMENTS OF THE INTRODUCTORY GENERATION OF LMFBRs ENVISIONED IN THE GAO OPTIMISTIC SCENARIO. BEYOND 2003 THE TOTAL FUEL FABRICATION THRUPUT REQUIRED WILL DEPEND ON THE RATE OF DEPLOYMENT OF ADDITIONAL LMFBRs BEYOND THE INTRODUCTORY GENERATION OF 128 REACTORS OF 2000 MWe EACH. THIS UNCERTAINTY IS SHOWN BY THE DASH CURVES AND "?" MARK.

THE DOTTED LINE SHOWS THE THRUPUT WHICH WOULD COME FROM A SERIES OF 14 FUEL FABRICATION PLANTS OF ABOUT CURRENT SIZE (200 METRIC TONS OF HEAVY METAL (U+Pu) PER YEAR), EACH INTRODUCED OVER A 2-YEAR PERIOD. THESE PLANTS ARE TIMED TO START OPERATION AS NEEDED TO MINIMALLY MEET REQUIREMENTS OF THE SOLID CURVE SCENARIO.

over a 2-year period. Within the decade spanning 1995 to 2004, a total of 14 such plants would have to be operating to meet the requirements of this scenario.

Reprocessing spent LMFBR fuel

To realize the advantages of the breeder system, the spent fuel released from reactors will have to be reprocesed and the newly bred fuel promptly recycled into reactors.

Once reactors begin to generate more plutonium than they consume, total plutonium supply will increase. The spent fuel released each year from each 2,000-MWe LMFBR--18 MT from the reactor core and 20 MT from the blanket--will contain 2.2 MT of plutonium. Since only 1.8 MT is needed to replace the plutonium removed from the core, each reactor will generate 0.4 MT (400 kilograms) of excess plutonium each year. 1/

As this excess plutonium accumulates and is recycled in the operating LMFBRs, less plutonium will actually be required than the amount previously calculated. For example, if LMFBRs are introduced according to the GAO Optimistic Scenario, by 2003 nearly 60 MT of excess plutonium will have been bred, and the total plutonium requirements will be lowered from 487.2 MT to less than 430 MT. The amounts of excess plutonium bred annually by the assumed groups of LMFBRs are listed in line m of table I-1; the cumulative total is listed in line n.

An important point to note is that by 2005, when all the LMFBRs of the introductory group are operating, they would annually breed 51.2 MT of excess plutonium. This excess amount could serve to fuel eight or nine additional reactors of the same size each year 2/, allowing the LMFBR industry to grow at a considerable rate with no additional supplies of plutonium required.

1/Our analysis assumes a gain of 0.4 MT a year for each of the 128 LMFBRs. Although this is somewhat optimistic for early plants, it is a reasonable average to be reached with advanced fuels expected to be available after several years of large-plant experience.

2/Assuming the requirements will be 4 MT of plutonium for each core and 1.8 MT of plutonium for refueling each reactor.

Reprocessing facilities required for LMFBRs

Since each operating reactor will annually release 38 MT of heavy metal, the reprocessing capacity required for commercial LMFBR fuel can be easily estimated. In 1999, with 16 reactors operating, a total of 608 MT will be released for reprocessing; in 2003 the 64 operating reactors will release 2,432 MT of spent fuel; by 2005, with the full introductory group of 128 reactors operating, the annual amount of spent fuel requiring reprocessing will rise to 4,864 MT.

Assuming that the annual reprocessing plant capacity will be 1,500 MT--the size of LWR reprocessing plants currently being designed--a first plant would be needed in the late 1990s to meet the requirements of the GAO Optimistic Scenario. This plant would reach full capacity by 2002-03, when a second plant could come into use. By 2004-05, a third plant would be needed, which would reach capacity by 2005-06. After that, as additional LMFBRs are built beyond the introductory group, greater reprocessing capacity would be necessary.

Effect of timing of reprocessing facilities

It will be critically important to an LMFBR industry to have reprocessing facilities operating on a timely basis. If newly bred plutonium is promptly recycled back into reactors, the available plutonium will be enough to meet the requirements of the industry.

If, on the other hand, reprocessing facilities are not available as required, spent fuel would accumulate and increasing amounts of plutonium would be captive in unprocessed fuel, possibly resulting in fuel shortages for new or existing reactors. 1/

Operation of the three large reprocessing plants by 1999, 2004, and 2006, respectively, would leave only relatively

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1/ An additional problem arising from unprocessed spent fuel is that the plutonium will contain about 8 to 10 percent Pu-241. Although a useful fissionable isotope of plutonium, Pu-241 decays naturally, with a half-life of 13 years, to americium-241. Allowing spent fuel to stand will result in a buildup of the americium decay product, which would represent a waste of the useful Pu-241 as well as another source of radioactive waste products with undesirably long half-lives.

small amounts of spent fuel unprocessed for reasonably short times; therefore, those years have been taken as the target dates for the required plants. Figure I-2 shows the potential effects on plutonium availability if reprocessing plants become operational by these target dates or later.

The solid curve in figure I-2 shows the supply of plutonium anticipated from light water reactors. If three 1,500-MT reprocessing plants start operation in 1999, 2004, and 2006 (lowest requirements curve), plutonium supply would amply meet reactor fuel requirements.

The second requirements curve, just skirting the supply curve for several years, would hold if the three plants were brought into operation in 2002, 2005, and 2007, representing delays of 3 years, 1 year, and 1 year, respectively.

The third requirements curve, lying well above the supply curve from 2003 to 2007, would hold if the three plants did not begin operation until 2004, 2006, and 2007 --delays of 5 years, 2 years, and 1 year, respectively.

The top requirements curve, crossing the supply curve in 2002 and steadily diverging from it, would hold if no reprocessing plants were operating until 2007, a delay of 8 years.

The shaded areas show plutonium deficits that would occur in the event of a 5-, 2-, and 1- year delay in reprocessing plant operation (double shading), or an 8- year delay (single shading).

As can be seen, only a 3-year delay in starting the first reprocessing plant would eliminate any margin for error or breakdowns, while any longer delay would result in requirements exceeding the supply. Unless additional sources of plutonium were found, such a shortfall could temporarily halt the growth of the LMFBR industry and put existing reactors out of operation.

Radioactive waste disposal

Problems of radioactive waste management are generic to all nuclear reactors; the commercial introduction of LMFBRs would only increase the urgency of finding prompt solutions to waste disposal needs.

One of the advantages the LMFBR promises to show over present LWRs is its ability to more efficiently convert portions of nuclear waste products into new fuel. Plutonium

PLUTONIUM REQUIREMENTS FOR GAO OPTIMISTIC SCENARIO OF LMFBR INTRODUCTION, COMPARED TO ANTICIPATED SUPPLY, SHOWING THE IMPACT WHICH WOULD ARISE IF LMFBR FUEL REPROCESSING PLANTS ARE NOT AVAILABLE AS REQUIRED TO RECYCLE PLUTONIUM FROM SPENT FUEL BACK TO REFUEL REACTORS.

The solid curve shows the supply of plutonium anticipated to be available, generated from light water reactors. The lowest requirements curve (— —) would hold if three reprocessing plants of capacity 1500 MT/yr (heavy metal) began operation in 1999, 2004 and 2006 respectively. The second requirements curve (-—-), just skirting the supply curve for several years, would hold if the three plants were brought into operation in 2002, 2005 and 2007 respectively, corresponding to delays of three years, one year and one year. The third requirements curve (•••••), lying well above the supply curve from 2003 to 2007, would hold if the three plants began operation in 2004, 2006 and 2007 respectively, delays of five years, two years and one year. The top requirements curve (-—-) crossing the supply curve in 2002 and steadily diverging from it, would hold if no reprocessing plants were operating by 2007, a delay of eight years. The shaded areas show plutonium deficits which would obtain in the event of the five-year-two-year-one-year delay of reprocessing plants (double shading), or the eight-year delay (single shading).

SOURCES.

Plutonium generated in light water reactors (LWRs) is expected to supply LMFBR requirements. The plutonium supply curve here, or estimate of the amount of LWR-generated plutonium expected to be available to fuel LMFBRs, is drawn from analyses of future growth of the nuclear electric industry made by ERDA's Office of Planning and Analysis.

Quantities of plutonium required for the LMFBRs of the introductory generation envisioned in the GAO Optimistic Scenario were derived by averaging quantities estimated in two designs submitted to DRRD/ERDA by potential commercial manufacturers of reactors.

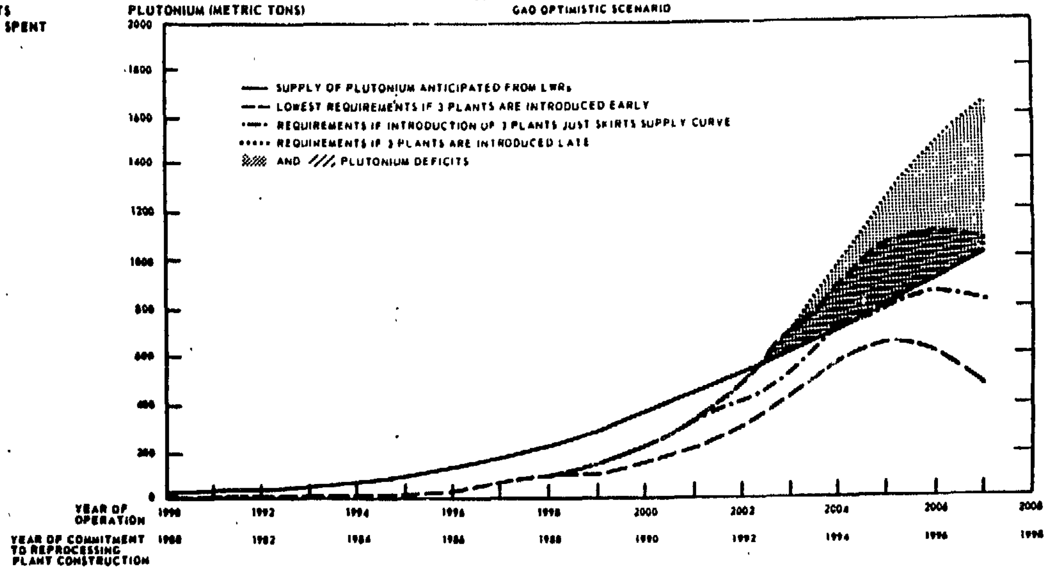
Minimum requirements are those which would prevail if reprocessing plants were operating in time to allow plutonium generated in LMFBRs to be reprocessed and recycled into reactor fuel within a year after spent fuel was released from LMFBRs.

Larger requirements would prevail if large-scale reprocessing plants were not operating during the time period covered. In that event, starting in about 1999 substantial quantities of plutonium would accumulate in stored spent fuel and additional new plutonium would have to be supplied to meet fuel requirements of LMFBRs. The extent of accumulation of plutonium in spent fuel would depend on the number of years of delay in availability of reprocessing plants.

FIGURE I-2

IMPACT OF AVAILABILITY OF REPROCESSING

GAO OPTIMISTIC SCENARIO



COMMENT:

The supply of LWR-generated plutonium can meet introductory generation LMFBR requirements if reprocessing plants are available in time to prevent much accumulation of plutonium in spent fuel. However, only a three-year delay in starting the first reprocessing plant would eliminate any margin for error or breakdowns, while any longer delay would result in requirements exceeding supply. Such a shortfall could temporarily halt growth of the LMFBR industry, as well as put existing reactors out of operation for lack of fuel for reloading, unless additional sources of plutonium were found.

If reprocessing is operating as needed, then requirements for externally supplied plutonium will actually decline in later years, as shown in the minimum curve, i.e., the first generation breeders will be able to provide fuel to other reactors as well as refuel themselves.

APPENDIX I

reprocessing essentially separates the fissile isotopes of Pu-239 and Pu-241--and refabricates them for use as reactor fuel. Those nonfissionable elements remaining are highly radioactive and require isolation for about a half million to a million years.

These high-level wastes are initially dispersed in chemical solutions but are required to be reprocessed into solids for disposal. Current NRC regulations stipulate that high-level radioactive waste be stored as liquids for no more than 5 years; a solidified product, stored in high-integrity containers, must be delivered to ERDA within 10 years after fuel processing. NRC has also recently proposed a regulation which would require that radioactive waste, converted to solid form if necessary, be transferred to ERDA no more than 5 years after generation.

Although the technology for processing these wastes into glass or other ceramic forms has been developed, it has been demonstrated only on a pilot scale with simulated waste. Methods for dealing with radioactive gaseous effluents are also being explored in current R&D efforts.

Low-level wastes, which include pumps, pipes, clothing, and other materials exposed to the radioactive environment, also require disposal. Compaction and subsequent burial is one widely used means of disposal. For those materials which are combustible, R&D is still needed to develop technology which can screen out plutonium particles before burning.

Disposal facilities

In 1972 the former Atomic Energy Commission initiated a program to develop retrievable surface storage of high-level wastes at a central Federal site. An environmental impact statement prepared in 1974, which outlined the design and construction of this facility was, however, criticized for failing to sufficiently consider the ultimate disposal of waste. Until a new generic environmental impact statement is completed, ERDA has deferred its retrievable surface repository work and has instead decided to accelerate the development of repositories in deep, stable geologic formations.

Current ERDA plans call for the investigation of several potential disposal sites in different types of geologic formations. A pilot facility is planned for operation in late 1983, probably at a site to be developed in southeastern New Mexico. ERDA plans to develop up to six other pilot facilities between 1985 and 1991, from which one or more will be chosen as disposal repositories. High-level wastes will be transported and stored in canisters measuring approximately 1 foot in diameter and 10 feet in length, with a volume of 6.25 cubic feet. These canisters will be stored in the pilot facilities until disposal sites are chosen.

Until disposal sites are identified, only tentative estimates can be made of the capacity that will be available for storage of wastes generated by a commercial LMFBR industry. Since each 2,000-MWe LMFBR is expected to generate 152 cubic feet of high-level radioactive waste a year, we calculate that 10,385 canisters will be needed to store the cumulative wastes generated by 128 LMFBRs. Three or more disposal facilities probably will be necessary to accommodate this level of waste production.

As one part of a comprehensive statement on nuclear policy, the President, on October 28, 1976, directed ERDA to take the necessary actions to speed up the program to demonstrate all components of waste management technology by 1978 and to demonstrate a complete respository by 1985. He also directed that plans for the repository by submitted to NRC for licensing to assure its safety and acceptability.

THE NUCLEAR FACILITY LICENSING PROCESS

MAJOR ELEMENTS

The Nuclear Regulatory Commission is responsible for licensing a nuclear facility for construction and operation at the proposed location without undue risk to the health and safety of the public. The licensing process is similar for all nuclear facilities and basically divides into two phases: a preconstruction review, leading to a construction permit, and the contruction process itself, leading up to an operating license.

Preconstruction review

The preconstruction review process encompasses two simultaneous reviews: (1) safety and (2) environmental acceptability, including [illegible] suitability. For reactor and plutonium reprocessing facilities, an antitrust review is also conducted.

Safety

At the outset, the applicant is required to prepare a Preliminary Safety Analysis Report (PSAR) and supporting documentation, usually in consultation with NRC. When the PSAR is considered [illegible], NRC dockets the application (i.e., places it on their [illegible] schedule) and begins its review.

On the basis of that review, NRC prepares a Safety Evaluation Report (SER). For reprocessing and reactor facilities, NRC forwards the application to the Advisory Committee on Reactor [illegible] (ACSR) for examination.

After comment [illegible] from ACSR and others, NRC prepares a supplemental [illegible] which incorporates all additional findings. The final stage of the process is a public hearing conducted by the Atomic Safety and Licensing Board (ASLB).

A finding of safety is based on:

--adequacy and soundness of design for operation under normal conditions.

--adequacy of [illegible] against the occurrence of accidents [illegible]

--adequacy of accommodation of low-probability accidents with acceptable consequences.

Environmental acceptability and site suitability

The applicant must conduct appropriate meteorological, radiological, water, and other site surveys; collect environmental data; and obtain approval from State and local authorities. On the basis of this information, the applicant prepares an Environmental Report (ER) which should demonstrate the environmental acceptability of the project and the suitability of the proposed site.

NRC prefers that the safety PSAR and environmental ER documentation be docketed at the same time, but it has permitted certain site work on light water reactors before the safety review is completed to accelerate construction.

After a review of the ER, NRC prepares a Draft Environmental Statement (DES). When all comments have been reviewed, a Final Environmental Statement (FES) is issued.

A generic environmental statement may be prepared initially to cover considerations common to a number of nuclear facilities of the same type. Individual environmental statements are then prepared for specific facilities and sites. NRC is currently preparing a generic environmental statement for plutonium reprocessing facilities, which includes considering the use of mixed plutonium oxide in LWRs, the reprocessing of mixed oxide fuel and mixed oxide fabrication plants. Current ERDA plans also include a generic environmental statement for radioactive waste disposal facilities.

NRC is now encouraging architect-engineer firms, reactor manufacturers and electric utilities to develop a generic safety review of standardized nuclear plants. Such reviews are now under way on five different reactor designs. If these standardized designs are approved, utilities willing to buy standardized plants will be able to accelerate the licensing process by attaching site-specific supplements to the approved standard documentation.

The ASLB once again conducts any public hearings required. Safety and environmental issues can be separated or accommodated in one set of hearings. If all issues have been satisfactorily resolved, NRC grants a construction permit.

For reactor facilities only, the applicant may submit the Environmental Report in advance of the PSAR to obtain a Limited Work Authorization (LWA). Consistence between the environmental and safety reports must be verified before the public hearings are held on the issuance of an LWA. Separate public hearings are required on the safety aspects of the reactor before a construction permit can be issued.

Under an LWA, site preparation and nonnuclear construction may be accelerated by as much as a year. ERDA is expecting to proceed with the development of the Clinch River Breeder Reactor under an LWA; it anticipates following the same procedure for the near-commercial and early commercial LMFBRs as well.

Antitrust

For reactor and plutonium reprocessing facilities, an antitrust review is conducted by NRC's Office of Antitrust and Indemnity, with advice from the U.S. Attorney General's Office. In July 1975 authorizing legislation was amended to require that antitrust documentation be submitted to NRC from 9 to 36 months before the safety and environmental parts of the application.

The objective of the review is to determine "whether activities under license (permit) would create or maintain a situation inconsistent with the antitrust laws." As part of this process, the Justice Department conducts public hearings for about 12 months. ASLB also conducts public hearings and makes an initial decision. NRC issues the decision before concluding all public hearings on the safety and environmental aspects of the proposed facility.

NRC experience indicates that the antitrust review takes the longest period of time and requires the longest public hearings.

Operating license review

The operating license review process deals with final design and operation of the facility, including the possession and handling of radioactive materials. The applicant prepare revised ER and a Final Safety Analysis Report (FSAR), althoug NRC staff members prepare an FES and an SER.

For fuel fabrication and plutonium reprocessing facilities, applicants request a materials license for the use of either natural or depleted uranium for "cold runs" to test and refine equipment and processes while operating license review is under way.

Once the operating license is issued, NRC inspectors continue to conduct surveillance of operating personnel licenses, safety, security, safeguards, quality assurance and other operational programs for the life of the facility.

LMFBR FACILITY LICENSING

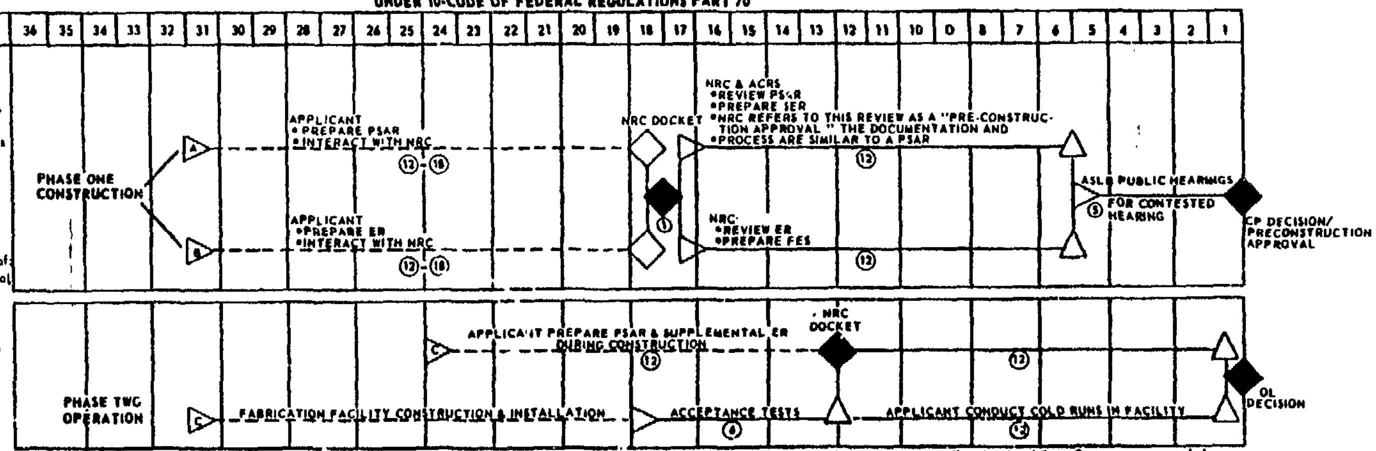
The amount of time required for the licensing process for each of the four required LMFBR facilities is shown in the following charts: figure II-1 describes the licensing process for fuel fabrication facilities; figure II-2, for reactors; figure II-3, for plutonium reprocessing facilities; and figure II-4 for disposal facilities for radioactive wastes.

These NRC estimates are based on over 15 years' experience with LWRs and their supporting facilities. Although the LMFPR has many features in common with LWRs, NRC has indicated that any new type of reactor is initially likely to experience longer licensing reviews than the more established LWRs.

The LMFBR also has some distinct characteristics which may lengthen these estimates until enough experience has been acquired by applicants and the NRC. These characteristics include: plutonium as the initial and continuing fuel, more plutonium-heavy isotopes through its fuel cycle, sodium as a coolant, higher power densities, higher temperatures, possible sodium-to-water reactions, and different safety characteristics which may result in different types of accidents.

FUEL FABRICATION FACILITY LICENSING PROCESSES
UNDER 10-CODE OF FEDERAL REGULATIONS PART 70

FIGURE II-1



A **SAFETY**

NRC assesses

1. *Adequacy* of Proposed Facility Safety Standards
2. *Hazards* of Proposed or Existing Reactor facilities

NRC prepares the Safety Evaluation Report (SER).

ASLB conducts any public hearings required.

B **ENVIRONMENT AND SITE SUITABILITY**

NCR assesses implications of:

1. Land use zone, historical architecture, farm, forest, etc.
2. Construction ecology, waterways, soil erosion, etc.
3. Operations effluents – radioactive, thermal, chemical.
4. Possible accidents and consequences.

NRC prepares the DES and FES.

ASLB conducts any public hearings required.

C **OPERATING LICENSE**

The Final Safety Analysis Report (FSAR) is prepared in accordance with the Final Engineering design. Fuel loading or other work with radiologically "hot" material cannot begin until an Operating License is issued.

The OL application process is intended by NRC to occur during construction to avoid delay of operation.

THE NUCLEAR FACILITY LICENSING PROCESS

Overall goal of the process is to insure that "the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public." Code of Federal Regulations 50.35

The Nuclear Facility Licensing Process under 10-CFR Parts 70 and 30 divides into two phases

1. Construction Permit/Pre construction Approval
2. Operating License

CONSTRUCTION PERMIT 'PRECONSTRUCTION APPROVAL

The preconstruction process for Fuel Fabrication and Radiological Waste Disposal Facilities has two lines of review:

1. Safety
2. Environment and Site Suitability

These same reviews apply to all nuclear facilities.

OPERATING LICENSE

The operating license review process deals with the Final Design and operation of the facility including the possession and handling of radioactive materials. In the case of fuel fabrication and reprocessing facilities, applicants can request a materials license to use either natural or depleted uranium for "cold runs" to test and refine equipment and processes while the operating license review is underway.

FUEL FABRICATION FACILITIES

Only seven facilities are presently licensed to fabricate plutonium fuel. All are considered to be of pilot scale capabil .

ASSUM IONS

1. The applicant has fully exercised the responsibility to be familiar with and to comply with requirements of the licensing process prior to tendering the application for a license.
1. Continuing interaction between the applicant's design and engineering functions, the regulatory entity NRC-- and the pertinent State and local agencies.
3. Site selection, as well as local and State Government approvals have been finalized by the applicant prior to tendering application.
4. Preparation of required documentation by the applicant and review by NRC regarding the completeness of the documentation constitutes the CP/license application. The Acceptance Review is repeated at the time of filing the FSAR and Supplemental ER. The milestone for agreement on completeness is called Docketing.
5. Schedule times are based on NRC estimates.
6. Licensing of first-of-a-kind facilities will likely require more time than subsequent applications.

- ▷ FORMALLY INITIATE EFFORT
- △ SIGNIFICANT MILESTONE, MODIFICATION NOT CRITICAL
- ◇ PACING MILESTONE ON CRITICAL PATH OF PROGRAM HAS TOLERANCE FOR SCHEDULE VARIATION
- ◆ CRUCIAL MILESTONE, PROGRAM CANNOT ACHIEVE ITS OBJECTIVE UNTIL THESE REQUIREMENTS HAVE BEEN SATISFIED
- — — PLANNED SCHEDULE
- •••• BAND OF UNCERTAINTY

LICENSING PROCESS NOMENCLATURE

ACRS	Advisory Committee on Reactor Safety
ASLB	Atomic Safety & Licensing Board
CP	Construction Permit
DES	Draft Environmental Statement
DOCKET	Agreement by NRC on Completeness of Documentation for Initiation of the License [illegible]
ER	Environmental Report
FES	Final Environmental Statement
FSAR	Final Safety Analysis Report
LWA	Limited Work Authorization
NRC	Nuclear Regulatory Commission
OL	Operating License Required to Load Fuel or otherwise handle radioactive material, go critical, or otherwise operate the Facility for its intended purpose
PSAR	Preliminary Safety Analysis Report
SER	Safety Evaluation Report
SSER	Supplemental Safety Evaluation Report

APPENDIX II

REACTOR FACILITY LICENSING PROCESSES

USING LWA OPTION UNDER CODE OF FEDERAL REGULATIONS PART 50

FIGURE II-2

MONTHS

A **SAFETY**

NRC and ACRS assess
1. Adequacy of Proposed Facility design
2. Acceptability of potential hazards arising from operation of the Facility.

NRC prepares the Safety Evaluation Report (SER) ASLB conducts any public hearings required

B **ENVIRONMENT AND SITE SUITABILITY**

NRC assesses implications of
1. Land use zone, historical, architecture, farm, forest, etc.
2. Construction ecology, waterways soil erosion, transmission lines, etc.
3. Operations effluents – radioactive, thermal chemical.
4. Possible accidents and consequences

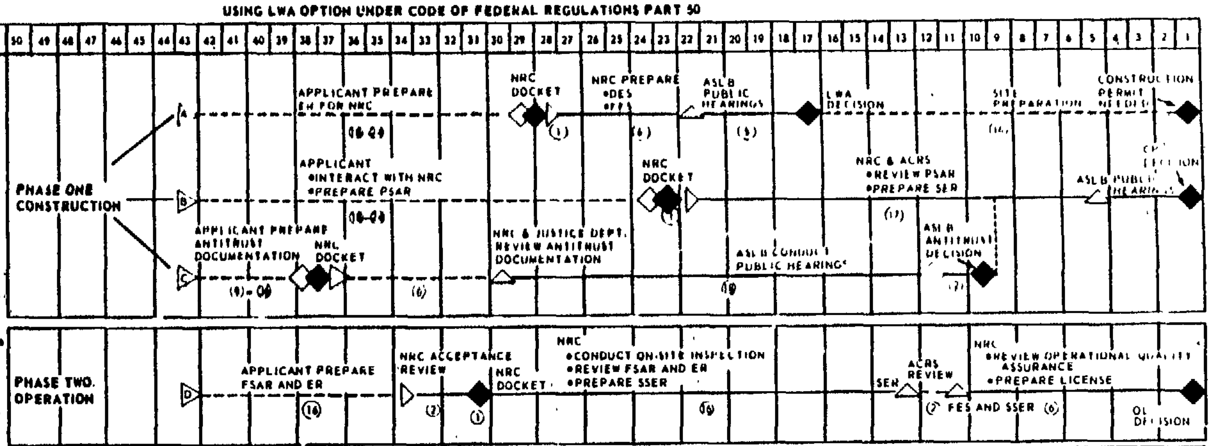
NRC prepares the DES and the FES, ASLB conducts any public hearings required An LWA permits an earlier start for construction. Following LWA, separate hearings on safety are then required for a CP

C **ANTITRUST**
1. NRC and Justice Dept review applicant and application to determine if the "activities under license (permit) would *create or maintain a situation inconsistent* with the antitrust laws."
2. ASLB conducts public hearings.
3. ASLB issues final decision before safety and environmental hearings are completed.
4. *Beginning July 28, 1975, Antitrust* documentation must be submitted 9 to 36 months before the safety and environmental parts of the application.

D **OPERATING LICENSE**

The *Final Safety Analysis Report* (FSAR) is prepared in accordance with the status of the facility as constructed Fuel loading or other work with radiologically "hot" material cannot begin until an Operating License is issued.

The OL application process is intended by NRC to occur during construction to avoid delay of operation.



THE NUCLEAR FACILITY LICENSING PROCESS

Overall goal of the process is to insure that "the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public."

The Nuclear Facility Licensing Process divides into two phases
1. Construction Permit
2. Operating License

PHASE ONE CONSTRUCTION PERMIT

The pre-construction process for Power Reactors and Fuel Reprocessing Facilities has three lines of review under CFR Part 50
1. Safety
2. Environment and Site Suitability
3. Antitrust

The Safety, Environment and Site Suitability Review Processes apply to all nuclear facilities

NOTE A For reactors only, Application for a Limited Work Authorization (LWA) can be made with the ER 6 months prior to docketing the PSAR Consistency between the *ER and PSAR must be verified before LWA public* hearings.

B An LWA enables an earlier start for the construction program Separate public hearings are then required for the safety aspects of the reactor before a CP can be issued

C The LWA option is not available for fuel fabrication, fuel reprocessing, or radiological waste disposal facilities

PHASE TWO OPERATING LICENSE

The operating license review process deals with the facility as finally built and authorizes the possession and handling of radioactive materials. In the case of fuel fabrication and reprocessing facilities, applicants can request a materials license to use either natural or depleted uranium for "cold runs" to test and refine equipment and processes processes while the operating license review is underway.

ASSUMPTIONS

1. *The applicant has fully exercised the responsibility to be familiar* with and to comply with requirements of the licensing process prior to tendering the application for a license.
2. Continuing interaction between the applicant s design and engineering functions, the several regulatory entities – NRC, CEQ, and EPA – and the pertinent State and local agencies.
3. Site selection, local and state government approvals have been finalized by the applicant prior to tendering application
4. *Preparation* of required documentation by the applicant and review by NRC regarding the completeness of the documentation constitutes the CP license application This acceptance review is repeated at the time of filing the FSAR and supplemental ER The milestone for agreement on completeness is called Docketing
5. Schedule times are based on LWR experience and assume LMFBR applicants will be sufficiently prepared prior to tendering the application for a license
6. *Licensing of first of-a-kind facilities will likely require more time* than subsequent applications

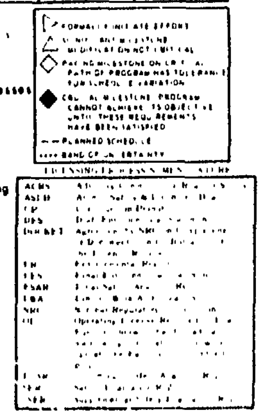


FIGURE II-3

FUEL REPROCESSING FACILITY LICENSING PROCESSES
UNDER CODE OF FEDERAL REGULATIONS PART 50

MONTHS

[A] **SAFETY**

NRC and ACRS assess
1. Adequacy of Proposed Facility Design Standards.
2. Acceptability of potential Hazards arising from operation of the Facility.

NRC prepares the Safety Evaluation Report (SER). ASLB conducts any public hearings required.

[B] **ENVIRONMENT AND SITE SUITABILITY**

NRC assesses implications of
1. Land use zone, historical, architecture, farm, forest, etc.
2. Construction ecology, waterways, soil erosion, transmission lines, etc.
3. Operations effluents – radioactive, thermal, chemical.
4. Possible Accidents and consequences

NRC prepares the DES and FES. ASLB conducts any public hearings required.

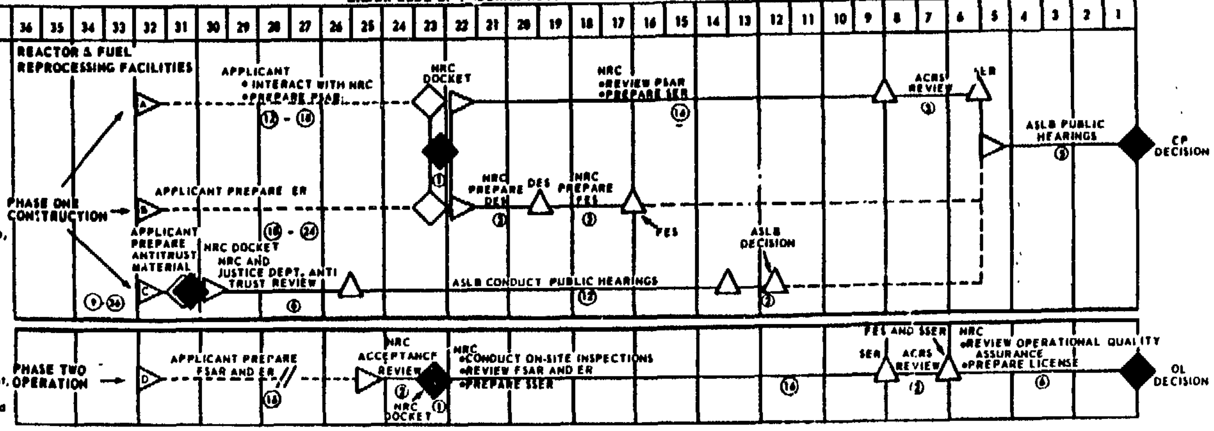
[C] **ANTITRUST**

1. NRC and Justice Dept. review applicant, and application to determine if the "activities under license (permit) would create or maintain a situation inconsistent with the antitrust laws."
2. ASLB conducts public hearings
3. ASLB issues final decision before safety and environmental hearings are completed
4. Beginning July 28, 1975, Antitrust Documentation must be submitted 9 to 36 months before the safety and environmental parts of the application.

[D] **OPERATING LICENSE**

The Final Safety analysis Report (FSAR) is prepared in accordance with the status of the facility as constructed. Fuel loading or other work with radiologically "hot" material cannot begin until an Operating License is issued.

The OL application process is intended by NRC to occur during construction to avoid delay of operation.



THE NUCLEAR FACILITY LICENSING PROCESS

Overall goal of the process is to insure that "the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public."

The Nuclear Facility Licensing Process divides into two phases
1. Pre-construction reviews resulting in a Construction Permit, and
2. Operating License

The licensing process is adapted as appropriate to the facility of interest, fuel fabrication, fuel reprocessing, high and low level waste disposal, and power reactors.

PHASE ONE CONSTRUCTION PERMIT

The preconstruction process for Power Reactors and Fuel Reprocessing Facilities has three lines of review under CFR Part 50
1. Safety
2. Environment and Site Suitability
3. Antitrust

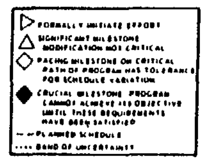
The Safety, Environment and Site Suitability Review Processes apply to all nuclear facilities.

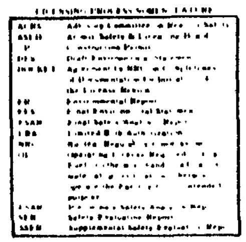
PHASE TWO OPERATING LICENSE

The operating license review process deals with the facility as finally built and authorizes the possession and handling of radioactive materials. In the case of fuel fabrication and reprocessing facilities, applicants can request a materials license to use either natural or depleted uranium for "cold runs" to test and refine equipment and processes while the operating license review is underway.

ASSUMPTIONS

1. The applicant has fully exercised the responsibility to be familiar with and to comply with requirements of the licensing process prior to tendering the application for a license.
2. Continuing interaction between the applicant's design and engineering functions, the regulatory entity -- NRC -- and the pertinent State and local agencies.
3. Site selection, local and State Government approvals have been finalised by the applicant prior to tendering application.
4. Preparation of required documentation by the applicant and review by NRC regarding the completeness of the documentation constitutes the CP license application. This acceptance review is repeated at the time of filing the FSAR and supplemental ER. The milestone for agreement on completeness is called Docketing.
5. Schedule times are based on LWR experience and assume LMFBR applicants will be sufficiently prepared prior to tendering the application for a license.
6. Licensing of first-of-a-kind facilities will likely require more time than subsequent applications.



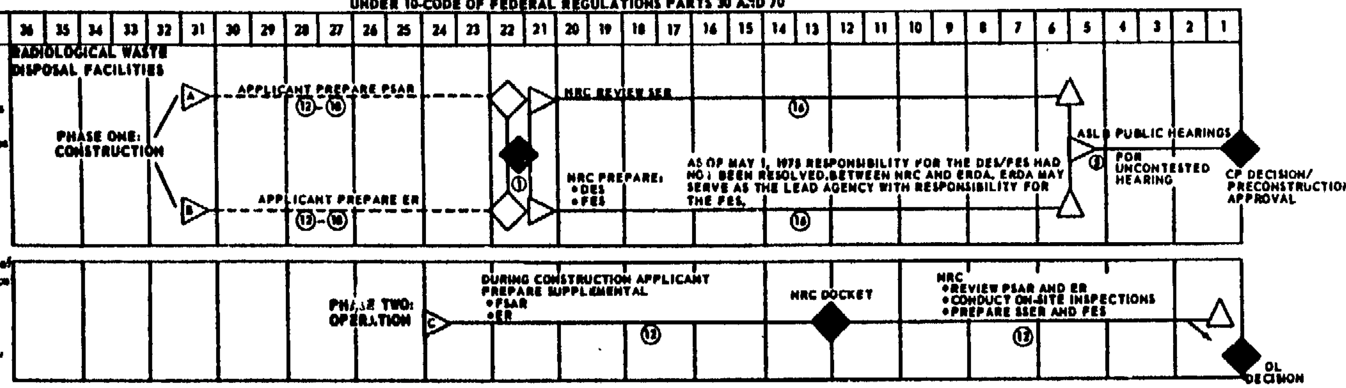


APPENDIX II

RADIOACTIVE WASTE DISPOSAL FACILITY LICENSING PROCESS

UNDER 10-CODE OF FEDERAL REGULATIONS PARTS 30 AND 70

FIGURE II-4



A **SAFETY**

NRC assesses:

1. Adequacy of Proposed Facility Safety Standards
2. Hazards of Proposed or Existing Reactor facilities

NRC prepares the Safety Evaluation Report (SER).

ASLB conducts any public hearings required.

B **ENVIRONMENT AND SITE SUITABILITY**

NCR assesses implications of:

1. Land use: zone, historic architecture, farm, forest, etc
2. Construction: ecology, waterways, soil erosion, etc.
3. Operations: effluents – radioactive, thermal, chemical.
4. Possible accidents and consequences.

NRC prepares the DES and FES.

ASLB conducts any public hearings required.

C **OPERATING LICENSE**

The Final Safety Analysis Report (FSAR) is prepared in accordance with the Final Engineering design. Fuel loading or other work with radiologically "hot" material cannot begin until an Operating License is issued.

The OL application process is intended by NRC to occur during construction to avoid delay of operation

THE NUCLEAR FACILITY LICENSING PROCESS

Overall goal of the process is to insure that "the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public." Code of Federal Regulations 50.26

The Nuclear Facility Licensing Process under 10-CFR Parts 70 and 30 divides into two phases.

1. Construction Permit/Pre-construction Approval
2. Operating License

CONSTRUCTION PERMIT/PRECONSTRUCTION APPROVAL

The preconstruction process for Fuel Fabrication and Radiological Waste Disposal Facilities has two lines of review:

1. Safety
2. Environment and Site Suitability

These same reviews apply to all nuclear facilities.

OPERATING LICENSE

The operating license review process deals with the Final Design and operation of the facility including the possession and handling of radioactive materials. In the case of fuel fabrication and reprocessing facilities, applicants can request a materials license to use either natural or depleted uranium for "cold runs" to test and refine equipment and processes while the operating license review is underway.

FUEL FABRICATION FACILITIES

Only seven facilities are presently licensed to fabricate plutonium fuel: All are considered to be of pilot scale capability.

ASSUMPTIONS

1. The applicant has fully exercised the responsibility to be familiar with and to comply with requirements of the licensing process prior to tendering the application for a license.
1. Continuing interaction between the applicant's design and engineering functions, the regulatory entity NRC-- and the pertinent State and local agencies.
2. Site selection, as well as local and State Government approvals have been finalized by the applicant prior to tendering application.
4. Preparation of required documentation by the applicant and review by NRC regarding the completeness of the documentation constitutes the CP/license application. The Acceptance Review is repeated at the time of filing the FSAR and Supplemental ER. The milestone for agreement on completeness is called Docketing.
5. Schedule times are based on NRC estimates.
6. Licensing of first-of-a-kind facilities will likely require more time than subsequent applications.

3. A Generic Statement may be prepared initially to cover the general considerations of a permanent disposal method. Supplementary Environmental Statements would then be prepared for specific sites.

▷ FORMALLY INITIATE EFFORT

△ SIGNIFICANT MILESTONE. MODIFICATION NOT CRITICAL

◇ FACING MILESTONE ON CRITICAL PATH OF PROGRAM HAS TOLERANCE FOR SCHEDULE VARIATION

◆ CRUCIAL MILESTONE, PROGRAM CANNOT ACHIEVE ITS OBJECTIVE UNTIL THESE REQUIREMENTS HAVE BEEN SATISFIED

--- PLANNED SCHEDULE

.... BAND OF UNCERTAINTY

LICENSING PROCESS NOMENCLATURE

ACRS	Advisory Committee on Reactor Safety
ASLB	Atomic Safety & Licensing Board
CP	Construction Permit
DES	Draft Environmental Statement
DOCKET	Agreement by NRC on Completeness of Documentation for Initiation of the License Review
ER	Environmental Report
FES	Final Environmental Statement
FSAR	Final Safety Analysis Report
LWA	Limited Work Authorization
NRC	Nuclear Regulatory Commission
OL	Operating License Required to Load Fuel or otherwise handle radioactive material, go critical, or otherwise operate the Facility for its intended purpose
PSAR	Preliminary Safety Analysis Report
SER	Safety Evaluation Report
SSER	Supplemental Safety Evaluation Report

APPENDIX II

UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
WASHINGTON, D.C. 20545

OCT 22 1976

Mr. Monte Canfield, Jr., Director
Energy and Minerals Division
U.S. General Accounting Office
Washington, DC 20548

Dear Mr. Canfield:

We appreciate the opportunity to review the GAO draft report entitled, "Considerations for Commercializing the Liquid Metal Fast Breeder Reactor." We have reviewed the draft with members of your staff and we understand that a number of changes and clarifications which we suggested will be made.

While the GAO report is correct in pointing out that closing the LMFBR fuel cycle on an expeditious basis is a critical determinant to the overall success of the LMFBR program, it should also be noted that internal ERDA program reviews had already come to the same conclusion and ERDA is undertaking efforts to provide a more integrated approach to each separate part of the LMFBR program. In particular, efforts are being made to revise the program to provide for earlier demonstration of the fuel cycle components of the LMFBR, specifically reprocessing and fabrication. Operational waste management facilities are also crucial to both the LWR and LMFBR fuel cycles. The current ERDA waste management schedules are consistent with reactor waste disposal requirements. We would also like to emphasize that the current LMFBR program plan now takes into account more fully the timing and rate of introduction of commercial fuel cycle facilities, with the goal of commercializing all parts of the LMFBR fuel cycle.

We note that the GAO report uses as its main source of information ERDA 76-1. Given the increased emphasis which has been placed on the LMFBR fuel cycle since the original data for ERDA 76-1 was prepared, many of the schedules and plans referenced in the GAO report are now out-of-date. No attempt has been made to point out all of the changes, since the major recommendations made by GAO are well taken. However, we request that the report indicate that the major changes suggested by GAO are already incorporated into the ERDA LMFBR program.

In general, the report explains the need to develop the technology and scaleup of the fuel cycle processes in close coordination with

Mr. Monte Canfield, Jr.

the technology and scale-up of electric power plants for LMFBR. The question of "commercializing," implied by the title of the report, however, is a little broader and institutionally more complex than the question of scale-up. It is a subject which ERDA faces with all the promising energy technologies and deals with the transition from Federal support to largely private investment risk based on competitive economics. The transfer of complex LMFBR technologies from a Federal to a commercial status is a far more complex consideration involving public policy beyond ERDA's charter to scale-up and demonstrate the technology and economics. As you know, the commercialization of the LWR fuel cycle for the current reactor plants has also not been completed. The report touches on these "institutional constraints" and understandably makes no recommendations concerning these considerations, but this limitation to scale-up and technology should be clearly noted in the title and scoping of the report.

ERDA does not presently plan to make a final decision as to the acceptability of full scale deployment of commercial breeders until about 1986. However, this does not mean that concern at this time about the commercialization aspects of the breeder is inappropriate. This is partly because the sequencing of the LMFBR program requires some commitments and decisions on the part of industry prior to the Administrator's decision on commercial deployment given the lengthy lead times involved in getting a plant on line. In particular, the next step in the reactor part of the LMFBR program is to have significant industry involvement in the design and construction of the next LMFBR reactor (the Prototype Large Breeder Reactor - PLBR) as well as the purchase of this reactor. Strong involvement of the private sector at this point in the program will help to provide a real test of the economic viability, or non-viability, of the breeder as part of the input into the 1986 decision.

Sincerely,

M. C. Greer
Controller

PRINCIPAL OFFICIALS

RESPONSIBLE FOR ADMINISTERING ACTIVITIES

DISCUSSED IN THIS REPORT

	Tenure of office From		To	
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION				
ADMINISTRATOR:				
Robert C. Seamans, Jr.	Jan.	1975	Present	
ASSISTANT ADMINISTRATOR FOR NUCLEAR ENERGY:				
Richard W. Roberts	June	1975	Present	
Robert D. Thorne (acting deputy)	Jan.	1975	June	1975
NUCLEAR REGULATORY COMMISSION				
CHAIRMAN:				
Marcus A. Rowden	Apr.	1976	Present	
William A. Anders	Jan.	1975	Apr.	1976
DIRECTOR, OFFICE OF NUCLEAR REACTOR REGULATION:				
Bernard C. Rusche	Mar.	1976	Present	
Edson G. Case (acting)	Jan.	1975	Mar.	1975