DOE/EIS-0085-FS

FINAL
ENVIRONMENTAL IMPACT STATEMENT

(Supplement to ERDA-1535, December 1975)

Liquid Metal
Fast Breeder Reactor
Program

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U.S. DEPARTMENT OF ENERGY

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COVER SHEET
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FINAL ENVIRONMENTAL IMPACT STATEMENT
(Supplement to ERDA-1535, December 1975)
LIQUID METAL FAST BREEDER REACTOR PROGRAM
U.S. DEPARTMENT OF ENERGY

1. A Final Environmental Impact Statement (EIS) for the U.S. Liquid Metal Fast Breeder Reactor (LMFBR) Program was issued by ERDA in December 1975 (ERDA-1535). This supplemental EIS focusses on changes in the LMFBR Program since 1975 and new information related to the environmental impact analyses in ERDA-1535.

2. The LMFBR program consists of developmental plants, The Clinch River Breeder Reactor Plant (CRBRP) and the Large Developmental Plant (LDP); the base technology program, including test facilities; and supporting fuel cycle programs.

3. Environmental issues associated with the LMFBR program - health effects, reactor safety, safeguards and waste management - are addressed. Ongoing R&D programs to resolve these issues are also described.

4. The following alternatives are analyzed in this supplement:

   (1) Alternatives Within LMFBR Program
   (2) No Action (Terminate LMFBR Program)
   (3) Alternate Long-Term Technologies
      (a) Fusion Energy (magnetic and inertial fusion programs)
      (b) Solar Electric Systems (wind energy conversion, solar photovoltaic conversion, solar thermal conversion and ocean thermal energy conversion)

5. A Notice of Intent to prepare this supplemental EIS was provided in the Federal Register on November 2, 1981 (46 FR 211, page 54397).

6. The supplemental draft EIS was forwarded to the U.S. Environmental Protection Agency on December 18, 1981 and an announcement of availability was printed in the Federal Register on December 24, 1981 (46 FR 247, page 62538). Comments were due February 8, 1982.

7. Written comments on the supplemental draft EIS were received from the Department of Commerce, the Environmental Protection Agency, the National Science Foundation, the Nuclear Regulatory Commission, and several States, industrial and environmental groups and individuals.

8. Copies of this supplemental EIS are available upon request from:

   Office of Nuclear Reactor Programs,
   Office of Assistant Secretary for Nuclear Energy,
   U.S. Department of Energy,
   ATTN: Mr. Wallace R. Kornack,
   NE-6, Room H-404, Germantown, MD 20545
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I. Preface

A draft environmental statement for the U.S. Liquid Metal Fast Breeder Reactor (LMFBR) program was first issued by the Atomic Energy Commission (AEC) in March 1974 for review and comment by interested parties. The AEC issued a Proposed Final Environmental Statement (PFES, WASH-1535) in January 1975, providing the newly created Energy Research and Development Administration (ERDA) the opportunity to review the PFES and LMFBR Program before issuing a final statement. The ERDA Administrator found that the PFES amply demonstrated the need to continue research, development and demonstration of the LMFBR concept and that significant problems, including in particular those related to reactor safety, safeguards, health effects and waste management were unresolved at that time. Subsequently, the Final Environmental Statement (FES) was prepared and issued as ERDA-1535 in December 1975, incorporating the PFES by reference.

In the ERDA Administrator's findings on the PFES, issued on June 30, 1975, it was noted:

> "...as the program develops and significant new information pertinent to the commercial deployment issue is generated, ERDA will update the existing Environmental Statement or prepare a Supplement to it...as may be appropriate and consistent with the National Environmental Policy Act."

The LMFBR program has progressed significantly since the issuance of ERDA-1535. A number of factors in the intervening six years have changed the LMFBR program and pertinent new information which may be relevant to environmental impact analysis has been developed, and the Department of Energy (DOE) has concluded that this supplement to the LMFBR Program FES is appropriate in that it would further the purposes of the National Environmental Policy Act.

In April 1977, the previous Administration deferred any U.S. commitment to advanced nuclear technologies that were based on the use of plutonium. In addition, it decided that the U.S. would defer indefinitely commercial reprocessing and recycling of plutonium. Consequently, that Administration proposed to cancel the Clinch River Breeder Reactor Plant (CRBRP) project. Research and development activities were to be continued. At ERDA's request, the U.S. Nuclear Regulatory Commission (NRC) suspended the licensing proceedings regarding the CRBRP. Congress, however, continued to authorize and appropriate funds for CRBRP, and design and component fabrication activities have continued until the present. At the present time, design work is about 90 percent complete and about 60 percent of the hardware has been delivered or is on order, amounting to about $600 million.

Though work on the CRBRP was significantly slowed over the intervening years, very significant progress was made in other elements of the LMFBR program. For example, the Fast Flux Test Facility, a major fuels and materials test reactor, was brought to initial criticality in February 1980, and having undergone a successful startup test program, is now being operated at full reactor power.

The decisions made by the previous administration were modified on October 8, 1981, when President Reagan announced that he was lifting the suspension on commercial reprocessing, and directed government agencies to proceed with the demonstration of breeder reactor technology, including completion of the CRBRP.

The LMFBR program described in ERDA-1535 contemplated gradual scale-up of demonstration facilities with government participation both in early commercial breeders and ultimately in making a decision with respect to the acceptability of widespread commercial deployment of LMFBR technology. There have been changes to the emphasis of this program, the most important of which is that the decision on deployment and commercialization of the LMFBR will be made by the utility industry. The government role will be limited to early development of the technical, engineering and industrial base needed to lower risks and uncertainties to levels consistent with normal commercial ventures and to demonstrate the safety, environmental acceptability and economic potential of LMFBRs.

This supplement examines the reduced scope of the program and the environmental impacts associated therewith. This includes a re-examination of the purpose and need and timing of the program, the present program structure, including reasonable program alternatives, and alternative electricity production technologies anticipated to be available within the same timeframe as the LMFBR technology option.

Moreover, this supplement documents new information pertinent to the environmental issues associated with the program, such as LMFBR safety, safeguards, waste management, and health effects. It is not intended to address issues for which little additional information has been generated since the 1975 review. Thus, except as they are examined in this supplement, the evaluation contained in ERDA-1535 of the environmental impacts associated with commercial deployment of the LMFBR technology are still considered valid by DOE.

Cost/benefit analyses of the LMFBR program were included in WASH-1535 and ERDA-1535. However, no such further cost/benefit analyses have been performed and none, therefore, are included in this supplement for this and the following reasons;

1. Cost/benefit analyses are not required in an EIS (see CEQ regulations, 40 CFR 1502.23),

2. Cost/benefit information for alternative long-term technologies (fusion and solar electric) has not been developed to a degree

that would make cost/benefit analyses of these alternatives meaningful, and

3. Parameters (e.g., discount rate(s), LMFBR introduction date(s), future nuclear capacity, future cost of coal) used in complex cost/benefit analyses of the LMFBR are so uncertain at present that the value of such analyses would be questionable. It is a goal of the breeder research and development program to reduce such uncertainties.

In addition to this supplement that updates the environmental review of the total LMFBR program, discrete NEPA reviews have been undertaken by DOE, and its statutory predecessors, in connection with specific decisions involving major facilities within the program as described in the following table. Furthermore, the NRC issued a Final Environmental Statement on the construction and operation of the CRBRP in February 1977 (NUREG-0139).

Facility	Document(s)*	Date
Fast Flux Test Facility (FFTF)	FEIS[1]	May 1972
Safety Research Experiment Facilities	FEIS[2]	September 1977
Maintenance and Storage Facility	EA[3] FONSI	May 1980 May 1980
Fuels and Materials Examination Facility	EA[4] FONSI EA Supplement	May 1980 July 1980 August 1981

*FEIS Final Environmental Impact Statement
EA Environmental Assessment
FONSI Finding of No Significant Impact

1. WASH-1510, FFTF Environmental Statement (AEC).
2. ERDA-1552.
3. DOE/EA-0111.
4. DOE/EA-0116.

In addition to the main body, the following appendices are provided.

Appendix A contains information concerning U.S. uranium resources. Estimates given in ERDA-1535 are contrasted with data from the NURE program and other, more recent evaluations. Basically, current estimates indicate about 50 percent more uranium than was indicated by the previous estimates.

Appendix B contains additional waste management program information.

Appendix C contains excerpts from the CRBRP Safety Study.

Appendix D contains additional information on plutonium toxicity, related to Section VI. A. (4).

Appendix E contains LMFBR safety program accomplishments (1976-1981).

Appendix F contains a discussion of the role of nuclear energy and electricity in meeting future U.S. energy needs.

Appendix G contains a discussion of how the CRBRP site was selected.

Appendix H contains comparative information on health effect risk estimates for low LET radiation.

II. Summary

Nuclear-generated electricity will play an increasingly important role in energy substitution as petroleum and natural gas become more scarce and expensive. Even though significant benefits are being derived from conservation measures, historical trends strongly indicate that future economic growth will be linked with increasing energy consumption. Much of the future growth in energy supplies will likely be met by increased production of electricity. Of the fuel alternatives for electricity production, only coal and uranium offer much potential for the generation of large amounts of affordable electric energy into the early part of the next century.

Deployment of current-generation light water reactor (LWR) plants will ultimately be limited by the availability of economically recoverable uranium ore. Creating an essentially inexhaustible supply of energy from uranium requires development of breeder reactors, which can extend the energy recoverable from uranium ore by about a factor of 60 over LWRs.

Research and development activities on promising long-term options, such as the LMFBR, fusion, and solar electricity technologies, are required to meet the future U.S. energy needs. Because of the relatively advanced state of LMFBR technology relative to other large-scale options, it is the surest of the inexhaustible supply options. If fusion, solar electricity, and the LMFBR development programs were all successful, the contributions of each would depend on their economics, among other important factors. Because today the LMFBR is presently in the most advanced stage of development, it provides the insurance against failure of the other long-term alternatives to develop in a timely way, and against the failure of coal to meet expectations. In this sense, the LMFBR could contribute vitally to the future prosperity and security of the nation.

The LMFBR is a complex undertaking that still requires years of intensive work before its technology is developed to a point of acceptable commercial risk. Technological feasibility has been demonstrated in a number of small and intermediate size LMFBRs built and operated in the U.S. and abroad. Future LMFBR progress will rely on the successful development of near commercial scale engineered systems rather than on significant technological break-throughs.

Since 1975 there have been changes in the LMFBR program, but the analysis in this supplement shows that new information concerning environmental issues developed since ERDA-1535 does not indicate any significant or substantial environmental impacts that were not evaluated in ERDA-1535. The number of major facilities planned for the current program, or for which federal partici-pation is contemplated, is reduced from the level discussed in the FES (ERDA-1535). Thus the environmental impacts of the current LMFBR program would be less than those that would have been associated with the program described in ERDA-1535. Moreover, progress has been made in addressing environmental issues that were identified in the ERDA Administrator's findings on the PFES as key to the determination of acceptability of the LMFBR for wide scale development.

Current LMFBR development planning includes, among other things, the construc-tion and operation of the intermediate-size Clinch River Breeder Reactor Plant (CRBRP) as soon as possible, and the planning, in cooperation with the private sector, for the near-commercial size LMFBR developmental plant. Because of the long lead-times involved, even with vigorous pursuit of this plan, a commercially viable LMFBR and significant LMFBR market penetration are decades away. Although there is uncertainty as to precisely when the LMFBR will be economically competitive with alternatives, prudent planning indicates that LMFBR development should be geared toward potential deployment early in the next century. This necessitates that the program progress expeditiously even at the risk of developing the option before it is economically competitive with LWRs. The consequences of early development, however, are minor compared to the risk of possible electricity shortages and economic penalties associated with late development. Furthermore, significant program delays may destroy the continuity that is essential to any high technology development program.

The LMFBR Program

The goal of the breeder program is to ensure that a proven long-term electricity supply option is available on a prudent time scale. To accomplish this goal the U.S. LMFBR program is established with the overall objective of developing the technical, engineering, safety, environmental, economic, licensing, and industrial data base that will be required for the design, construction, and operation of future LMFBR power plants on a utility grid. The program consists of three broad elements that are essential to meeting this goal; (1) construction and operation of developmental plants, (2) a supporting base technology program including test facilities, and (3) supporting fuel cycle programs.

Construction and operation of the developmental power plants is essential to the advancement of the state of LMFBR technology. Each plant is sized such that it represents a significant step towards establishing the technology needed for eventual commercial breeder reactors, but does not entail excessive engineering risk in scale-up.

The base technology program provides the basic data, processes, methods, components, and systems that are utilized during the entire course of the LMFBR program in the design, construction, fabrication, testing, licensing, and operation of LMFBR power plants. While the base technology program directly supports the needs of each plant project, the projects in turn feed back the key information to the base technology areas that make program optimization possible.

Concurrent development of other elements of the LMFBR fuel cycle (reprocessing, fuel fabrication, transportation, and waste management) is recognized as essential to any assessment by the nuclear industry of readiness to deploy breeders in significant numbers.

Construction and operation of the 350 MWe net CRBRP is the current focal point of the LMFBR program. The CRBRP represents a technology scale-up step that is firmly within the size range commensurate with sound engineering practice, and that has been planned or taken by all nations making substantial commitments to an LMFBR program. The CRBRP will help demonstrate the technical performance, reliability, maintainability, safety, environmental acceptability, and economic feasibility of an LMFBR central station electric power plant in a utility environment. It will also confirm the value of this concept for conserving important nonrenewable natural resources.

Work on the final design of the CRBRP as well as its associated R&D is almost complete. Hardware manufacturing is continuing from its present level of about 60% delivered or ordered. Construction on the site has not been initiated. Obtaining site work authorization from the NRC is currently an intensive part of an expedited project effort to have the CRBRP in operation as soon as possible (i.e., by about 1990).

LMFBR program planning also calls for planning, in cooperation with the private sector, for the design, construction, and operation of a large developmental plant (LDP) to follow, and incorporate the results of, the CRBRP as the next step in LMFBR development. It is anticipated that the major portion of the construction costs of a large developmental plant would be borne by the private sector. The LDP project has progressed to the stage of advanced conceptual design of the more critical components of the plant. In addition, large plant studies will evaluate plant siting criteria, develop design and construction schedules, identify R&D requirements for the base technology program, prepare implementation plans, and establish detailed cost estimates. Successful operation of the LDP, together with the FFTF and

CRBRP experience and results from the supporting base programs, will signal to the utility industry the viability of the LMFBR for commercial development.

The base technology program has proceeded essentially along the lines outlined in the FES, resulting in significant progress over the past six years. There are five main elements of the base technology program.

(1) The safety program provides the technology base that helps assure the safe design and operation of LMFBRs.

(2) The components program places emphasis on development and testing of large steam generators and primary coolant pumps, in addition to developing other critical components such as fuel handling equipment, intermediate heat exchangers, small valves, and instrumentation and controls.

(3) The materials and structures program develops the guidelines for high-temperature structural design, seismic design, sodium system design and nondestructive testing of LMFBR components and systems.

(4) The physics program provides the critical measurements, nuclear data, and computational methods that are required for the design and operation of developmental breeder plants.

(5) The fuels and materials program encompasses the development of fuel, blanket, and control core components for LMFBRs; the development of materials for use in these components; and the development of equipment, processes, and facilities to fabricate fuel.

The fuel cycle program is conducting the research and development and plant development needed for a self-sufficient fuel cycle. Programs for fuel reprocessing, fuel fabrication, and waste management are being planned and conducted to meet not only the immediate needs of the LMFBR program, but also to establish the foundations necessary for commercial scale-up, as appropriate.

Program plans for near-term facilities are modest compared to those for facilities capable of supporting 80 large LMFBRs, as described in the FES. Environmental effects should therefore be no greater than those described in WASH-1535.

Alternatives to the Proposed Action

Alternatives within the LMFBR program as well as alternatives to the breeder are discussed. The reasonable alternatives within the program include; (1) termination of the CRBRP and proceeding directly to the LDP project, (2) completion of the CRBRP as the last developmental plant of the overall program (i.e., no LDP), and (3) termination of both developmental plant projects.

The gains from these three alternatives are the financial savings from eliminating the construction cost of each respective plant, as well as avoiding the environmental impacts associated with construction and operation. In the first alternative, the termination of the CRBRP Project, the scale-up of LMFBR technology from small plants to near-commercial size would be accomplished through results of the base technology program and the operational experience of the FFTF. Major losses would be incurred in early data on startup, operation, individual component performance, overall plant performance, reliability, environmental impacts, and maintainability of an LMFBR in a commercial utility environment. Utility participation in LMFBR construction and operation would also be lost, with attendant erosion of utility confidence. By requiring such a large scaleup step, this decision would also be a break with sound engineering practice. The problems that would result from CRBRP cancellation would increase the risk that the LDP would have major problems, which would negate any possible cost and time savings and could possibly jeopardize the goal of the LMFBR program for supplying the nation with an important long-term energy option.

In the second alternative, the elimination of the LDP, the program is disrupted and foreshortened. The implication of this action would be that the base of technology and engineering needed for establishing the viability of the breeder for commercial application by the nuclear industry would be incomplete. Because the CRBRP is not intended to establish breeder economics, an LDP-type plant is required to demonstrate the economic and technological viability and technical acceptability of a commercial-size LMFBR. Extensive delay in the LMFBR program brought about by eliminating the LDP could result in significant losses in the technically-trained LMFBR work force.

The third alternative is the cancellation or deferral of both developmental plants with continuation of only a generic base R&D program. This alternative would lead to an indefinite delay in any potential deployment date for LMFBRs because licensing and plant operating experience would never be obtained. Even the remaining base program would lose focus without specific plant projects on which to concentrate its efforts. Many of the opportunities for the involvement of utilities and reactor manufacturers would be lost also.

In the no action alternative, the entire LMFBR program would be terminated. Such a termination would mean turning away from 35 years of progress in developing a technology which has an excellent potential for supplying a substantial amount of energy in the next century. Technological feasibility is proven and no fundamental scientific breakthroughs are required for further engineering development and eventual deployment. Termination of the LMFBR program would result in the loss of the existing pool of experienced technical specialists and in the loss of specialized R&D facilities. Failure to develop the LMFBR as a long-term electricity supply option would have serious consequences for the nation should other long-term options either fail to develop adequately or be constrained in usage, leaving the U.S. vulnerable to foreign energy supply pressures.

Alternative Long-Term Technologies

The most promising of other technologies that ultimately may compete with the LMFBR as long-term electricity supply options are fusion reactor plants and various types of solar electric systems. Progress in the development of these technologies is summarized in this supplement. The goals, accomplishments, and focal points of both the magnetic and inertial confinement fusion programs are described. Goals, accomplishments, implementation plans, and problem areas for four solar electric technologies (wind energy conversion, solar photovoltaic conversion, solar thermal conversion, and ocean thermal energy conversion) are addressed. Until these alternative long-term technologies meet their development goals, it is not possible to determine their competitiveness with the LMFBR.

Environmental Consequences of LMFBR Program and Alternatives

Reactor Safety

In the period since WASH-1535 was issued, there have been no new safety issues identified which would prevent the design, construction, and operation of safe and licenseable LMFBRs. The safety research and development program continues to build upon the comprehensive base of safety-related information (as described in the PFES and FES) aimed at providing realistically conservative LMFBR power plant designs and resolving safety issues so as to assure the breeder's acceptability to regulatory authorities, industry, and the public. Substantial progress toward the resolution of key safety questions has been made. Results to date include the following:

- o Designing systems and structures in LMFBR plants to be highly reliable has been and remains the most important element in assuring plant safety. In this area, substantial evidence from component and system tests along with a more limited data base from operating plant experience is now available to support analyses which predict very high reliability for LMFBR shutdown and shutdown heat removal systems.

- o It has also been recognized that LMFBR plants can be designed to have intrinsic response modes which provide a further barrier against accident occurrence, should key systems fail. In this area, tests at FFTF have demonstrated that natural circulation is a practical method of removing decay heat from the primary sodium system during loss of electrical power events and consequent loss of power to primary pumps. Furthermore, the test results have confirmed that the analytical models used to predict natural circulation under various conditions are both accurate and valid.

- Despite the high degree of assurance that core-disruptive accidents are very improbable in LMFBR plants, efforts have continued toward reducing uncertainties associated with the ability to predict the consequences of these accidents. Progress has been made in each of the areas associated with core-disruptive accidents that were addressed in ERDA-1535. This progress provides further assurance that CRBRP can meet requisite safety requirements in this area.

A number of additional safety issues have arisen since ERDA-1535 was prepared. FFTF and CRBRP safety review activities highlighted the need for more research on core debris accommodation. The current technology base supports the adequacy of core debris accommodation capabilities of relatively small plants, such as CRBRP. Additional work is underway which addresses this issue for larger plants.

The Three Mile Island accident underscored the safety importance of the man-machine interface. Many light water reactor developments in this area will apply to the LMFBR. Nonetheless, LMFBR-specific R&D has been initiated in particular areas.

Most of the safety test facilities described in ERDA-1535 have been used in the safety program to obtain data for resolving safety issues. This use will continue. The Safety Test Facility, a major new transient test reactor whose need was projected in ERDA-1535, has not been constructed because changes in the overall LMFBR program coupled with significant improvements in the understanding of accident phenomena gained from ongoing tests in existing facilities now indicate that it is not needed.

The final safety topic addressed in ERDA-1535 was LMFBR risk assessment methods development. Application of existing methodology (after ERDA-1535 was issued) to CRBRP showed that the risks from operation of that plant would be comparable to light water reactor risks. Probabilistic risk assessment has now been further developed, and is used as an aid in the design of LMFBRs.

Safeguards

Existing safeguards capabilities are designed to deter, detect, respond to and interdict adversary actions. These capabilities have been improved over the last 6 years (since ERDA-1535 was issued) to assure increased effectiveness and to further reduce risks associated with adversary actions. Section VI.A.(2) discusses these improvements and their application to the LMFBR fuel cycle.

The improvements have been developed to assure that all elements of the LMFBR fuel cycle will be adequately protected. Over the last 6 years, there has been a concerted effort to improve the performance of physical protection components, such as barriers, interior and exterior intrusion sensors, closed circuit television (CCTV) surveillance, personnel identifiers, and automatic protective mechanisms and guard force performance. A number of sensors, such as microwave, ultrasonic, and buried cable motion detectors, have been tested and proven effective at identifying intrusions. Effective systems of sensors for surveillance and evaluation of the seriousness of an incident have also been developed. Combinations of these technologies have been used at various commercial and government facilities, such as at Pantex at Amarillo, Texas, and the FFTF at Hanford, Washington.

Another focus of concern is the control of access into sensitive areas of LMFBR facilities. Reactors, reprocessing plants, plutonium storage facilities, and fuel preparation and fabrication facilities all have sensitive areas which must be protected from sabotage or special nuclear materials (SNM) losses. It is necessary to assure: (1) that only those who have a need to have access can enter these areas, (2) that contraband (such as explosives or weapons) cannot be brought into the areas, nor SNM taken out, and (3) finally that those that have access can be monitored to prevent a hostile or malevolent act from occurring.

Not only will the present badge or card key identification systems be available to control access by individuals to sensitive areas but technologies that would include more sensitive indicators of identity such as hand geometry (physical dimension of the hand) have been tested and one or more of these technologies would be available for application in the future. Equipment to detect attempted removal of special nuclear material (SNM) has been developed and is now commercially available.

Another important component of the overall safeguards system for the LMFBR will be accounting for plutonium moving throughout the system. A variety of automated destructive and non-destructive instruments for assay of uranium and plutonium have been installed and successfully tested. Data from the instruments can be fed into a computer-based acccounting and instrumentation system.

Finally, transportation of nuclear materials has been considered an area of critical concern, because of perceived vulnerability. When plutonium is transported, a variety of protective techniques can be used. In particular, DOE now has extensive experience with transporting significant quantities of SNM employing its Safe Secure Transportation (SST) system. This includes vehicles with immobilization devices, and hardened driver cabs. Thus technology and operational approaches to secure plutonium in transit are available. The actual manner in which these approaches are utilized for fresh fuel or separated plutonium would be regulated by the Nuclear Regulatory Commission.

These techniques or technologies can effectively prevent an individual having access to materials and facilities from engaging in criminal acts, making it exceedingly difficult and thus undesirable to attempt the theft of plutonium or engage in acts of sabotage.

Waste Management

Over the past 35 years, management techniques have been developed and refined to safely store and control radioactive wastes. Low-level waste is effectively disposed of in shallow land burial sites at government and commercial facilities. Spent fuel from commercial reactors is stored at reactor sites and at facilities in Morris, Illinois and West Valley, New York. Defense high-level waste in liquid form has been stored in steel tanks since the advent of nuclear energy. DOE is now evaluating sites and designing facilities for the isolation of high-level and TRU waste from man's environment in geologic repositories, including wastes from LWRs and LMFBRs. The basic technology is in hand now for the development of such geologic repositories and candidate sites are being evaluated. Additionally, current law requires DOE to obtain a license from NRC before constructing a full scale geologic repository.

DOE plans to construct exploratory shafts at three locations. This is consistent with NRC licensing procedures for a geologic repository (see 10 CFR Part 60). It is planned that construction of exploratory shafts would be underway at basalt and tuff sites by the end of 1983 and at a salt site in 1984. A license application for construction of the full scale repository is expected to be submitted to NRC by 1988 with operation of the repository expected before 2000.

In 1985, a site will be selected for the construction and operation of a Test and Evaluation Facility. A few hundred packages of high-level waste will be emplaced in the facility to gain experience in the handling of waste, in situ R&D, occupational exposure control, emplacement techniques and so on, as well as to verify the adequacy of waste handling equipment designs. The Test and Evaluation Facility is scheduled for operation by 1989. Extensive and aggressive research and development programs are underway to develop and refine the technology, hardware, and systems that support the program objective--to safely isolate existing and future radioactive wastes from the biosphere such that they pose no significant threat to public health and safety.

Health Effects

ERDA-1535 analyzes the full range of potential impacts of operating an LMFBR industry. Both radiological and non-radiological consequences are treated in this analysis. A matter of principal concern were uncertainties associated with descriptions of the potential human health impacts of transuranic elements produced and utilized in the LMFBR fuel cycle. The following discussion provides an update on this issue which incorporates the results of research conducted over the last six years.

Section VI. A. (4) evaluates the potential human health effects due to the release of transuranic elements that would likely result from operation of an LMFBR fuel cycle. Evaluations are expressed in terms of a 1000 MWe LMFBR power plant (and supporting fuel cycle) operating for a year at an 80% capacity factor.

A release of 0.36 mCi of alpha-emitting transuranic elements per 1000 MWe-year is estimated to occur as a result of normal operations of the fuel cycle. Accidents are predicted to contribute insignificantly to total releases because of the low probabilities associated with accidents. The total release is assumed to be in the form of airborne particulates. These are distributed according to a meteorological model which assumes release from a single point in the North Central United States, with downwind population density 10 times the U.S. average.

Deposition in man is assumed to occur as a result of (1) direct inhalation of the airborne release, (2) inhalation of resuspended material after deposition on the ground, or (3) ingestion of material incorporated in or on foods. Disposition in man is estimated according to conservative models, for periods of time extending for the lifetime of the radioactive materials.

Absorption of the transuranics by man, and their distribution and retention within man, are assumed to follow models prescribed by the International Commission on Radiological Protection (ICRP) except for one major exception, where substantially higher estimates for absorption of ingested transuranics are employed. ICRP procedures are also employed in the calculation of radiation doses to various human organs and tissues which result from transuranic element depositions.

Evaluation of the possible human health consequences of predicted radiation exposures is approached from two standpoints. First, the predicted exposures are compared with measured exposures to fallout transuranics present in our environment as a result of nuclear weapons tests; to plutonium depositions that have resulted from occupational exposures; and to natural background radiation, including that from internally deposited, naturally occurring alpha emitters. Fallout plutonium in the United States exceeds by a factor of about 50 million the estimated LMFBR release per 1000 MWe-year; 1000 LMFBRs, each rated at 1000 MWe and operating for 50 years, would be predicted to release only 1/1000 of the plutonium deposited from past weapons tests. The amount of plutonium estimated to be present in a few thousand plutonium workers, in whom no serious health effects attributable to plutonium have been seen, is 1000 times the estimated quantity that would be inhaled by people per 1000 MWe-year of LMFBR operation. The radiation dose to a single generation from naturally occurring alpha emitters is from 30 million to a billion times larger, for different critical organs, than is the cumulative radiation dose to all generations per 1000 MWe-year of LMFBR operation. These comparisons provide no measure of absolute risk, but do serve to place these risks in perspective, relative to other unavoidable risks of a similar nature.

A second approach to the evaluation of possible human health consequences involves estimation of absolute risks, based on rather uncertain relationships between radiation dose, and cancer and genetic risks, as developed by such bodies as the ICRP, the National Academy of Sciences Committee on the Biological Effects of Ionizing Radiation (BEIR), and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). This approach leads to estimates of 0.0012 cancer deaths and 0.0006 serious genetic effects per 1000 MWe-year of LMFBR operation. Expressed in other terms, about one cancer death would be attributed to 1 year's operation of 1000 LMFBR power plants of 1000 MWe rated capacity; and about one serious genetic effect to the same number of plants operating for 2 years. About one-third of the predicted cancers would occur in persons exposed during the period of LMFBR operation, and about one-third of the genetic effects would occur in their first generation offspring. The remaining two-thirds of all predicted effects would occur over ensuing thousands of years at a much diminished and decreasing rate, for the lifetime of the transuranics involved.

Because of unavoidable uncertainties in the models employed for estimation of absolute risk, it is suggested that primary reliance be placed on the qualitative comparisons of exposure from estimated LMFBR releases, fallout plutonium, and natural background radiation. Attempts to place absolute numbers on specific risks should be looked upon as an exercise lending qualitative support to the more valid comparative evaluations.

Major differences between Section VI. A. (4) and the earlier version of this material in WASH-1535 are summarized in the following tables.

Table 1

MAJOR CHANGES IN MODEL PARAMETERS

	WASH-1535 (1974)	Supplement (1981)
Source Term	No Changes	
Environmental Dispersal	No Changes	
Transport Via Food Chains		
Plant/Soil Transuranic Concentration Factor	0.1	0.01
Metabolism in Man		
Gastrointestinal Absorption Fraction for Plutonium	3×10^{-5}	10^{-3}
Dosimetry		
Dose Commitment Interval	70 years	50 years
Quality Factor (rem/rad)	10	20
Dose to Bone	Averaged Over Total Bone and Multiplied by 5 to Correct for Non-uniform Distribution	Separately Calculated for Surfaces and for Red Marrow

Table 2

CHANGES IN HEALTH EFFECT ESTIMATES

	WASH-1535 (1974)	Supplement (1981)
Dose Equivalent Commitment (rem)	(70 Yr Commitment, Q = 10)	(50 Yr Commitment, Q = 20)
Lung	4	9
Bone	26	86 (Surface)
		7 (Marrow)
Liver	10	18
Gonads	0.4	1
Risk Factors (per 10^6 organ-rem)		
Lung	16 - 110*	35
Bone	2 - 17*	5 (Surface)
		25 (Marrow)
Liver	1 - 7*	15
Gonads	60 - 1500*	1000
Excess Cancer Deaths		
Lung	.000064 - .00044*	.00032
Bone	.000052 - .00044*	.00043 (Surface)
		.00018 (Marrow)
Liver	.000010 - .00007*	.00027
Total	.0001 - .001*	.0012
Genetic Effects		
Total	.0002 - .002*	.0006

* Lower estimate based on absolute risk model, higher estimate based on relative risk model.

Environmental Impacts of Alternative Long-Term Technologies

Qualitative and limited quantitative comparisons are included in this section. Non-radiological LMFBR impacts (unchanged since ERDA-1535 was completed) are compared with estimated similar impacts for magnetic fusion, wind energy conversion, solar photovoltaic, solar thermal and ocean thermal systems, on a unit basis (i.e., per 1000 MWe equivalent plant capacity).

Detailed quantitative comparisons between the LMFBR and alternative long-term technologies are not possible because only the environmental impact information for the LMFBR is complete at this time. Such information on alternatives is still quite incomplete and uncertain.

III. Purpose and Need for the LMFBR Program

This Section discusses the fundamental rationale for LMFBR development, and factors affecting appropriate timing of the development program. Although the basic rationale for the LMFBR program is essentially unchanged from that in WASH-1535 and ERDA-1535, changes have occurred in the information upon which the program is based, and therefore in the program elements. There have been changes in the projection for installed nuclear generating capacity and also in the projected growth in electricity demand.

Because of these changes, this Section is supplied to update, or supersede, similar material found in WASH-1535:

Section 1.1.1 Origin and Purpose of the LMFBR Program

Section 1.1.4 Notes on Several Assumptions Used in the Statement

Section 2.1 Relationship of the LMFBR to the U.S. Energy Economy

A. Role of Nuclear Energy

The energy supply problems of recent years have demonstrated the nation's need for stable, secure, domestic energy sources. The nation needs to develop energy options which can provide substantial amounts of energy over the long term. Energy sources will be needed to replace the increasingly scarce supplies of oil and gas which currently supply 70% of the nation's energy needs.

Proven supply technologies must be ready when needed. Electricity can play a
11, very important role in the nation's long-term energy supply security because
21 electricity can be produced independent of petroleum supplies and because
electricity can replace oil and gas in many end-use applications such as high-efficiency heat pumps in the commercial and residential sectors (see National Energy Policy Plan, July 1981, page 15). An expanded role for electrical

energy is essential in that almost three-quarters of the existing U.S. energy supply comes from rapidly depleting reserves of oil and natural gas. About one million barrels of oil per day, mostly residual oil, are consumed in the production of electricity. For the past several years, the amount of oil used in electrical generation has been approximately equal to that imported from Saudi Arabia. Oil supplies about 10 percent of U.S. electricity now; it is projected to decline to about 1 percent in the 2000 to 2020 timeframe. Expediting the transition to alternatives, including greater electricity reliance, would save existing petroleum supplies for such end uses as transportation, where substitution is difficult. Of the currently available central station alternatives for electricity production, only coal and nuclear power from light water reactors (LWRs) can provide substantial amounts of energy. Coal is a large but finite resource, and expanded coal use is a key element in the U.S. energy strategy. Large quantities of coal might also be used in the future as feedstock for synthetic liquid and gaseous fuels. Further expansion of coal use to preclude the need for LWRs and LMFBRs is considered by many to be infeasible from a supply perspective.

There is also concern that continued and expanded coal use could present adverse environmental impacts, especially with regard to increases in global carbon dioxide and associated changes in climate and to sulfur dioxide emissions and their effect upon acidic precipitation.[1-4] However, given the current state of scientific understanding of the acid rain phenomenon, the cause and effect relationship between coal use and acidic precipitation remains highly speculative.

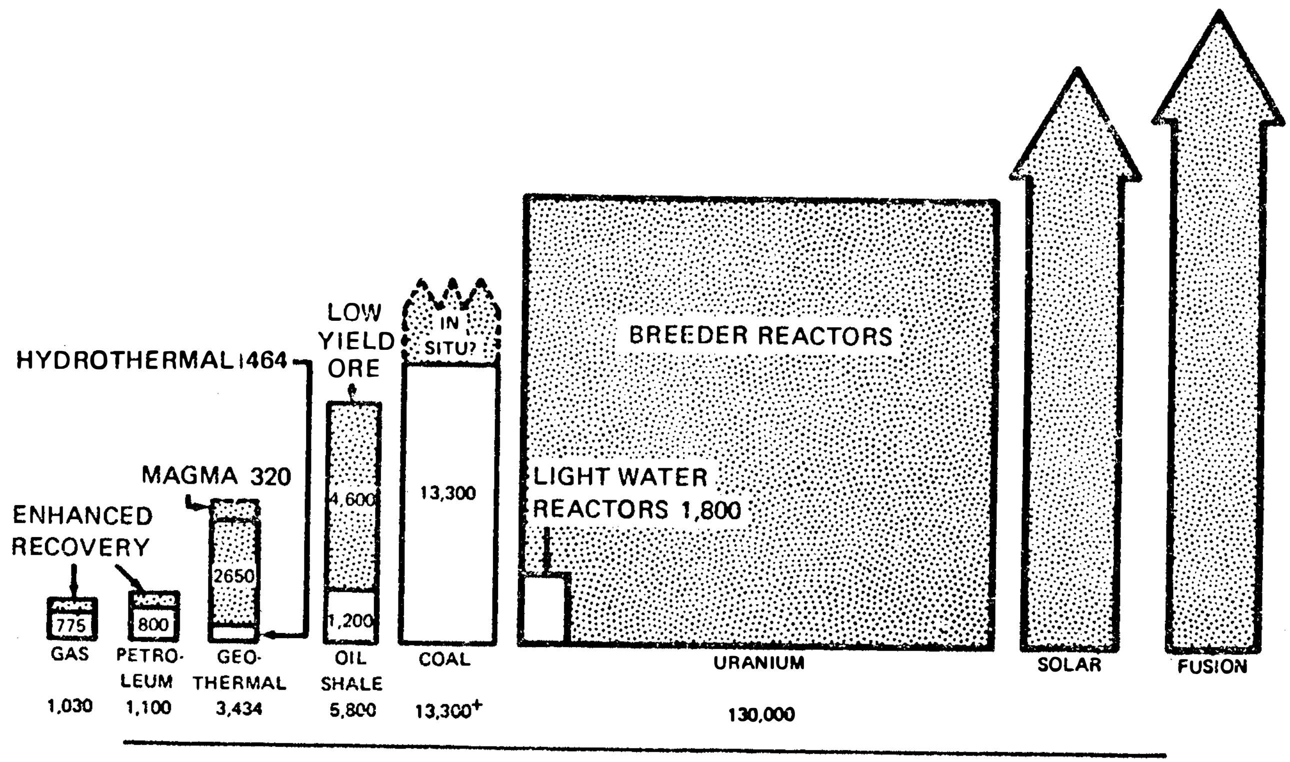
The most practical end use for the energy content of uranium is in producing electricity or process heat. Thus, nuclear energy can play a unique and important part in the nation's energy supply structure. Uranium, as used in the current generation of nuclear plants, is also a finite resource. But, unlike power plants using fossil fuels, the next generation of nuclear plants, the LMFBRs, can extend the uranium resource potential to essentially inexhaustible proportions (see Figure 1).

B. Energy and the Economy

An update of background information on energy/economic considerations is provided in Appendix F and will only be summarized in this section. It should be noted that this Supplement is not intended to be a detailed or exhaustive
21 study of future trends in the economy or in energy use. There have been many such studies conducted recently and the current DOE energy supply and demand projections along with comparisons with projections by other groups have been published (Energy Projections to the Year 2000, DOE/PE-0029, July 1981).

Adequate energy supplies are vital to a healthy, growing economy. Historical economic data show, with few exceptions, that changes in energy consumption and changes in gross national product (GNP) move in step. However, since 1975 there have been some significant quantitative changes in the trends in U.S. energy consumption and in the perceived future growth in energy demand. The greatest change in recent years has been the large increase in energy costs, mostly driven by increases in petroleum prices. These higher costs have resulted in a slowing of the historical rate of increase in energy consumption and, in a few recent years, in an actual decrease in energy consumption. The historical trend of GNP moving in step with energy consumption has generally continued. The GNP growth, like the growth in energy consumption, has been relatively low, actually declining in a few years. For prudent planning purposes, it may be concluded from both the recent and longer-term

ENERGY AVAILABLE IN QUADS (10^{15} BTU) SHOWN GRAPHICALLY BY AREA



Recoverable Domestic Energy Resources

Figure 1

Adapted from ERDA 76-1
(A National Plan for Energy Research, Development
and Demonstration: Creating Energy Choices for the Future, 1976)

historical energy consumption and GNP trends that even a modest continued growth in GNP will lead to increased energy consumption.

It is also probable that the rate of increase in energy consumption will be less than that experienced in the 1960s when energy costs were low. The historical data show that the economy does respond to changes in energy prices with changes in energy efficiency (ratio of GNP to energy use) -- higher prices have led to increased conservation of energy. However, the response is quite slow. It is probable that the annual rate of efficiency
21 improvements, averaged over the next few decades, will not exceed the 1.6% per year which occurred during the period 1971-1980 when energy prices increased greatly (see Appendix F).

One consistent historical trend is the increase in the fraction of energy provided by electricity. Electricity is a flexible and convenient energy form, and electricity demand may be expected to continue to increase at a somewhat higher rate than the overall energy demand. However, as mentioned earlier, a more important point is that electrical energy production can be independent of fossil fuels, and increased use of electricity can help in the very large energy substitution problem faced by the U.S. as fossil fuels, especially oil and natural gas, become increasingly scarce and costly. Together energy growth potential and the need for oil and gas substitutions provide the motivation for developing long-range, essentially inexhaustible electrical energy sources such as the LMFBR.

C. Rationale for LMFBR Development

As a promising long-term, large-scale technology, continued development of the breeder appears warranted. Similarly, continuation of research and development activities on other promising long-term options, such as fusion and solar electricity technologies, also appears warranted. Because of the relatively advanced state of LMFBR technology relative to other large-scale, inexhaustible options, the breeder must be considered the surest of these supply options. If fusion, solar electricity, and the LMFBR development programs were all successful, the contribution of each would depend on their relative economics, among other factors. Moreover, since the LMFBR is today the furthest along, it provides the insurance against failure of alternatives to develop in a timely way and against coal failing to be able to fill any gap in energy supply that occurs. In this sense the LMFBR could contribute vitally to prosperity and security of the nation.

Important elements in the rationale for U.S. LMFBR development are:

- The need for nuclear power to meet a significant fraction of future electrical energy requirements. In the near-term only coal and nuclear power can be counted upon to meet the bulk of the U.S. electrical energy requirements.
- Limits to economically recoverable uranium which limits contributions from current generation nuclear powerplants, and an essentially unlimited electrical energy supply from breeders.
- Forecasts for LMFBR electrical generating costs.
- The relatively advanced state of breeder reactor development, compared to other large-scale, inexhaustible technologies.

The first element, the need for nuclear power, has been addressed in the previous section and in more detail in Appendix F. In this section, the remaining factors are examined.

1. Uranium Resources and Nuclear Energy

As discussed previously, nuclear power is likely to play an important role in providing a significant fraction of the nation's near-term and long-term electrical energy requirements. Although the present-day nuclear power technology, based on the LWR, can provide a vital contribution to meeting the nation's electrical energy needs in the near-term, LWRs utilize only a small fraction (about one percent) of the energy available from uranium resources. To assure that nuclear power can continue to make a major contribution to the nation's long-term energy needs, it is necessary to utilize the uranium resources more fully. By virtue of their fuel breeding characteristics, LMFBRs enable the energy potential from uranium resources to be increased by about a factor of sixty. Used in LMFBRs, the energy potential of the uranium already mined and stored as a byproduct of the enrichment process is roughly equivalent to the energy potential of all of the U.S. coal reserves (430 billion tons that are considered economically recoverable at the present time).[5] Like the renewable resources, the fertile uranium resource base for the LMFBR is so large that fuel costs would not be influenced by resource availability.

The National Uranium Resource Evaluation (NURE) program has conducted studies to assess better the magnitude of U.S. uranium resources and to improve technology for discovery, assessment, and production of these resources. The potential uranium resources estimated as a result of the NURE program[6] appear in Table A-1, Appendix A, by forward-cost category and resource category. The current resource estimates are summarized in Table 3:

Table 3

U.S. URANIUM RESOURCES
(As of January 1, 1981)

Forward Cost Category*	Thousand Tons U_3O_8 Reserves	Probable	Possible	Speculative	Total
<$30/lb	470	885	346	311	2012
<$50/lb	787	1426	641	482	3336
<$100/lb	1034	2080	1005	696	4815

Previous uranium supply estimates are contrasted with present estimates in Appendix A (Table A-2). The Committee on Nuclear and Alternative Energy Systems (CONAES) study of the National Research Council recommended that only those uranium deposits in the reserves and probable resources categories should be taken as a basis for prudent planning.[7] Moreover, they cautioned that availability of U_3O_8 in the higher forward cost categories (lower uranium concentrations in the ore) is known with such little certainty that it should not be used for planning purposes. Thus although the possible and speculative resource categories might be considered in a very long-term context, taking a U_3O_8 resources estimate in the 2-3 million short ton (ST) range is a prudent assumption for planning purposes.

*For purposes of this report, forward costs are the yet-to-be-incurred costs of producing U_3O_8 from a given resource, and include the direct costs of developing and operating a mine and building and operating a uranium mill. They are used to indicate the economic availability of a uranium resource. A forward cost category includes all resources at or below the stated forward cost. Forward costs are not to be confused with price, which includes past costs, exploration costs, cost of money, marketing costs, rate of return, profit, some taxes, etc. For this study, a rough rule of thumb is that price is up to two times forward cost.

9 The annual uranium requirement for a LWR varies between 140 and 200 ST U_3O_8,[8] depending on whether a once-through, improved once-through, or recycle fuel cycle is used. Thus, reserves and probable resources of 2-3 million ST U_3O_8 could support about 10-20,000 GWe/yr of LWR operation (330-670 LWR's for assumed 30 year lifetimes) if the current once-through fuel cycle is maintained, or more if the industry were to improve the once-through fuel cycle or go to the recycle mode. Thus, the reserves and probable resources could be committed as early as the first part of the next century or as late as several decades later. Timing of the uranium resource depletion is highly uncertain, but irrespective of whether present U.S. uranium resources are committed soon after the year 2000 or somewhat later, the contribution to nuclear power by LWRs will ultimately be limited by the availability of economic uranium resources.

With breeder reactors, uranium resource utilization will be greatly extended compared to current generation LWRs. Nuclear capacity can reach thousands of GWe instead of hundreds (see Figure 1), and the time span of the nuclear energy contribution can be many hundreds of years instead of only a few decades. As shown on this figure, solar and fusion represent an inexhaustible energy supply. The role of breeders in the future energy economy should be viewed as a technology option that can provide an essentially inexhaustible fuel supply to the electrical-generating system.

2. Forecasts for LMFBR Electricity Costs

Compared to other possible sources of large-scale, inexhaustible energy supply, estimates of the future costs of electricity generated by LMFBRs favors continued development. As with any large new technology under development, there are uncertainties in LMFBR cost estimates that can only be resolved by developing the technology to a near-commercial stage. However, the uncertainties associated with the cost of electricity from LMFBRs are much less than the cost uncertainties associated with other, less well-developed technologies.

The economic comparison between the LWR and the LMFBR is determined by a number of factors. The major cost components are:

- o Plant Capital Costs
- o Fuel Costs
- o Operation and Maintenance Costs

Basic trends in LWR/LMFBR comparisons are established for these major costs. The LMFBR is projected to have a higher capital cost, which will be offset by a lower fuel cost during operation of the LMFBR. The difference in these costs and the escalation of these costs over time will determine the relative economics of the two reactor systems.

Many systems analysis studies have been performed in recent years which resulted in predicted dates when the LWR and LMFBR costs will be the same. Such dates have been interpreted as the time in which the LMFBR will be needed. The date that results from such systems studies is highly dependent on the assumptions used. Some studies conclude that the LMFBR will or could be needed by 2000, while others conclude that a date several decades later is more likely[9,10,11]. The mid-range of opinion, as expressed in several of the more extensive recent studies,[12,13,14] appears to be that LMFBR development should be geared toward meeting a potential deployment need early in the next century. The pace of LMFBR development will affect the cost of breeders relative to LWRs. A more rapidly paced program will accumulate more reactor and fuel cycle experience by an earlier date, and hence the learning experience will result in lower costs at an earlier date.

Regardless of whether a particular economic model predicts 2010 or 2030 or some other date of economic competitiveness between LMFBRs and other technologies, responsible national energy policy dictates that the pace of the LMFBR development program be structured to accommodate significant uncertainties. This point is addressed in Section III.D.

3. Advanced State of LMFBR Development

The LMFBR is in a relatively advanced state of development, both in the U.S. and worldwide.[15] In the U.S. the EBR-II, which began operation in 1964, has operated reliably for 17 years supplying 18 MWe of electrical energy. The U.S. Fast Flux Test Facility (400 MWt) has recently (1980) begun operation as a fuels and materials irradiation facility. In France, the Phenix Reactor (250 MWe) has been in operation since 1974. A follow-on commercial-size LMFBR, Super-Phenix (1200 MWe), has been designed and is presently under construction, with completion scheduled for 1983. In the U.K., the 250 MWe Dounreay PFR has operated since 1974. The U.S.S.R. recently (1980) began operation of BN-600, a 600 MWe LMFBR, following by seven years the 1973 startup of BN-350, a 350 MWe-equivalent LMFBR. The SNR-300, a 300 MWe reactor, is under construction in West Germany (now 50 percent completed), and Japan is preparing to begin site preparation for MONJU in 1982, another 300 MWe plant. In the U.S., design work is nearly complete, and component fabrication is well along for the CRBRP.

Compared to other large-scale, inexhaustible alternatives, LMFBR technology is therefore relatively advanced. Technical feasibility of the LMFBR has been clearly demonstrated and the remaining work is to conduct engineering scale demonstration of the technology at a size leading up to that of commercial plants. Even though no fundamental scientific breakthroughs are required, the work that remains will take time.

The ability to use foreign LMFBR technology has been considered. Because of the unique U.S. licensing environment, foreign reactor designs could require modification. While the extent of such modifications is unknown, they could be extensive, costly, and take time to accomplish.

A domestic LMFBR industry would have several additional economic benefits. It could preclude negative balance of trade aspects that would occur if the U.S. were to import foreign technology and could provide an export item when a world LMFBR market develops.

D. Timing of LMFBR Development

Many studies of U.S. and international energy policy conclude that LMFBR development is a prudent course.[14-17] However, the pace of the development has been an issue, and it is useful to consider development timing under current conditions. There are four main reasons to proceed expeditiously with the U.S. LMFBR development program:

- Even with a relatively vigorous LMFBR development program, a commercially viable LMFBR cannot be available for several decades.
- There is significant uncertainty in any prediction of a date for LMFBR need.
- In view of uncertainties, the penalties for developing the breeder too early are small compared to the penalties for developing too late.[18]
- Continuity is essential to progress in any high technology development program.

These four reasons are discussed in the following sections.

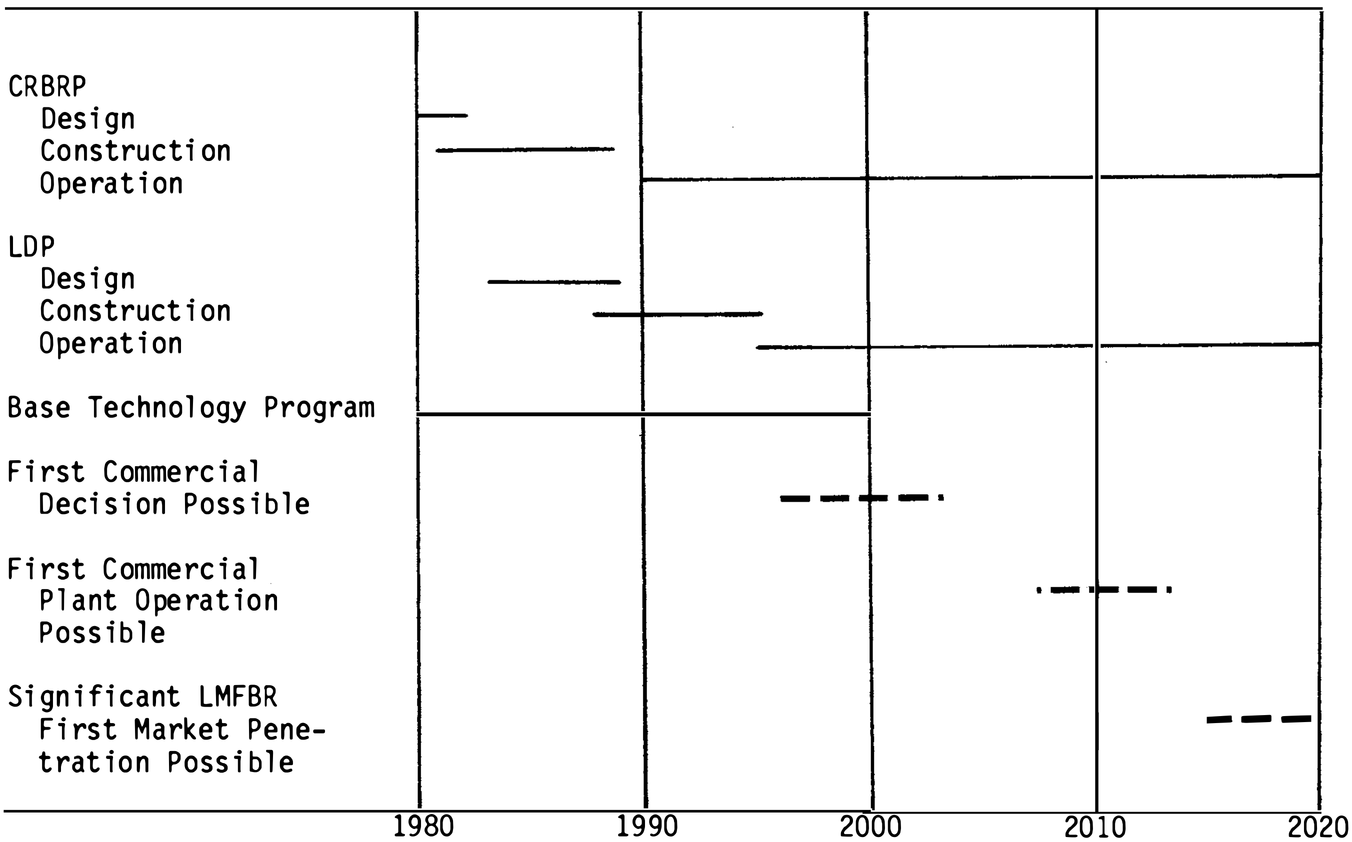
1. Inherent Long Lead Time for Development

Even if the LMFBR program is pushed ahead now in a vigorous fashion, commercial-scale demonstration cannot be accomplished until the mid-1990's and resulting utility commitments to commercial LMFBRs would result in LMFBR generating plants no earlier than 2005 to 2010. Figure 2 illustrates the period that will be required to obtain a significant market share with the LMFBR. It appears that 2010-2020 is the earliest that significant numbers of LMFBRs could be brought on-line in the U.S. Even this will require prompt implementation of the development schedule shown.

This development schedule is consistent with U.S. experience in commercializing the LWR. About 25 years were required to progress from the announcement of the first LWR demonstration plant (1953) to commercial viability and significant market penetration (the late 1970s). However, this was done in a regulatory and economic environment that differs considerably from that today, and perhaps from that which can be anticipated in the future. Thus 35-40 years to complete a similar commercialization process for the LMFBR is not unrealistic. Even in the French LMFBR program, which also has a less constraining economic and regulatory environment, about 30 years will have elapsed from LMFBR demonstration announcement (c. 1970) to significant market penetration (c. 2000).

Figure 2

LMFBR Development Schedule



Beginning CRBRP construction in 1982 or early 1983 will allow completion around 1990. The project will provide experience in the construction and operation of an LMFBR system in a utility environment. The CRBRP will demonstate an integrated system design, and will reduce the risk involved in the scale-up to larger plants. To provide data on plants of a scale near that which is most economical for central station power production, the program envisions that a large developmental plant (LDP) would begin operation in the mid 1990's. A decision on proceeding with a large scale plant could be made in the next few years based on satisfactory completion of implementation planning. Design and construction of the LDP would continue to build on the experience with FFTF and CRBRP as well as on international experience that is available. The project timing of the CRBRP and LDP will allow utilization of the present experience base including efficient transfer of experienced design personnel from one project to another. Relative timing is discussed further in Section IV.A.

The successful demonstration of the LMFBR option by design, construction and operation of the CRBRP and the LDP before the turn of the century is expected to provide utilities with the confidence required to begin breeder commercialization when market factors dictate.

2. Uncertainty Inherent in Timing of LMFBR Need

Considering the experiences of the last decade (rapidly escalating energy prices, oil embargoes, etc.), the date at which the LMFBR will be economically competitive depends on many future events; progress within the LMFBR program, capital costs, future costs of alternative electricity options, future electricity demand, future development of other long-term energy options, and resolution of environmental issues. Each of these items involves uncertainties that must be considered in planning a prudent course.

For example, if the electrical growth rate is larger than presently expected, the date at which numbers of LMFBRs are needed may be earlier than is now considered likely, perhaps as early as the beginning of the next century. On the other hand, if the supply of uranium ore were to be significantly larger than presently believed, the date at which significant numbers of LMFBRs are introduced would likely recede.

As noted earlier, the prudent course is to gear the development program toward possible commercialization of LMFBRs fairly early in the next century. Prior to breeder commercialization it will be necessary to demonstrate acceptable LMFBR performance, reliability, safety, environmental acceptability and economic merit. Thus, with lead times for designing and constructing reactors at 10-12 years, minimum, CRBR should be completed as expeditously as possible and operation of a large-scale developmental plant needs to take place prior to 2000. Given the results of this program and then-current data on energy growth, uranium resources, and other factors, an informed decision on LMFBR commercial deployment by the utility industry would then be possible. This course provides the maximum programmatic flexibility and minimizes the risk of not having options available. If during development it becomes known that the date at which the LMFBR will be needed is later than expected, the additional time can be utilized by the nuclear industry to refine the LMFBR design and enhance its economic performance prior to large-scale deployment. Unforeseen obstacles could be encountered in the development phase; substantial incentives exist for discovering such obstacles as far in advance of expected deployment as possible.

3. <u>One-sided Risk of Delay</u>

If the LMFBR is developed in such a way that is not economically competitive when the development program is complete, it means the government will have invested several billion dollars earlier than needed. With a specific choice of the time-cost of money and the length of the period involved, a cost for too-early development can be calculated. As an example, if one assumes an expenditure of $600 million per year for 15 years at a discount rate of 5-7% 9
(an interest rate assuming no inflation), then the present value of the

expenditure is $5.5-6.2 billion. This represents the present value of the maximum savings that could be achieved by complete cancellation of expenditures. In a case where the start of the 15-year expenditure is delayed 10 years, the
9 present value of the delayed expenditure is $2.8-3.8 billion. Thus, in this example, the value of the delay in expenditure is $2.5 billion. Some indirect savings might be expected from, for example, decreased budget deficits.

If the LMFBR is not ready to begin deployment when needed, the costs could be large. In 1979, sales of about 2000 billion kWh of electricity generated roughly $100 billion in revenue[19]. Using these 1979 values, if a technology could reduce the average cost of electricity by even a few percent, the direct savings would be billions of dollars annually, and would be supplemented by indirect benefits such as increased output and employment opportunities. Thus if the sole effect of deploying the LMFBR was a reduction in future electricity costs of a few percent, the economic penalties of developing the LMFBR and finding out that its deployment will be deferred are far outweighed by the potential economic penalties of needing the LMFBR and not having developed it. If, however, it turns out that the alternatives to the LMFBR are either very costly, or constrained in some fashion, the potential benefits of going ahead with the LMFBR become very large.

In noting that economic analyses of LMFBR timing are based on numerous assumptions that are inevitably subject to challenge, the ERDA Internal Review Board stated:[20]

> "The Board is wary of facile attempts to resolve these areas of controversy, dependent as they are upon future events which are more or less speculative. With regard to projections of energy demand, it seems prudent to assume a moderate level of growth for planning purposes. This is so not because ERDA is committed to any particular growth scenario, but simply because the penalties for underestimation are likely to be far more severe than those for overestimation. A program can be scrapped

if its need does not become actualized. But the long lead times involved in research and development programs and plant construction make it relatively difficult to accelerate efforts which have been held in abeyance pending an unmistakable confirmation of their need."

4. Continuity of High-Technology Programs

Significant work has already been performed to bring U.S. LMFBR technology to its current state. The nation has a considerable investment in the team of people and the facilities that now make up the LMFBR program. If development were substantially deferred, experienced people would be lost to other fields, and existing facilities would have to be closed. Reacquisition of the expertise and reactivation or reconstruction of facilities would be a costly process. High-technology programs simply cannot be turned off, deferred for a period of time, and restarted without incurring very high costs. As noted in a recent review of the French program:[21]

> "Considering the overall French breeder program, a principal reason for the excellent breeder progress in France is the steady pace from one project to the next without debilitating gaps. So far, France has been able to get on with each new project within about a year of the startup of the prior one. Rapsodie went into service in 1967, and the start of Phenix construction began in 1968. Phenix produced its first electricity in December 1973, and the site work on Superphenix 1 was begun one year later in December 1974 near Malville in the parish of Creys-et-Pusignieu. Superphenix 1 is slated for startup in 1983 by which time EdF is expected to be ready to proceed with the ordering of a twin unit fast reactor station, embodying the Superphenix 2 series, 1500-MWe units."

Additional evidence which shows that high technology programs cannot be turned off or deferred comes from considering U.S. program examples. Considerable synergism resulted from the timing of the FFTF and Clinch River Breeder Reactor program. This synergism included not only the direct design experience but also the direct transfer of experienced personnel. Without a vigorous continuing plant design and construction program, these experienced personnel are irretrievably lost.

Thus, both the success of the French program and recent U.S. experience argue strongly that continuity of high technology programs is essential to prevent unnecessary costs and delays due to loss of technically experienced personnel.

If the U.S. were to reject current development of the LMFBR, it would be rejecting or deferring a relatively certain technology capable of producing an essentially inexhaustible electrical energy supply. The government has recognized an obligation to assist in timely development of the technologies that offer large-scale, long-term, economic, energy supply potential. Although not the only candidate, the LMFBR is today the surest. A relatively vigorous path of LMFBR development is therefore prudent for the government to pursue, based on the promise of the LMFBR and the uncertainty over future energy events.

REFERENCES FOR SECTION III

1. Atmosphere-Biosphere Interactions: Toward a Better Understanding of the Ecological Consequences of Fossil Fuel Combustion, Committee on the Atmosphere and the Biosphere of the National Research Council, National Academy Press, Washington, D.C., p.3, (1981).

2. Hutchinson, T.C. and M. Havas, eds. "Effects of Acid Precipitation on Terrestial Ecosystems," Plenum Press, New York, (1980).

3. Likens, G.E., Wright, R.F., Galloway, J.N., and Butler, J.T., "Acid Rain," Scientific American, Vol. 241, p. 43 (1979).

4. Energy in Transition, 1985-2010, Final Report of the Committee on Nuclear and Alternative Energy Systems, National Research Council and National Academy of Sciences, W.H. Freeman Co., San Francisco, p. 60 (1979).

5. ibid, p. 121.

6. "An Assessment Report on Uranium in the United States of America," DOE GJO-111 [80], U.S. Dept. of Energy, Grand Junction, Colorado (1980).

7. op. cit, Energy in Transition, p. 229.

8. International Nuclear Fuel Cycle Evaluation, Report of Working Group 5: Fast Breeders, IAEA, Vienna, p. 69 (1980).

9. "U.S. Energy Supply Prospects to 2010; The Report of the Supply and Delivery Panel to the Committee on Nuclear and Alternative Energy Systems," National Academy of Sciences, Washington, D.C. (1979).

10. Nuclear Power Issues and Choices, results of a study sponsored by the Ford Foundation and administered by the Mitre Corp., Ballinger Publishing Co., Cambridge, Mass., p. 356 (1977).

11. Energy, The Next Twenty Years, results of a study sponsored by the Ford Foundation and administered by Resources for the Future, Ballinger Publishing Co., Cambridge, Mass., pp. 447-448 (1979).

12. Nuclear Proliferation and Civilian Nuclear Power, Report of NASAP; Volume V: Economics and Systems Analysis, DOE/NE-0001/5, U.S. Dept. of Energy (1980).

13. C.E. Till, et al., "Fast Breeder Reactor Studies," ANL-80-40, Argonne National Laboratory (1980).

14. M.K. White and E.T. Merrill, "Evaluation of the Commercial FBR Introduction Date," PNL-3597, Pacific Northwest Laboratory (1981).

15. op. cit, INFCE Report of Working Group 5.

16. op. cit, Energy in Transition, p. 70.

17. op. cit, Nuclear Power Issues and Choices, p. 359.

18. J. B. Burnham, "Analysis of Alternative FBR Development Strategies," PNL-3600, Pacific Northwest Laboratory (1981).

19. Energy Information Administration Annual Report to Congress: 1979, II, DOE/EIA-0173(79)/2, U.S. Dept. of Energy, pp. 147-149 (1979).

20. Liquid Metal Fast Breeder Reactor Program, Final Environmental Statement ERDA-1535, I, U.S. Energy Research and Dev. Admin., p. IV 8-27 (1975).

21. The Achievements, Findings, and Lessons of the Phenix LMFBR Power Plant Experience, EPRI NP-1972 Executive Summary Electric Power Research Institute p. 8-1 (August 1981).

IV. Alternatives Including the Current LMFBR Program

In this Section, part A describes the current LMFBR program, part B discusses alternatives within the current program, part C considers program termination, and part D discusses alternatives to the LMFBR for long-term production of electricity. This material updates or supersedes similar material found in ERDA-1535,

Section I.3 An Evaluation of Alternative LMFBR Program Plans

I.4 Analysis of the Resolution of Major Issues and Compatibility with LMFBR

III.H Alternative Long-Term Energy Systems Options

and in WASH-1535, Section 3, LMFBR Program.

The current LMFBR program plan and alternatives are considerably scaled back from what they were in ERDA-1535. The key elements of the reference program, i.e., the two developmental plants and the base technology program, are still in place. However, some follow-on plant projects and some other facilities are not included in the current plan. The Clinch River Breeder Reactor Plant (CRBRP) is still the intermediate-size developmental plant, but the Prototype Large Breeder Reactor (PLBR) of the previous plan has been replaced by the Large Development Plant (LDP) as the next large size plant.

Because the current LMFBR program plan essentially is scaled down from the previous one, the environmental effects due to implementing the present plan are expected to be less than those analyzed in ERDA-1535. In addition there have been advances in the base technology program since 1975 that extend confidence and reduce uncertainty in the environmental acceptability of the LMFBR program.

A. Reference LMFBR Program

1. Overview

The basic objective and direction of the current breeder program remains essentially as it was in 1975. Its goal is to ensure that a proven long-term electricity supply option is available on a prudent time scale. To accomplish this goal, the U.S. LMFBR program was established with the overall objective of developing the engineering and industrial base that will be required for design and construction of LMFBR plants. As a result of this program an industry determination can be made of the economic potential, environmental acceptability, safety, and reliability of the LMFBR system. The decision on LMFBR commercialization will be made on the basis of this determination.

The LMFBR program consists of:

- o Developmental plants (CRBRP and LDP);
- o The base technology program, including test facilities; and
- o Supporting fuel cycle programs.

The LMFBR program is focused on the construction of a sequence of developmental plants that will integrate several complex technologies into an overall engineered system. Construction of sequential developmental plants is the best way that the state of the technology can be evaluated and issues can be identified that need to be resolved. The base technology program provides those basic data, processes, methods, and components that are utilized during the entire course of the LMFBR development program in the design, licensing, construction, and operation of LMFBR powerplants. The base technology program also directly supports the needs of each specific plant project. In turn, the design, licensing, and operation of the development plants provides key information back to the base technology areas, thus allowing optimization of all elements of the program. Ultimately, a system of LMFBRs depends on a closed fuel cycle. Fuel cycle activities, including fuel fabrication, fuel reprocessing, and waste management, are thus an important part of bringing the LMFBR to the point where commercialization is feasible.

The LMFBR program has its foundation in significant past accomplishments. LMFBR development began in the U.S. in the late 1940's, and had its first significant step in 1951 with operation of the Experimental Breeder Reactor No. 1 (EBR-I). In 1964, EBR-II began operation and has provided 17 years of reliable service to date. Supplying 18 MWe of electricity, it was one of the nation's first certified cogeneration facilities. The Fast Flux Test Facility (FFTF), generating 400 MWth, has recently begun operation as a fuels and materials irradiation facility. Construction and operation of these and other reactors such as Fermi-I and SEFOR (Southwest Experimental Fast Oxide Reactor), operation of test facilities, design and fabrication experience from the CRBRP, concept studies for other plants, and some information from foreign exchange programs provide the foundation for the U.S. LMFBR program.

All foreign LMFBR programs are broadly similar to the U.S. program in the approach to technology development. In all programs the plan is to scale-up the technology through a sequence of plants, supported by significant activities in areas identified in the U.S. as elements of the base technology program. Recognizing the ultimate dependence of the LMFBR upon a closed fuel cycle, each program incorporates fuel cycle research and development.

The engineering basis for scaling technology from the laboratory to the commercial plant is well established. Sound engineering practice has established that successful technology scale-up is acccomplished through a sequential series of engineering projects of increasing size, culminating in a successful commercial technology. Information gained at each step can be used to modify the direction of the program. The magnitude of each sequential scale-up is determined by weighing the cost of development against the risk of failure. While small steps may entail substantial time and development costs, even more time and money may be lost in a single large step, because of overly-conservative design, extensive back-fitting, or even failure.

The U.S. program has continued to follow this line of sound engineering practice, as have foreign LMFBR programs. The U.S. program now includes EBR-II at 18 MWe, FFTF at 400 MWth, the CRBRP at 350 MWe, and the LDP at 1000 MWe.

Size of an LMFBR plant is a technical issue, in that the larger the plant the more demanding the requirements on components and systems. But size is not the only issue. The government has the responsibility to conduct a prudent program, one that ensures that the taxpayers' investment is wisely spent. It is important to have the technology base firmly established when the time approaches for a commercialization decision to be made. Basically this means that the program should be structured to result in an economic, environmentally acceptable, reliable, and safe LMFBR that can be constructed and licensed in a variety of locations.

A decision on specific plant sizes to be built involves choosing from a prudent range, trading off between minimizing total development costs and maintaining high technical confidence. The CRBRP at 350 MWe is the next step in scale-up of U.S. LMFBR technology. This plant scale was chosen, after exhaustive study[1], as a logical next step. This choice is supported by decisions made in foreign programs, in that each foreign LMFBR program includes a plant within the 230-350 MWe range.

A key feature of the U.S. development program is avoiding premature foreclosure of technological alternatives. In any construction project, design choices must be made among feasible alternatives. To the extent possible during development, there is merit in keeping open options that might be exercised later.

For example, the design of the primary heat transport system in LMFBRs falls into two categories: the pool (where the entire primary system is contained within a relatively large primary vessel) or the loop (where piping external to the reactor vessel transports sodium to pumps and heat exchangers). Experience indicates that either concept can be constructed and operated safely and reliably. Indeed the French, British, Soviet, and U.S. programs have all included at least one shift in the loop/pool choice.

The DOE Conceptual Design Study (CDS) concluded that there was no overwhelming advantage to either concept.[2] It was also concluded that there would be no environmental differences and that safety differences would be insignificant. Participants, drawn from the industry, recommended a loop concept for what is now the LDP, but recognized that there may be merit in the pool concept for commercial plants.[2] Regardless of the choice, the developments that are required in components and other key base technology areas are much the same. For example, the steam generators are equally applicable to either concept, and much of the plant required for a pool system is essentially the same as that now being developed for a loop system. In both instances, the design, manufacturing, and operating experience gained are an effective base for future plants. The conclusion is that the U.S. program, now on the loop path for the CRBRP and the LDP, is not precluded from a future switch to a pool system, either for the LDP design or for a subsequent plant. Thus, the program retains more flexibility than does a specific project, in which changes in choice of concept can add considerable expense.

Another example of the flexibility built into the U.S. program deals with fuel type. In the Conceptual Design Study for a large plant, flexibility was maintained with respect to choice of fuel type by making the design of the reactor internals capable of accepting either the reference oxide fuel design, or an advanced fuel design. Similarly, it was shown that the CRBRP could operate satisfactorily on a variety of fuel cycles, and the reference core design was switched from homogeneous to heterogeneous without other significant changes in environmental or safety aspects of, or expense incurred by, the project.

2. Program Elements

The elements of the LMFBR program exist to meet the objective of developing the engineering and industrial base required for a decision on commercialization of the LMFBR. The principal elements of the program are the design and construction of developmental plants; the base research and development activities; and the associated fuel cycle research and development activities. Construction and operation of the developmental plants will provide a demonstration of the industrial base and will establish the utility confidence that is necessary for the commercialization decision. The base program is providing the technology development that is required for the engineering design, safety analysis, and scale-up of the powerplants. Development of the nonreactor parts of the LMFBR fuel cycle, such as reprocessing and fuel fabrication, is necessary prior to commercial deployment of the LMFBR.

a. Developmental Plants

The technologies needed to make the LMFBR option available will be the end result of a planned sequence of developmental breeder and other reactor facilities that began with Experimental Breeder Reactor I (the world's first source of nuclear-generated electric power), followed by the 18 MWe Experimental Breeder Reactor II, the 65.9 MWe Enrico Fermi Atomic Power Plant (the first LMFBR plant to supply electricity to a commercial utility grid), the 350 MWe Clinch River Breeder Reactor Plant, and a proposed 1000 MWe Large Developmental Plant. In addition to zero-power reactors for determining the configurations and nuclear characteristics of LMFBR cores and blankets, the breeder program was also supported by the 20 MWth Southwest Experimental Fast Oxide Reactor (SEFOR), which was operated essentially for physics experiments and has since been decommissioned. The program is now being supported by the 400 MWth FFTF, a fuels and materials test facility. To attain the objective of developing an engineering and industrial base, vigorous efforts will be resumed on the construction and operation of the CRBRP, and a program will be initiated to perform the preliminary design and to conduct implementation planning in cooperation with the private sector for the final design, construction, and operation of the near-commercial-sized LDP. These developmental plants are discussed in detail in the following two sections.

(1) The Clinch River Breeder Reactor Plant

The CRBRP is a liquid-sodium-cooled breeder reactor that will produce 350 MWe of net electrical power. Its construction is planned for a site adjacent to the DOE reservation at Oak Ridge, Tennessee, where it will be operated as a part of the Tennessee Valley Authority (TVA) electricity supply network. The CRBRP is authorized under Public Law 91-273. The contractural arrangement has been in effect since 1973 among AEC/ERDA/DOE, the Project Management Corporation (PMC), the TVA, and the Commonwealth Edison Company of Chicago.

Funding for the project is provided by the federal government, the utilities, reactor manufacturers, and equipment vendors. The federal government is to provide all project funding in excess of the utilities' contributions of approximately $260 million and the reactor manufacturers' and vendors' contributions of approximately $10 million. Total estimated federal expenditures are approximately $3.3 billion.

The involvement of many organizations is an important part of the CRBRP Project. Approximately 3500 people are employed in these activities in 29 states and the District of Columbia as of November, 1981. Besides the DOE, the lead reactor manufacturer, and the architect-engineer, about 25 companies are involved in manufacturing and testing components for the plant. In addition, 753 electric systems from the public, private, municipal, and cooperative sectors of the electric power industry support the project through the non-profit Breeder Reactor Corporation (BRC). Development of this type of industrial and utility base is necessary for the ultimate commercialization of the LMFBR.

(a) Objectives

As in ERDA-1535, the CRBRP will serve as an important step in beginning the transition of the fast breeder reactor program from the technology development stage to the decision point of large-scale commercial utilization. The major objectives of the project are:

- o to demonstrate the technical performance, reliability, maintainability, safety, environmental acceptability, and economic feasibility of an LMFBR central station electric powerplant in a utility environment;
- o to confirm the value of this concept for conserving important nonrenewable natural resources.

(b) Role of the CRBRP

The CRBRP is a key part of the overall DOE long-range LMFBR research and development program. It is designed to be an integrated electric powerplant with a liquid-sodium-cooled breeder reactor supplying the thermal energy to produce steam to drive a turbine-generator. With the initial reactor core of uranium and plutonium mixed-oxide fuel, the plant is expected to produce 975 megawatts of thermal power (MWth) and a net output of 350 electrical megawatts (MWe). Thus, the CRBRP will be analogous to Phenix (233 MWe) in France, PFR (250 MWe) in Great Britain, BN-350 (350 MWe equivalent) in the U.S.S.R., SNR-300 (300 MWe) in the Federal Republic of Germany, and Monju (300 MWe) in Japan. Since the utilities have been involved in the project from the beginning, a successful CRBRP project will bolster utility confidence that the LMFBR can be built, licensed, and operated. In addition, since the CRBRP Project is presently authorized, the design is nearly completed and procurement has already started, it should be completed as expeditiously as possible to minimize government expenditures and to make a significant step in satisfying the technology availability goals of the LMFBR program.

(c) Site Selection

The Clinch River site was selected for the CRBRP Project as a result of a series of programmatic decisions by the DOE's predecessor agencies, the AEC and ERDA. Although proposals were actively sought from all areas of the country, only three were received, and the TVA/Commonwealth Edison proposal was selected for further negotiation. This selection process narrowed the range of acceptable sites to those within the TVA region. The eventual negotiations resulted in the unique contractual arrangement for the project, and the ultimate selection of the Clinch River site. No preferrable sites within the TVA region have since been identified. Sites outside of the TVA region cannot be considered for the CRBRP because of the contractual arrangement. Continuance of that arrangement is essential to the success of the project in attaining its goals. Finally, the NRC's 1977 Final Environmental Statement and Site Suitability Report found the site to be acceptable on both programmatic and environmental grounds[3]. The Clinch River site remains the preferred alternative for meeting LMFBR program as well as CRBRP project objectives. An expanded discussion of the CRBRP site selection process is contained in Appendix G.

(d) Status of the CRBRP

The CRBRP is a loop-type LMFBR plant that incorporates much of the experience gained in construction of the FFTF. In particular, the fuel pin and the assembly hardware are essentially the same type used in the FFTF. The intermediate heat exchanger design of CRBRP was changed because of unfavorable manufacturing experience with the FFTF. Results of the natural circulation tests in the FFTF and in the EBR-II were used in the CRBRP design. It is worth noting that such tests could have been conducted only in an operating reactor.

Significant progress has been made to date in the design, development, and hardware procurement areas. The project is in a position to begin site clearing and construction upon receipt of the necessary approvals from the Nuclear Regulatory Commission. The following list includes some of the significant accomplishments to date:

- Overall plant design about 90% completed and project-funded research and development about 95% completed;
- About 7,000 architect-engineering drawings of the required 9,400 prepared;
- Procurement contracts for over $500 million of hardware representing approximately 60% of the total required project hardware placed;
- Manufacture of approximately $251 million of hardware completed and about $120 million of effort accomplished on other hardware in process;
- Contributions made to advancement of the worldwide state-of-the-art in LMFBR plants, such as the heterogeneous core;
- Continuous evaluation and updating of the plant design to remain current with changing regulatory requirements;
- Issuance in 1977, by the Nuclear Regulatory Commission, of the Site Suitability Report and the Final Environmental Statement, which concluded that the site is suitable for the plant and that the action called for under the National Environmental Policy Act and 10 CFR Part 51 is the issuance of a construction permit;
- Licensing activities were resumed with the Nuclear Regulatory Commission staff in 1981; and
- Prototype steam generator and prototype primary pump delivered to Energy Technology Engineering Center for testing in sodium.

(e) Information Provided for the Next Plant

The CRBRP design will demonstrate a number of fundamental characteristics of LMFBRs which are not particularly sensitive to size. These include basic properties and characteristics such as high-temperature materials properties, thermal hydraulic characteristics, and such physics properties as breeding and burnup of the fuel and blankets. In addition, much of the CRBRP equipment, components and systems have some fundamental features and characteristics which are directly applicable to large LMFBRs. The heterogeneous core of the CRBRP is more advanced than any built or planned in any of the foreign programs, and will provide vital information for the U.S. commercial-size reactors.

Extensive research and development has been conducted to verify the high-temperature characteristics and the design methods required for the piping and vessel designs. These characteristics and methods, which are applicable to commercial size LMFBRs, will be demonstrated for an integral system in the CRBRP. In addition, the CRBRP will provide verification in an operating system of thermal hydraulics analysis methods, and will give confidence that the methods can be extrapolated to larger systems.

Successful operation of CRBRP will give confidence that breeder fuel cycle models are adequate for progression to larger systems. In addition, most of the basic safety codes being developed for CRBRP are directly applicable to larger plants. Valuable experience will be gained in writing the Safety Analysis Report and in dealing with the NRC on safety and licensing requirements.

Components and systems being used on CRBRP which have fundamental features and characteristics of commercial-scale LMFBRs include:

- o Fuel
- o Upper core internals
- o Reactor closure rotating plug seals, bearings, insulation and cooling
- o In-reactor vessel coolant separation methods
- o Reactor vessel coolant outlet thermal striping and mixing models
- o Piping
- o Sodium pump seals, drives, and design methods
- o Intermediate Heater Exchanger (IHX) bellows, IHX design methods, and fabrication techniques
- o In-vessel refueling equipment
- o Steam generator relief system
- o Sodium clean-up systems
- o Sodium drain systems
- o Inert gas systems
- o Seismic design of piping and components
- o Instrumentation and control equipment and systems
- o Radioactive waste treatment systems

Besides supplying important data on hardware, systems and methods, the CRBRP project will supply essential experienced technical personnel for the design, construction, and operation of future LMFBR plants. Maintenance of cadres of skilled personnel is necessary for orderly progress in the LMFBR program. In addition, the manufacturing capability will be in place and the necessary industrial/utility/laboratory infrastructure will exist to insure the successful construction and operation of a near-commercial-size plant.

Given the vast technology base that will be transferred to the follow-on plant, the CRBRP represents the next logical and necessary step in the disciplined progress of this country's 35 years of research and development of the LMFBR concept. It will represent considerable progress towards the goal of providing the option for deployment of large commercial-scale breeders.

(2) The Large Developmental Plant (LDP)

The importance of a large-scale developmental plant (LDP) has been recognized for many years in the LMFBR program. The LDP is expected to provide a large-scale (1000 MWe) demonstration of the LMFBR technology as an essentially inexhaustible power production option for meeting future U.S. electrical energy requirements. Data from design, construction, and operation of the LDP will form a large part of the basis for an ultimate LMFBR commercialization decision.

Most specifically, the project will:

- Advance the state-of-the-art of LMFBR plant design, construction and operation and demonstrate on a near-commercial scale the viability of the breeder option for possible future deployment;
- Involve multiple industrial contractors and make maximum use of the existing broad base of U.S. LMFBR industrial expertise, thus assuring that a sound LMFBR supply industry exists in the 1990s to compete for a fair share of the world market;
- Provide a sharp technical focus for the LMFBR base R&D program and fuel cycle development activities through the continuous identification of the development requirements necessary for generating a base of data on which a future LMFBR deployment decision could be based;
- Be a valuable tool in further development and validation of codes and criteria for large LMFBR plants;

- o Provide a stepping stone to commercially deployable plants;
- o Generate nearly 1000 MWe for distribution over a utility system, thus generating a substantial amount of net revenues.

The present objectives of the LDP Project are to perform advanced conceptual design on the more critical portions of the plant, to attempt to develop cooperative arrangements with the private sector and foreign nations, and to attain a state of readiness to proceed, if authorized, with the design and construction portion of the project.

Current planning calls for a decision on LDP design, construction and operation in the mid-1980s, with operation in the mid-1990s. A commitment to design, construct and operate the Large Developmental Plant does not imply a commitment to commercialize the LMFBR. Proceeding with the Large Developmental Plant will, however, provide valuable information on LMFBR cost, schedule, and operational characteristics for use in support of a future decision on commercial deployment. The current approach involves fundamental utility participation which must allow necessary flexibility to respond to utility needs. It is anticipated that the private sector will provide the major portion of the capital funding for the project. However, details of the financial arrangements are yet to be specified. There is also the desire for international participation in this venture.

As described in the FES (ERDA-1535), LDP construction is planned to overlap the construction of CRBRP. Current planning indicates an overlap of a few years. This schedule would allow for assimilation of knowledge gained in design, construction, and licensing of CRBRP. Overlap would allow for a more efficient use of the design team through continuity of effort as well as assimilation of all available project information. Such key information as base program R&D, construction and planning techniques, and equipment manufacturing experience is already being used in the LDP program. Results of component tests will be available in 1982 for use in the preliminary LDP design. CRBRP startup and testing data that will be particularly useful in the LDP effort include data associated with sodium systems and inert gas systems.

The principal accomplishment on the LDP to date consists of the completion in March 1981 of the Conceptual Design Study (CDS) that was authorized by Congress and initiated in October 1978. The CDS final report[4] was issued in March 1981. Since that time, an effort to simplify and reduce the cost of the LDP design has been conducted. Included in this effort are:

- evaluations of siting criteria,
- development of a design and construction schedule,
- identification of required research and development efforts for the LMFBR Base Program,
- evaluation of potential benefits of foreign cooperation,
- development of implementation plans in cooperation with the private sector, and
- development of detailed cost estimates.

As described in the FES (ERDA-1535), construction of the follow-on breeder (PLBR) was planned to overlap the construction of CRBRP. Current planning calls for the LDP to overlap CRBRP by a few years. Overlapping permits a more efficient utilization of design teams through continuity of efforts. This approach also permits the assimilation of knowledge gained in design, construction, startup, operation, and licensing of CRBRP and its associated research and development program.

Design and equipment procurement for CRBRP has continued despite the actions taken by the previous Administration to delay construction. As a result, design of the CRBRP is nearly complete and many of the major plant components have been procured or are on order.

Experience gained from design of CRBRP was factored into the conceptual design of the LDP, and further benefits will be realized as the design of the LDP continues. For example, CRBRP equipment design and fabrication experience will be directly applicable to the LDP as most of the CRBRP components will be fabricated before preliminary design of the LDP is initiated.

CRBRP construction planning and techniques are currently being incorporated in the LDP construction planning evaluations. CRBRP construction experience will provide valuable input for the final planning and implementation of a cost-effective and schedule-oriented LDP construction plan.

Start-up testing of systems at CRBRP will provide systems and equipment confirmation data useful in design activities and subsequent test operations for the LDP. This testing input can be particularly useful in the liquid metal and inert gas systems.

Operation of CRBRP will provide additional on-line information useful for verification of designs and component concepts common to the LDP and the CRBRP and will provide additional input for testing procedures in such areas as remote fuel handling. CRBRP operating experience will also be factored into the procurement specifications of such LDP systems as the plant-wide computerized control system. In the event that early CRBRP operation discloses an unexpected system problem, the phasing of the two projects provides time to implement corrections on the LDP.

Additionally, operation of the CRBRP, in the course of demonstrating the technical performance, safety, and economics of an LMFBR plant in a utility environment, will develop information and expertise in plant start-up operation, and maintenance. This experience will be valuable in the planning and implementation of these key functions for the LDP and in contributing to the broad base of experience and information that is important for commercial and industrial application of the LMFBR concept.

CRBRP experience is also applicable to the LDP in plant confirmatory research and development work where much of the CRBRP work developed in the areas of safety, physics, fuels, materials, and component development is directly applicable to the LDP. Nearly all this work will be completed before preliminary design of the LDP. In addition, critical CRBRP components such as the steam generator and primary sodium pump will undergo thorough testing in 1982 and information developed during this testing program will be factored into design of the LDP.

CRBRP operation and the follow-on operation of the larger scale LDP will serve to provide important experience and data regarding the LMFBR technology, environmental acceptability, economics, and value as a practical future option for generating electric power and conserving nonrenewable natural resources.

b. <u>Base Technology Program</u>

The base technology program is structured to satisfy the goal of developing the technological data required to support LMFBR power plant design, construction, and safe operation. The elements of the base program include safety, components, materials and structures, fuels and other core materials, and physics. A description of each of these program elements and their individual goals was contained in the FES, and no basic changes have occurred since then. The direction of the base technology program has been essentially along the lines indicated in the FES. As a result of progress in the base technology program, confidence in the environmental acceptability of the LMFBR option has been enhanced. Moreover, confidence in the CRBRP design has been improved. The following is a brief summary of the program elements and some of the significant program accomplishments* since the FES was issued:

(1) Safety

The mission of the safety program is to provide an adequate data base for assessment of risk to the public, and to improve safety-related design features of LMFBRs. Specifically, the goal of the LMFBR safety program is to provide a technology base fully responsive to safety considerations in the design, evaluation, licensing, public acceptance, and economic optimization of LMFBRs for electric power generation. The program effort falls into two main areas, prevention of accidents and mitigation of accident consequences.

Breeder reactor safety technology is advanced by analyses and experiments conducted by national laboratories, industrial reactor-vendor contractors, and universities. Current planning calls for the early transfer of safety input to LMFBR plant designers, performance of safety-related R&D in support

*Additional LMFBR Program information covering accomplishments:

1. "Energy and Water Development Appropriations for 1982, Hearings before a Subcommittee of the Committee on Appropriations, House of Representatives, Ninety-seventh Congress--First Session," Part 8, Testimony of Mahlon E. Gates, Acting Assistant Secretary for Nuclear Energy.
2. U.S. Department of Energy, "Fission Energy Program of the U.S. Department of Energy: FY 1981," DOE/NE-0006, March 1980.
3. U.S. Department of Energy, "Fission Energy Program of the U.S. Department of Energy: FY 1980," DOE/ET-0089, April 1979.
4. U.S. Department of Energy," Fission Energy Program of the U.S. Department of Energy: FY 1979," DOE/ET-0048(78), June 1978.

of plant design choices, the prompt involvement of the NRC in safety reviews, and maximization of the value of contributions from foreign agreements.

Progress in LMFBR safety research is described in Section VI and Appendix E of this document. Confidence in LMFBR safety has been strenthened by that progress, as evidenced by the following:

- The reliability of the reactor shutdown system and shutdown heat removal system has been established through extensive out-of-reactor laboratory testing.
- Experiments conducted with molten fuel have provided important data for validation of analytical methods to be applied to fuel movement from breached pins. As a result, self-termination of unprotected overpower accidents can be predicted. For the other major class of accidents (unprotected loss of flow), it can be shown that extensive system damage is unlikely.
- The experimental data base, together with computer codes that extrapolate those data to prototypic accident conditions, indicates that the inherent nature of fuel motion under molten core conditions makes the core self-dispersive, and that recriticality is therefore unlikely.
- Earlier uncertainty over the limit which can be placed on the extent the damage associated with a postulated whole core accident has been substantially reduced. For the CRBRP, the adequacy of the plant design to withstand such an accident has been established.

(2) Components

This program is designed to meet the specific objectives of (1) developing key LMFBR components to assure availability of tested designs for application to large plants, and (2) providing sufficient technology, data, and experimentally verified codes to support the design, fabrication, and operation of reliable and economic systems and components.

Primary emphasis has been given to long-lead and unproven but essential components, such as large steam generators and main coolant pumps. Important data and information from design, fabrication, test, and operation of components for EBR-II, FFTF, and CRBRP are continuously utilized in the program.

Component vendors design and fabricate model components and perform the concept-dependent supporting development. Tests and generic-type development are conducted by the national and engineering laboratories and the reactor manufacturers.

Although the primary emphasis has been on steam generators and primary coolant pumps, technology is being developed and key features tested for other components such as fuel handling equipment, intermediate heat exchangers, small valves, and instrumentation and controls. Supporting development is being conducted in the areas of flow induced vibration, thermal/hydraulic effects, and natural circulation.

Significant progress in LMFBR component technology during the past few years is indicated by the following:

- o Tests were completed on the FFTF prototype pump in 1977. The test facilities at the Energy Technology Engineering Center (ETEC) were subsequently modified to accommodate CRBRP-size components.
- o A CRBRP prototype pump and steam generator have been fabricated and are being installed for testing in 1982.
- o Prototype components representative of LDP-size components are being fabricated for eventual testing in the ETEC.

(3) Materials and Structures

The technology areas covered in the materials and structures program are those for high-temperature structural design, seismic design, mechanical properties design data, fabrication, nondestructive testing, corrosion, tribology (friction, wear, and self-welding), advanced structural alloys, materials properties documentation, and sodium technology (e.g., impurity and radioactivity control).

The specific goals of the program are (1) to provide the technology required to assure with high probability that LMFBR components and systems will be free from significant structural failures during their design lifetimes, and (2) to develop materials, design methods and criteria, materials property data, and procedures that are consistent with good economics, are not overly conservative, and provide for broad flexibility in component and system design.

The output of the program is directly useful to the specific LMFBR projects. The overall strategy includes: 1) providing timely guidance to design teams, 2) performing all necessary R&D in support of the ultimate design choices, 3) maximizing the use of information derived from previous generic and specific (e.g., FFTF, CRBRP) research and development, and 4) maximizing the use of information derived from foreign exchange arrangements.

The program produces technical guidelines, design rules, data, and documentation. These are included in reports, guideline documents, contributions to NE (RDT) standards, contributions to consensus standards (e.g., ASME-BPV Codes and ASTM Standards), and the Nuclear Systems Material Handbook, which is a repository for design data.

There has been significant progress since 1975 in developing the technology base for materials data, fabrication, nondestructive examination, advanced alloys, sodium technology, and high temperature design methods and criteria. The program provided major input to the development of design rules which have been adopted by the ASME Code and which are being applied worldwide to the design of LMFBR plants.

(4) Physics

The physics program is directed toward the development of the fast reactor neutronics measurement and analysis capabilities required to provide reliable design data, accurate safety analyses, and well qualified fuel management and reactor operating procedures.

The physics program is structured to satisfy these objectives by providing critical measurements, nuclear data, and computational methods as required to assure the successful design and operation of developmental breeder plants; and maintaining a strong physics technology base to support FFTF operations and the CRBRP and LDP design efforts.

The physics program provides experimental determinations of core and shield properties, nuclear data measurements and evaluations, and development of computational methods for predicting core performance, shield effectiveness, and safety parameters. These activities support the available options for fuel types, reactor configurations, and nuclear fuel cycles available to FFTF, CRBRP, and LDP. The program includes analysis of the FFTF neutronic performance and changes due to core reload and test requirements. A program of mockup, benchmark, and interpretive critical experiments establishes the neutronic characteristics of those LMFBR cores selected for first-of-a-kind developmental reactors. Cross sections of reactor materials are measured over a wide range of energies to assure reliable core design calculations. State-of-the-art experimental and analytical physics support is provided for determination of the radiation doses utilized in fuels and materials irradiation test programs.

There was significant progress in the physics program during the years since the FES was issued. Some of the highlights are:

- Benchmark critical experiments in the Zero Power Plutonium Reactor (ZPPR) established the neutronic design properties of CRBRP-size heterogeneous cores.

- Studies of FFTF physics measurements were initiated to confirm developmental LMFBR design methodology and to improve knowledge of the FFTF test irradiation environment.

- Preliminary analyses of a shielding concept for a large LMFBR showed potential for major reductions in plant costs through rigorous design practice and careful selection of shielding materials.

(5) Fuels and Other Core Materials

The fuels and materials programs encompass the development of fuel and control components for LMFBRs; the development of materials for use in these components; and the development of equipment, processes, and facilities to fabricate fuel and assure a supply of such fuels for breeder reactors. The fuel fabrication activities are covered separately in Section IV.A.C.2 of this report. The base program has the specific objectives of confirming the performance of, and establishing lifetime limits for, FFTF fuel system core components; developing improved and advanced fuel, blanket, and absorber materials/assemblies for fast breeder reactors, in particular for CRBRP and LDP; and developing fabrication technology to assure an LMFBR fuel supply while minimizing personnel exposure, improving safeguards, and enhancing personnel safety through automated and remotely operated equipment.

The core components and materials program consists of two parallel activities: (1) the confirmation of previous development work on reference FFTF fuel-system materials (i.e., U/Pu oxide fuel and Type-316 stainless steel cladding and ducts) to support the safe and reliable operations of FFTF as a test reactor, and (2) the performance of sufficient investigations on advanced fuels, blankets, and absorber concepts to narrow the options to the point where prime candidates can be selected and developed. The program depends heavily on irradiation testing of fuels and materials conducted in the EBR-II and to be conducted in the FFTF. Significant aspects of the irradiations program in EBR-II have included: (a) carrying advanced fuels tests to and beyond goal burnups to identify ultimate performance limits, (b) continuing irradiation of advanced cladding and duct materials to high exposures, and (c) performing Run-Beyond Clad-Breach (RBCB) tests. Key aspects of the irradiations to be conducted in FFTF include: (a) qualifying FFTF driver fuels, (b) testing candidate advanced cladding and duct materials, and (c) testing advanced fuels and blanket pins. These experiments will lead to tests of full-scale assemblies of prime candidate advanced fuels and blanket concepts, which will be followed by large-scale qualification runs with partial core loadings of such assemblies.

The program for measuring and improving the performance of replaceable core components for FFTF will be conducted principally within the framework of a systematic driver fuel and absorber evaluation plan, involving periodic removal of reference driver fuel assemblies for thorough post-irradiation examination. The advanced core components effort involves the development of long-lived, highly reliable components that will enhance plant efficiency and reliability while providing good breeding properties. Major emphasis is placed on obtaining a comprehensive base of component performance information, derived for a wide variety of design options and a broad range of operating conditions. The experimental portion of this activity consists of a series of tests of pin and assembly variables that will provide a broad coverage of fuel type, advanced cladding and duct materials, pin design, and analytical capabilities.

Some of the more significant accomplishments in the fuels and materials programs since 1975 are the following:

- Reference FFTF fuels and cladding were successfully tested to goal burnup and beyond clad breach in the EBR-II.
- Fabrication of pins for four FFTF cores was completed.
- Control assemblies lifetimes were doubled.
- Improved alloys that promise significantly extended lifetimes for fuel pin cladding were developed. The list of candidate alloys has been narrowed to three.
- Criticality of the Fast Flux Test Facility was achieved in February 1980. Full power was demonstrated in December 1980 and natural circulation was demonstrated in 1981.
- The Experimental Breeder Reactor II operated at 71-77% capacity while serving as a fuels and materials test facility from 1976-1980.

c. Fuel Cycle Programs

The LMFBR fuel cycle programs are structured to develop the technological and industrial base that will be required for ultimately closing the LMFBR fuel cycle. They encompass fuel reprocessing, fuel fabrication, waste management, and transportation. Most of the LMFBR fuel cycle programs are closely associated with past developments in LWR fuel cycle technology. Independent development within the LMFBR fuel cycle activities has concentrated on those areas where significant differences exist between technology requirements for LMFBR and LWR fuels. Developmental plants such as CRBRP and LDP initially will be dependent on these fuel cycle programs for support in fuel fabrication, spent fuel storage, and waste management. Arrangements after initial operations of the power plants will be made after future developments in fuel cycle R&D and possible commercial ventures become clearer.

The assumptions concerning model LMFBR fuel cycle facilities in WASH-1535 were based on commercial-scale fuel cycle capabilities sufficient to sustain about 80 large LMFBR plants. Present LMFBR program plans for developmental fuel cycle facilities are modest relative to these assumptions. Therefore, the environmental effects should be no greater than those projected in the PFES, WASH-1535.

This section describes the U.S. DOE programs on reprocessing, fabrication, and transportation. Waste management activities are covered separately in Section VI.A.(3) and in Appendix B.

(1) Fuel Reprocessing

After residence in the reactor for a 2-3 year period, LMFBR fuel must be removed and fresh fuel provided. This replacement is necessary because of; (1) damage to cladding and other structural materials by fast neutrons, (2) a depletion of plutonium and buildup of fission products in the fuel rods which reduce the system reactivity and ultimately would prevent the reactor from reaching full power, and (3) plutonium produced in the blankets needs to be recovered in order to produce additional fuel elements.

The fuel removed (spent fuel) would be processed to recover the plutonium and the uranium in a reprocessing plant. Because the LMFBR requires a large inventory of fissile material and because the bred plutonium is needed to sustain LMFBR operation, recovery and recycle of plutonium from LMFBR spent fuels is mandatory in a mature system of LMFBRs. A description of LMFBR fuel reprocessing, including its environmental impacts, is presented in Section 4.4 of the PFES, WASH-1535.

The reprocessing research and development program focuses on both the need to supply fuel for developmental reactor plants from LWR fuel reprocessing and the need to demonstrate technology for reprocessing of LMFBR fuel. The current program calls for initial operation of a Developmental Reprocessing Plant (DRP) in about 1996, a few years after initial criticality of the CRBRP.

Objectives of the fuel reprocessing programs are: (1) to develop and demonstrate technology for reprocessing of LMFBR fuels which are more difficult to dissolve, contain a larger percentage of plutonium, and are more highly irradiated than LWR fuels, and (2) to improve technology for light water reactor fuel reprocessing and resolve institutional uncertainties so that the private sector can build and reliably and economically operate plants for reprocessing of light water reactor fuel in accordance with acceptable standards for safety, safeguards, and environmental and radiation protection. However, the emphasis of the current R&D program is on technology for LMFBR fuel reprocessing.

Reprocessing of light water power reactor fuels has been carried out in the U.S. and other nations since the mid-1960's, and operations in those facilities indicated the need for improvement in plant operability and in radiation protection of workers. Commercial LWR fuel reprocessing is not being carried out in the U.S. at present. In addition, there are presently more stringent requirements for safeguarding of fissile materials, for reductions in releases of radioactive material to the atmosphere, and for treatment of radioactive wastes. Research and development activities including design efforts carried out at Oak Ridge National Laboratory, Savannah River Laboratory, the Barnwell Nuclear Fuel Plant (BNFP), other DOE and DOE contractor sites, and by private industrial organization have resulted in many technological advances which provide increased assurance that operability, maintainability, safeguards, and environmental and radiation protection of future LWR reprocessing plants will be superior to those of the earlier plants. Among the more important achievements are: (1) development of high speed solvent extraction equipment which will (a) reduce solvent degradation thereby improving product purity, and (b) significantly improve the capabilities to measure product inventories, thereby upgrading safeguards; (2) development of new maintenance techniques and systems to reduce plant downtimes and employee radiation exposures; (3) development and cold demonstration systems for krypton-85 removal from reprocessing plant off-gas; (4) development and partial cold demonstration of a computer controlled process-monitoring/safeguards system for an LWR reprocessing plant; and (5) full-scale demonstration of borosilicate glass waste solidification processes using irradiated LWR fuel.

The status of technology for reprocessing of LWR fuels is adequate to support initial operations of a full scale plant beginning in about 1990, with reasonable assurance that regulatory requirements for safeguards, environmental protection, and radiation protection will be met, and that a high containment factor will be achieved.

President Reagan's nuclear policy statement of October 8, 1981, endorsed nuclear fuel reprocessing by private industry. Purchase of plutonium for use in LMFBR development programs will be an incentive for operation of a plant by the private sector. The Department of Energy has requested private industry to consider the possibility of making a future commitment to build and operate a reprocessing plant to meet near-term industry requirements. Should the industry not make such a commitment in a time frame compatible with LMFBR program needs, and especially those of the CRBRP,* other alternatives are available, such as the modification and use of existing reprocessing facilities, construction of new facilities, or possible multinational ventures.

Research and development for reprocessing of LMFBR fuel has been and is being conducted, and both cold and hot processing demonstrations are planned because of differences between LWR and LMFBR fuels. The higher fuel burnup at higher specific powers for breeder fuel results in considerably higher radiation levels and heat generation rates than are present with LWR spent fuel. This introduces problems in fuel handling, dissolution, and solvent extraction steps. The LMFBR spent fuel will contain a larger fraction of plutonium than LWR spent fuel. Criticality control is thus a factor in plant design and operation. The higher plutonium concentration also requires more sophisticated techniques for assuring safeguards comparable to those for an LWR fuel reprocessing plant.

A new fuel disassembly machine and shear device have been designed which incorporate provisions for the higher heat generation and radioactivity levels of the LMFBR fuel. A new rotary dissolver has been fabricated and is being tested to assure high dissolution rates. New high speed solvent extraction systems have been developed incorporating centrifugal contacters which have been demonstrated for over 15 years at the Savannah River Plant. New centrifugal contactors will permit not only processing the fuel at higher radiation

*Adequate supplies of plutonium are projected to be available from DOE-produced material to startup and operate the Clinch River Breeder Reactor Plant for several years. Options are being examined to assure that additional fuel will be available when required. One potential option is to acquire this material from reprocessing of LWR spent fuel.

levels, but also permit much shorter time for startup of the plant, and easier and faster maintenance of equipment following failures. A large volume of experimentation with high plutonium concentrations at critical mass laboratories is showing that an LMFBR fuel reprocessing plant can be operated with a degree of safety that is comparable to that of other non-reactor, nuclear fuel cycle facilities. Advanced concepts for precise measurement and control of large quantities of plutonium in an LMFBR reprocessing plant are being developed and limited demonstrations of advanced systems have been accomplished. The system proposed for future reprocessing plants will rely on extensive use of computers. Considerable effort is underway to achieve the reliability needed for safeguards applications.

Equipment and systems developed for reprocessing of LMFBR fuels are to be cold tested in the Integrated Equipment Test Facility (IETF) to provide assurances of long-term operability, ease of maintainability, improved process integration, and good measurement control. The integrated process demonstration is expected about September 1982.

Demonstration of technology for reprocessing and recycle of LMFBR fuels is planned to begin a few years after the planned initial criticality of the
CRBRP.* An early demonstration of LMFBR fuel reprocessing is essential to 5
commercialization of the LMFBR.

Preliminary conceptual design for the DRP has been completed. An environmental analysis for this plant indicated that such a facility can be built and operated within existing and proposed environmental guidelines. Preliminary design efforts have been developed and a nucleus of an organization has been

*Britain and France have already successfully reprocessed substantial quantities of spent LMFBR fuel from DFR, PFR, Rapsodie and Phenix at their reprocessing 5
facilities (Dounreay, Scotland and Marcoule and LaHague, France).

established to address further the environmental impacts of the DRP (formerly called the Hot Experimental Facility).

Reprocessing capacity for the DRP has been set at 1/2 metric ton of heavy metal per day. Preliminary design concepts for the DRP have focused on both a "stand-alone" facility, and a "breeder head-end" (probably through first cycle solvent extraction) on an existing reprocessing plant. Final decision on a "stand-alone," "breeder head-end," or alternative DRP will consider cost, environmental impact, and importance of a reliable demonstration.

The fuel reprocessing plant presented in the PFES (WASH-1535) was assumed to have a processing capability of five metric tons of heavy metal (uranium plus plutonium) per day, which would permit the plant to serve about eighty LMFBR power plants each having a capacity of 1000 MWe.

Environmental impact and public health effects, due to radiological emissions that would result from normal as well abnormal (accidents) operations of the DRP, having a throughput capacity of 1/2 metric tons of heavy metal per day, will be significantly less than those impacts from the much larger capacity reprocessing plant (five metric tons per day) described in the PFES. However, impacts on a unit capacity basis (i.e., per MWe) would be essentially the same as those given in the PFES. Site requirements for a large reprocessing plant are similar to those for an LMFBR power plant. Without a significant economic penalty, a reprocessing plant can be located in an area relatively remote from centers of power usage (and hence population). Access to facilities for transportation of heavy loads by rail, truck, and perhaps barge, is a necessity for a reprocessing facility. The nonradioactive gaseous and liquid chemical effluents expected from the routine operations of the reprocessing plant would be treated as required to reduce the concentrations of those substances to acceptable levels.

(2) Fuel Fabrication

Fuel fabrication is one of the major elements of the LMFBR nuclear fuel cycle. Operations for manufacture and assembly of fuel pins into fuel assemblies for an LMFBR would be performed in a fuel fabrication plant. The current development program, and hence the following discussion, addresses the fabrication of plutonium bearing core materials. Commercial capability already exists to fabricate LMFBR blanket assemblies which contain only uranium dioxide.

Past LMFBR fuel manufacture was characterized by manual, glovebox fabrication of fuel pellets and fuel pins. This method of fabrication will not meet future fuel requirements of the LMFBR program (FFTF, CRBR, and LDP) because of the desire to maintain high production rates and very low personnel radiation exposures, the need to fabricate fuel containing higher percentages of ^{240}Pu, and the need to provide enhanced safeguards for Special Nuclear Material (SNM).

To satisfy the immediate fuel fabrication needs of the program, a Secure Automated Fabrication (SAF) Program was established. Its objective is to develop and demonstrate an advanced manufacturing line for plutonium oxide breeder reactor fuel pins. The SAF line[5] will have a production rate of 6 metric tons of U/Pu mixed oxide fuel per year, which is sufficient to fuel both FFTF and CRBR. To support the next large development plant (LDP), additional fabrication capacity will be required. The SAF line is to be installed in the Fuels and Materials Examination Facility (FMEF) at the Hanford Engineering Development Laboratory (HEDL) and will utilize technology that incorporates improved safety features for protection of plant operating personnel, the public, and the environment. Equipment and process improvements incorporated in the SAF line will yield significant gains in nuclear materials safeguards, product quality and productivity. The SAF line provides the key link between development and full-scale demonstration of technology that will enable commercialization of LMFBR fuel fabrication in the future.

Fabrication of fuel on the SAF line in the fully automated and remotely operated mode results in the following important advances over current manual fuel fabrication technology:

- Reduced radiation exposure to plant personnel
- Reduced access to Special Nuclear Materials (SNM)
- Improved containment of SNM
- Near real-time accountability of SNM
- Improved product cost and quality
- Increased protection of the public and the environment from radiation.

As plant equipment is delivered, it will be installed and pretested in the SAF Cold Test Facility (CTF) at HEDL. As cold testing of equipment continues in CTF using non-nuclear feed materials, process testing of key unit operations will be performed concurrently in the HEDL Fuels Development Laboratory using plutonium/uranium mixed oxide. Pretesting and modification of production units for the SAF line will be completed prior to their installation in FMEF in 1984. Further testing of equipment will occur in the FMEF after all equipment is installed. Preproduction qualification runs beginning in 1985 will precede FFTF fuel production, scheduled to commence in mid-1986.

The basic fabrication process includes receiving and assaying nuclear ceramic powders, blending of the powders, pelletizing and sintering the powders into fuel pellets, and loading these pellets into finished fuel pins. The SAF line will include necessary support systems for nondestructive assay, SNM accountability, rapid chemical analysis, waste and scrap handling, maintenance, and material handling. All processing equipment and support systems will be combined to form an interdependent, fully integrated, automated and remotely operated fuel fabrication system. Each unit process and the equipment to be used are based on fully developed technology.

SAF process equipment will be partitioned in shielded process enclosures. Each enclosure will contain one or more process, storage or analytical functions as well as material handling and material accountability equipment. These enclosures will provide the primary plutonium/uranium containment boundaries and major neutron and gamma radiation shielding. Storage for in-process materials will be included in most process enclosures and will be adequately sized to provide continuity of operation for the process line. Secondary confinement walls will be erected around logical groups of process enclosures. Process control stations located at several points near the process equipment, but external to the secondary confinement, will be used as the primary means of remote control. An operations center located in a separate room adjacent to the SAF line will provide for centralized process data collection and will supervise material transfers and overall line operation.

Development of the technology required to achieve the SAF line objectives is complete. Prototype equipment for numerous unit operations is being tested at HEDL, GE, and WARD. Installation of the SAF line in the FMEF will begin in 1984 upon completion of the FMEF. An Environmental Assessment for the FMEF that incorporates fuel fabrication in the SAF line has been completed.[6,7,8] The CTF is operational and cold unit testing is underway. For purpose of assessment in the PFES (WASH-1535), a fuel fabrication plant was assumed to have a capacity of five metric tons per day (about 1500 metric tons per year) which could produce the fuel required annually for eighty LMFBR power plants, each having a capacity of 1000 MWe. This capacity would be needed to support the needs of a widely deployed breeder economy. The current federal program for meeting fuel fabrication needs of reactor plants of the LMFBR program is smaller in scope, involving the design, construction and operation of fuel fabrication capability of only six metric tons per year, but containing design features that could be scaled-up to meet future commercial requirements. Consequently, the environmental impacts of the current program are expected to be less than those presented for the much larger plant described in the PFES. Given also that the FMEF/SAF facility is located at a relatively remote site (at HEDL), public health effects on a unit capacity basis (i.e., per MWe) are expected to be less also. Impacts due to construction of the fuel fabrication plant would not be markedly different from those of construction of the LMFBR power plant or other large construction projects.

(3) Transportation

Within the LMFBR fuel cycle, transportation includes shipments of unirradiated and irradiated material from the power plants, the fuel fabrication plant, and the reprocessing plant. Developments in nuclear fuel cycle transportation have been due primarily to research conducted for government facilities and for LWR fuel. Transportation system safety has been backed by a program of designing and testing packages under severe conditions. The goal of that program is to ensure that, in the event of an accident, the probability of release of any radioactive material would be very small.

There are unique requirements for transportation within the LMFBR fuel cycle. Specifically, some of the requirements are enhanced cooling capacity for spent fuel, enhanced radiation barriers around spent fuel, and adequate safeguards for separated plutonium. The more stringent spent fuel requirements are the result of the need for rapid recycle of LMFBR fuel in order to obtain optimum breeding performance. These limited cooling times add to the requirements that result from the high burnups characteristic of LMFBR fuel.

Requirements and environmental impacts for LMFBR fuel cycle transportation are essentially the same as those that were considered in WASH-1535. The current LMFBR development plan involves fewer facilities and less transportation, and the environmental effects from implementing the plan should be no greater than those discussed in the PFES.

Since the PFES was issued, containers for fresh CRBRP fuel have been designed, and the Safe Secure Trailer (SST) system has been put into effect for plutonium transport. Spent fuel shipping casks have been developed to the conceptual design stage.

B. Alternatives Within the LMFBR Program

The program alternatives are somewhat more focused than they were in ERDA-1535. There, the reference plan was for a broader, more expanded program involving more plants and facilities. Seven alternatives to the reference plan were identified. Current planning now identifies only two major developmental plant projects. Three program alternatives are identified: proceed directly to the

LDP, cancel the CRBRP; complete CRBRP, cancel LDP; and cancel or defer both CRBRP and LDP. The direct environmental effects of these options are neither substantially nor significantly different from similar ones identified in ERDA-1535.

1. Proceed Directly to the LDP, Cancel the CRBRP

The design of the CRBRP is essentially complete. Many of the major components have been fabricated, and much of the component testing has been completed or is in progress. It has been proposed that in its present state the CRBRP has provided sufficient information and that construction and operation are not necessary. This alternative substitutes instead continuation of the LMFBR program with the LDP as the first developmental plant.

The gains from deleting CRBRP construction and operation are limited to the saving of the construction costs not already committed and of any operating costs not covered by electricity sales as well as avoiding environmental impacts associated with construction and operation. Because of its advanced state of design and fabrication, about one billion dollars have already been committed of the total project cost of somewhat more than three billion dollars.

The losses from terminating CRBRP construction and operation include early data on startup, operation and individual component and overall plant performance. Such experience is important for early identification and resolution of problems and simply to provide greater information on component performance, reliability and maintainability to the LDP program and to the eventual LMFBR commercialization decision. For example, the cell construction experience at FFTF resulted in design improvements for CRBRP. Early data on plant performance provides the opportunity to optimize fuel performance, plant capacity factor and thermal efficiency. In the reference plan the CRBRP operating data will start accumulating and be available for use during the critical last half of the LDP design effort. While early project decisions will have been made on components and system designs, there will still be ample opportunity to make LDP design modifications based on CRBRP experience. Much of the CRBRP information, such as results of the components tests and additional R&D work in safety, materials, and physics, will be available in 1982 for factoring into the preliminary LDP design.

Early utility involvement in construction and operation of an LMFBR will also be lost, which will likely lead to delays in the LDP program. More seriously, CRBRP cancellation could lead to eroded utility confidence in federally-sponsored advanced-reactor programs. Cancellation of CRBRP with its utility commitment of money and effort may preclude utility involvement in future LMFBR programs.

Another loss will be in licensing experience. Knowledge gained during the CRBRP licensing process by the utilities, vendors, operators and regulators should be readily applicable to LDP. Any generic licensing problems can be identified and resolved early. Furthermore, important environmental impact and safety information to be gained during CRBRP licensing and operation would not be obtained.

Cancellation of the CRBRP would constitute a break with sound engineering practice. The construction of a plant in the 350 MWe-size range between the present plants (18 MWe EBR-II and 400 MWth FFTF) and the proposed 1000 MWe LDP plant follows the step taken by all other countries currently developing the LMFBR and follows the steps taken in the U.S. light water reactor program. The intermediate-size plant allows for reasonable scale-up of all major plant components such as sodium pumps, heat exchangers and steam generators. Direct scale-up from current technology to 1000 MWe entails an extra technological risk that some component will not perform as intended. Such performance failures could result in delays and increased costs. Increased technological risk may also reduce the willingness of industry to participate financially in the LDP Project.

In summary, cancellation of the CRBRP will provide only a relatively small, short-term financial savings. But the losses will be large to the LMFBR program in operating and licensing experiences, component and plant performance data, in utility commitment, and in greater technical risk to the LDP.

2. Complete the CRBRP, Cancel the LDP

This option, building the CRBRP and cancelling the LDP, proposes that the 350 MWe CRBRP will provide all of the plant operating experience that is necessary prior to turning the LMFBR commercial deployment decision over to industry and the utilities. Scale-up to a plant of near-commercial size (1000-1200 MWe) would be accomplished by testing the core design with critical experiments, testing the major heat-transport components individually, finishing fuel and other core component testing in the FFTF and the EBR-II, sharpening the available design tools, improving safety analyses of large LMFBRs, and doing tests on other components of the system as deemed necessary.

The benefits for removing the LDP from the LMFBR program are the savings from construction costs and the savings, if any, from plant operating costs not covered by electricity sales as well as avoiding environmental impacts associated with plant construction and operation. DOE programs to handle fuel fabrication, spent-fuel storage, transportation and reprocessing will still be required, as they are with the CRBRP, until a complete commercial fuel cycle is realized.

The arguments against this proposed option are many. A major concern is that the capability for commercial deployment of LMFBRs may be delayed indefinitely. The CRBRP is not intended to provide, and cannot by itself provide, proof of commercial viability of the LMFBR. The financial and technological risks of making a commercialization decision based on operation of a roughly one-quarter to one-third size plant are obviously much greater than making the decision to scale-up from 1000 MWe to 1200-1500 MWe. Furthermore, the costs of a first-of-a-kind plant are necessarily much higher than for conventional power plants. In view of the recent regulatory and licensing climate, utilities may not be willing or able to bear the entire costs of demonstrating commercial LMFBR technology. Failure to have developed this long-term option for nuclear-electricity generation by the time it is needed will be the likely result of this option.

A second major concern in eliminating the LDP is the probable significant erosion of the industry/utility/laboratory infrastructure that will form the basis for future LMFBR commercialization. The most significant loss will be many of the highly-trained technical personnel. Another serious loss will likely be some capability in sodium-system component manufacturing. Without the LDP project, some focus will also be lost from the base technology program. If the utilities were unable, by themselves, to maintain momentum in the LMFBR program, the financial cost to the federal government of re-establishing the

LMFBR infrastructure could be substantial, offsetting any savings from LDP cancellation.

To summarize, the current LMFBR program plan includes fundamental and extensive utility and federal involvement in the LDP project. Details of financial arrangements have not yet been specified. However, termination of Federal involvement will terminate the project and signal the end of developmental plant construction. The CRBRP alone cannot generate a sufficient basis of safety, construction, environmental impact (including potential mitigating measures), and operating data to permit a sound commercialization decision by utilities. Furthermore, it does not appear reasonable to require the utilities to assume the entire burden and risk of the first large LMFBR. A utility decision to do so essentially involves a commitment to LMFBR commercialization. It is unlikely that such a commitment could be made in time to prevent significant erosion of the required industrial/technological infrastructure. Moreover, a decision on LMFBR commercialization involves considerations, national as well as international, that are far beyond the scope of a utility network. Fundamental Federal participation in such a decision seems essential.

3. Cancel or Defer All Developmental Plants

If both the CRBRP and LDP were cancelled or deferred indefinitely, only the base technology program and associated supporting fuel cycle activities would remain. A sound decision to commercialize the LMFBR can only be made if each of the major elements in the LMFBR program has been carried far enough to assure that the program objectives are attained. Developmental plants comprise the single most important elements of the LMFBR program. They are essential to any serious commitment to develop LMFBR technologies in the U.S.

Without operating plants there is no significant involvement of utilities and reduced involvement of industrial suppliers in LMFBR development programs. Construction, startup, operating and licensing experience will be completely lacking. Deletion of demonstration plants will seriously disrupt the continuity of the current program. Personnel and facilities engaged in plant and component design and fabrication will be lost by even a few years delay, and their retrieval will be difficult. The risk of losing this expertise now and accepting the large expense of reacquiring it later is not prudent policy. Based on the experience of the CRBRP, a 5-year delay in construction of the developmental plant schedule implies a likely delay of even greater magnitude in possible deployment.

A long-term delay of construction involves significant losses and risks. Most important, it will not be possible to obtain integral operating system data on the operating and economic performance of LMFBRs which is required for a decision on eventual commercialization. As a consequence, the potential date of LMFBR deployment is pushed back with the increased risk to the nation's energy security and the potentially high economic penalty of not having the LMFBR available when it is needed. In addition, the surviving base technology program may begin to lose focus without well defined performance objectives for its activities. The base program will lose the important feedback information from plant operating and licensing experience. Environmental impact and safety information to be developed during licensing and operation of the developmental plants would not be obtained. In addition, potential measures to mitigate LMFBR powerplant environmental impacts would probably not be developed.

Without the CRBRP and the LDP, the utilities cannot be expected unilaterally to finance and construct another LMFBR plant. Therefore, if and when a positive decision on the wide-spread deployment of LMFBRs is made, the state of LMFBR technology in the U.S. would be defined by whatever progress had been made in basic research and development. The gains from deleting the construction and operation of all developmental plants are the financial savings of the construction costs and the operating costs not covered by electricity sales and avoiding environmental impacts associated with plant construction and operation.

C. No Action (Terminate the LMFBR Program)

Terminating the LMFBR program implies turning away from 35 years of progress to develop this technology. Several widely-recognized energy policy studies have addressed the role of the breeder reactor and have been supportive of continued breeder development. The Ford-Mitre study concluded:[9]

> "While there are good reasons to delay commitment to plutonium breeders* and such a delay would not be economically consequential, breeders are a major energy resource. They provide high confidence insurance against failure of other energy sources in the future. The breeder option should be preserved since the cost of uranium will eventually rise, coal may eventually be found to have unacceptable adverse consequences that cannot be avoided, and other alternative energy sources may prove to be very expensive."

The Resources for the Future Study concluded:[10]

> "Specifically, the United States needs a vigorous R&D program focused on providing candidates for a decision whether to build one or two large-scale (but not commercial) steam-generating breeder reactors. The target decision date, given the possibility that a commercial breeder may need to be deployed by 2010 or so, should be 1985-1990."

*The Ford Mitre report considered LMFBR commercialization as early as 1993.

The National Research Council's CONAES study said:[11]

> "At relatively high growth rates in the demand for electricity, the attractiveness of a breeder or other fuel-efficient reactor is greatest, all other things being equal. At the highest growth rates considered in this study, the breeder can be considered a probable necessity. For this reason, this committee recommends continued development of the LMFBR so that it can be deployed early in the next century if necessary. Any decision on deployment, however, should be deferred until the future courses of electricity demand growth, fluid fuel supplies, and other factors become clearer."

Current government policy is along the lines suggested in the National Research Council recommendation; a decision by the private sector on commercialization of the LMFBR, and that decision to be made later as development program results and other factors become clearer.

As discussed in WASH-1535, it has been proposed that another alternative would be for the U.S. to purchase foreign technology rather than to pay for our own domestic LMFBR fuel cycle development program. Such proposals often neglect to account for the extensive domestic development work that would still be necessary to assure that foreign breeder designs would satisfy unique U.S. licensing requirements. This may involve, among other things, the need to make substantial plant modifications to key safety features such as the reactor containment building, reactor safety systems, and shutdown heat removal systems.

Some foreign LMFBR development programs, particularly in France, are aimed more vigorously at commercialization than that in the U.S. It might seem that the U.S. could forego LMFBR development expense by purchasing foreign technology. However, one of the central features of U.S. energy policy of the past four Administrations has been to reduce U.S. reliance on foreign sources of energy supply. Regardless of current alliances, political or commercial barriers 20-40 years hence could prevent a foreign LMFBR supplier from selling to the U.S. Even if reactors were sold, without a complete domestic fuel cycle capability, the U.S. would have to rely on foreign sources of reactor fuel supply. This could have national security implications that are not unlike those associated with current U.S. dependence on foreign supplies of oil (see Vol. IV, page 11.1-18 of WASH-1535 for additional material on importing foreign breeder reactor technology).

The major gain from termination of the LMFBR program is the saving of about 10 billion dollars over the next 20 years or so. Environmental impacts associated with the program would be avoided. The loss to the nation's long-term energy supplies is potentially severe. Significant work has already been done to bring U.S. LMFBR technology to its current state. The technology has been proven and no fundamental scientific breakthroughs are required for its future development. While the money saved from the LMFBR program might be spent on other potential inexhaustible electric energy supplies, no other large-scale, long-range electricity supply option has achieved the advanced state of the LMFBR. No other long-range electricity option is close enough to large-scale deployment for reasonably certain cost projections to be made. Finally, the LMFBR option is needed as insurance against the failure of other alternatives to develop.

D. Alternate Long-Term Technologies

Solar electric and fusion were the two technologies singled out in ERDA-1535 as major candidates, in addition to the breeder, to provide an essentially inexhaustible source of energy to help meet the Nation's electrical energy needs in the next century. These are still the primary candidates for meeting long-term U.S. energy needs. Government policy is that public spending is appropriate in long-term energy research, where the risks and potential payoffs are high.[12] The LMFBR, solar electric and fusion programs are all being pursued. All three technologies may be needed in the 21st century.

There is no need to choose among these three long-term alternative energy technologies now. Instead, the marketplace and/or electric utilities will make selections based on environmental, economic, regulatory and other grounds, when the technologies are developed.

The Government strategy is, and has been, to pursue a broad program of research and development, to ensure that these technologies can be deployed when they are needed.[13] The solar and fusion energy programs are described in the following subsections. This material is revised and updated replacements for the comparable material presented in ERDA-1535.

(1) Fusion Energy

MAGNETIC FUSION PROGRAM

The goal of the magnetic fusion energy program is to develop fusion's highest potential; i.e., to realize the most promising commercial opportunities for fusion energy. Historically, the primary approach of the fusion program has been toward the single goal of developing systems for the commercial production of central-station generated electrical power. However, there are other applications of fusion systems apparent today such as the production of chemical fuels.

Within the program itself, a number of alternatives are being examined. Such alternatives include different fuel cycle concepts (deuterium-tritium, deuterium-deuterium, etc.) and several varying technological approaches to magnetic confinement (tokamaks, mirrors, etc.). At present the most likely near-term fusion reaction involves two isotopes of hydrogen: deuterium (D) and tritium (T). The fuel atom deuterium is present in water in sufficient quantities to be available for many millions of years. The isotope tritium does not naturally occur in the environment in sufficient quantities to fuel a fusion power economy. Therefore, it will be necessary to "breed" the tritium from lithium, which is an abundant element both on land and in seawater, in a layer of material called a "blanket" surrounding the plasma region.

A number of reactions other than D-T fusion, referred to as alternate fuel concepts, are of potential use and are being studied in the program. However, because of the relatively low temperature required and the high reaction energy, a favorable energy gain Q is far easier to achieve with D-T fusion than with any of the alternate fuel reactions. When greater temperatures, densities, and confinement times can be achieved, alternate fuel concepts will have major advantages. For example, they may eliminate the need for tritium by using only naturally occurring fuel (e.g., deuterium), and allow the design of reactors that would produce electricity directly (i.e., without the use of a thermal heat cycle). Thus, these alternate fuel cycles may favorably influence the environmental impact of fusion power many years hence, but will follow development of the D-T cycle.

To establish the viability of magnetic fusion energy as a commercial power source, the National program is directed toward construction of a demonstration or prototype reactor that will demonstrate the safety, reliability, environmental acceptability, and economics of fusion power in a manner that extrapolates to commercial reactors. Scientific feasibility or breakeven levels of fusion energy have not as yet been demonstrated, but recent research developments in magnetically confined plasmas give a high degree of confidence that net fusion energy devices can be built. In fact, the significant achievement of fusion breakeven conditions is expected to take place in the mid-1980's with the operation of the Tokamak Fusion Test Reactor at Princeton Plasma Physics Laboratory in Princeton, New Jersey. Within this time frame, the magnetic fusion program is expected to begin moving from basic and applied research into technology development. The Magnetic Fusion Energy Engineering Act of 1980 (H.R. 6308) targets 1990 as the latest date for the operation of a magnetic fusion engineering device and the early 1990's for demonstrating the engineering feasibility of magnetic fusion. The implementation of this act will signal a shift in program focus from plasma physics to engineering and technology development.

INERTIAL FUSION PROGRAM

The goal of the inertial fusion program is to develop the maximum potential of inertial fusion for application to weapons physics research and to commercial fusion power. Energy production by inertial confinement of fusion reactions has already been demonstrated with the hydrogen bomb. The challenge is to achieve and support such reactions on a scale millions of times smaller.

The focus of the program in the near term is on a thorough understanding of driver-target interactions in the range of laser or particle-beam energies obtainable with experimental facilities presently under construction. The knowledge gained will support a decision in the mid 1980's on the most promising driver-target approach to pursue toward the milestones of thermonuclear ignition of small fuel masses, scientific feasibility, high energy gain, and engineering feasibility.

Three different driver technologies are currently being pursued: short-wavelength lasers at Lawrence Livermore National Laboratory with support from KMS Fusion, the Naval Research Laboratory, and the University of Rochester;

long-wavelength lasers at Los Alamos National Laboratory; and pulsed power (light-ion) generators at Sandia National Laboratory. Experiments with each kind of laser will measure and verify theoretical understanding of important energy coupling properties and will extend existing scaling data 1 - 3 orders of magnitude higher in driver energy. Pulsed-power experiments will allow a determination of beam focus capabilities with the current technology, which is the critical issue for this approach.

One of the significant advantages of inertial fusion from an engineering point of view is that the bulky and complex parts of the reactor are separate from the reactor vessel itself, and can be removed some distance. This means that an inertial fusion reactor may have a relatively small containment volume; that its operation, maintenance, and repair should be fairly simple; and that the most expensive components, including the massive inner wall of the reactor, need not be subject to neutron bombardment and activation. The potential also exists for a wide variety of power plant sizes and configurations.

(2) Solar Electric Systems

The program is organized into four sub-programs:

- o Wind Energy Conversion Systems (WECS)
- o Solar Photovoltaic Conversion
- o Solar Thermal Conversion
- o Ocean Thermal Energy Conversion (OTEC)

This priority ranking is based on the near-term power production capacity objectives of the four types of solar electric systems and on their present state-of-the-art. Summary information on these programs, primarily covering changes since ERDA-1535 was issued, is given in the following paragraphs.

Wind Energy Conversion

The intermittent nature of the wind and the wide geographical and seasonal variations in the availability of this energy source require either supplementary energy storage capabilities or interties of wind energy conversion systems (WECS) with conventional energy systems. The projected high capital costs of initial large-scale WECS prototypes (i.e. 100KWe, rated, or larger) need to be reduced by a factor of approximately 2 for such systems to be competitive over very large regions with conventional systems in utility applications. Cost reductions in the area of rotors, hubs, and advanced systems configurations could achieve this goal. Estimates of lifetime of large-scale WECS are uncertain because of insufficient data on operational dynamics of rotors and other components. At present, there are inadequate capabilities to estimate accurately the annual energy output of WECS units, of a specific design, located at a specific site. In addition, there is limited information on utility interties and operational requirements and almost no experience with large scale windfarms.

Present institutional problems include: (1) incomplete information on possible environmental effects of large multi-unit WECS such as television interference caused by rotating WECS blades; (2) insufficient information on legal and regulatory questions and (3) uncertainties in the availability of sufficient investment capital and experienced personnel to meet the WECS growth rate required to produce a significant impact on the Nation's energy requirements in the near- and mid-terms. In addition, the present acceptability to public utilities of large-scale WECS is limited by their intermittent operational characteristics. These are acceptable when WECS are used in a "fuel saver" mode; however, their use to supply base load capacity for utility networks will require large associated energy storage capabilities or backup by conventional systems for electrical generation.

Extensive utility applications of WECS will require reliable, cost-effective, large size wind machines frequently employed in a cluster or windfarm. The Federal program has supported the development, test and demonstration of a series of WECS systems of increasing sizes and power output capabilities, advanced the technology through R&D projects, and addressed barriers to large scale implementation through studies of institutional constraints. 100-KWe to 2-1/2-MWe systems have been demonstrated. In the mid-1980's multiple individual units or windfarms with total output capacities of 10- and 100-MWe may be installed and tested in privately sponsored projects.

Methods of improving the performance-to-cost ratios of the types of WECS systems described above will be explored through a series of projects that address rotor dynamics, aerodynamics, improved components and system economics. Advanced system designs, using vertical axis rotors, diffusers and vortex concepts, will be examined.

Projects may be undertaken that examine various possible agricultural applications of WECS including electrolyzing water to produce hydrogen for on-site fertilizer manufacturing, space heating, and crop drying. The capability to rapidly locate and assess sites with sufficiently high average wind velocities for WECS viability will be addressed through modeling, methodology development, and wind resource and forecasting studies. Separate studies of environmental effects will be undertaken to determine the possible impact of large-scale WECS applications.

Solar Photovoltaic Conversion

Photovoltaic technology is well-developed and proven for relatively small electric power systems and remote area needs (e.g., space satellites and telecommunication relays), but the present installed system costs are about a factor of ten too high to compete with more common electric power systems for general U.S. electric power needs. The present high cost of installed systems arises mainly from the high cost of solar arrays and the need for large collector areas because of the relatively low energy density of the solar energy radiation reaching the earth's surface. In addition, the design of practical systems must address the problems of providing power from a resource that varies diurnally, seasonally, and geographically, as well as with weather conditions. Thus, photovoltaic systems normally require the availability of either supplementary energy storage capabilities or interconnection with conventional energy systems.

The 1981 costs of commercially available flat-plate silicon photovoltaic arrays are about $7000 per kW peak, which is one-half to one-third the nominal cost of an installed system. An installed photovoltaic system would cost $15,000 to $20,000 per kW peak, which is a factor of 10 too high for such systems to be competitive with conventional systems for widespread applications in U.S. residential use. These cost estimates include the nominal costs of converting the low voltage DC output of existing photovoltaic collectors to the requirements for many applications. Present photovoltaic arrays convert solar energy to DC electricity with efficiencies of about 10 percent and have endurance and lifetimes in terrestrial environments of about 20 years. Various possible constraints to rapid system implementation include possible ecological impacts of large arrays, although these impacts do not appear to be significant.

Projects are planned through the mid-1980's to improve technical design efficiency, reliability, lifetimes and energy payback times of solar photovoltaic conversion systems through studies on:

- o Crystal growth
- o Low-cost silicon solar arrays
- o Encapsulation
- o Alternative materials
- o Promising concentrator devices
- o Operating and maintenance procedures
- o Testing and standards
- o Long-term energy storage for independent operations
- o Power conditioning and electrical utility grid interfacing

Automatic array manufacturing and testing processes and improved design and installation techniques for solar photovoltaic conversion systems need be pursued by industry. Industrial objectives are to achieve a production of solar arrays with a cost goal of $700/peak kW by 1986 for a solar array production rate of about 500 kW peak per year, and with a cost goal of $150 to $400 per kilowatt in the 1990's at a production rate of about 2 GW peak per year. A research and technology transfer program is underway as a Federal responsibility. A series of federally-sponsored tests, experiments, and applications of solar photovoltaic conversion systems was initiated in 1979 and are providing performance data in selected user environments. A series of studies have been conducted to determine possible environmental, legal, societal, or institutional impacts, as well as means of removing these types of constraints, if any, on public and user acceptability.

Solar Thermal Conversion

Solar thermal conversion systems collect the sun's radiant energy for the direct production of process heat, the generation of electricity or the manufacture of transportable fuels and industrial feedstocks. Such systems entail the use of concentrating collectors (point-focus central receiver, parabolic troughs, parabolic dishes and hemispherical bowls) and salt-gradient solar ponds. Each concept is expected to satisfy important segments of U.S. energy requirements, for example, central receivers for large utility electric power generation and high temperature heat, troughs for mid-temperature on-site process heat or electricity generation, and dishes for mid- and high-temperature process heat, and small or remote electrical applications. The integration of low-cost thermal storage with concentrating collector systems permits system operation during periods of intermittent insolation and the extension of such operation to meet conventional intermediate load requirements. Salt-gradient pond systems are expected to operate in the peaking, intermediate or base load mode, depending on system design, due to inherent thermal storage in the pond fluid and associated containment.

Solar thermal system concepts are in various stages of development. For example, parabolic troughs are entering the commercial market, a central receiver pilot plant will begin operations in 1982, parabolic dish subsystems are being tested, and the first U.S. solar pond prototype powerplant is under design. Consequently, from a broad perspective, technological issues related to solar thermal systems may be generally categorized as follows:

- o Systems operating experience that provides assurance of availability and reliability to meet demand requirements and that allows projection of operating and maintenance costs of full-scale systems;
- o Systems, subsystems, components and materials testing sufficient to verify achievement of lifetimes comparable to conventional energy systems;
- o Materials, components and subsystems research to reduce costs substantially and to increase efficiencies, thereby enabling solar thermal suppliers to enter the marketplace at the accelerated pace necessary for "take off" as private endeavor; and
- o Identification and proof of technical feasibility of processes for bulk production of fuels and chemical feedstocks made from solar thermal energy.

Some electric utilities are contemplating the introduction of solar thermal systems that operate in the fuel-saving mode, i.e., by repowering existing gas or oil fired powerplants. Such systems are not expected to be impacted by periods of low insolation. At least one utility is contemplating a "stand alone" plant in which the grid would compensate for low insolation. Extensive use of "stand alone" systems in a particular utility network will require comparable reserves, either in the form of conventional capacity or storage, and the ability to dispatch it economically. Such dispatch capability can be developed and will not adversely impact utility operations. Moreover, the integration of solar thermal systems into a utility grid is expected to be fully compatible with state and local regulations and normal utility operations and maintenance procedures.

<u>1976-1979</u>

- o System, subsystem, materials, environmental and socio-economic studies conducted to identify cost-effective technical concepts and address institutional issues.

- Successfully built and tested small but first-of-a-kind parabolic trough systems in electricity-generation application (irrigation pumping).

- Successfully tested highly reliable 150kWe trough system (irrigation).

- Established test facilities for all concentrating collector concepts: Central Receiver Test Facility, Mid-Temperature Solar System Test Facility, both at Albuquerque; Advanced Concepts Test Facility, Georgia Tech; Parabolic Dish Test Facility (Edwards AFB).

- Began design of first-of-a-kind central receiver and parabolic dish systems (10 MWe pilot plant and "Shenandoah" total energy/cogeneration facility).

- Initiated series of field tests for application of parabolic troughs to low- and medium-temperature Industrial Process Heat requirements.

- Initiated diverse program for low-temperature heat utilization in agricultural applications.

1980-1981

- Completed construction of 10 MWe proof-of-concept central receiver pilot plant; operation scheduled in 1982.

- Completed construction of total energy dish project; operation scheduled in 1982.

- Improved cost and efficiency characteristics of parabolic troughs in 200°F to 500°F experimental applications at numerous industrial sites.

- Progressed towards developing dish systems with a solar/fuel hybrid capability.

- Mobilized teams of scientists, engineers and managers at universities for innovative contributions to solar thermal research.

- Completed second-generation heliostat design, checkout and qualification efforts.

- Completed test of first-of-a-kind molten salt receiver (central receiver subsystem).

- Successfully tested, at 2600°F, Brayton-cycle receiver for use in parabolic dish systems.

- Established scientific feasibility of "sunfuels" processes for fuels and chemicals production.

1982--(plans)

- o Conduct sodium receiver subsystem experiment (central receivers).
- o Complete conceptual design of large-scale salt-gradient solar pond (Salton Sea project).
- o Conduct Stirling engine tests at Edwards (dish test site).
- o Complete molten salt storage experiment (at CRTF).
- o Operate 10MWe pilot and Shenandoah projects.

Ocean Thermal Energy Conversion (OTEC)

Problems

Technological:

- o Design and testing of large diameter cold water pipes for deployment to depths up to three thousand feet must be demonstrated.

Institutional:

- o Environmental impacts associated with circulating large quantities of ocean water need to be determined and weighed. Implications of navigational rules, maritime certification and licensing requirements* and resource-recovery structures associated with maritime law need to be examined.

Implementation

The development program for ocean thermal conversion systems is comprised of system definition and the development of critical components, followed by proof of concept and demonstration units.

Facilities have been established on both land and sea for test and evaluation of critical components and subsystems. Supportive studies are being conducted for identifying possible barriers to optimum implementation and to explore energy conversion, storage and delivery systems. Based on test results and

6 *The National Oceanic and Atmospheric Administration (NOAA) has published the licensing requirements for commercial OTEC plants (15 CFR Part 981).

supporting studies, OTEC proof-of-concept experiments are planned for deployment in the mid to late 1980's. These experiments could simultaneously investigate the feasibility of electricity production and the capability to produce energy - intensive products, such as ammonia for fertilizer and fuels such as methanol and hydrogen. The following projects have been conducted:

- System design, critical component research and development and studies of biofouling, materials problems, energy delivery, and legal and environmental issues.
- Conceptual and engineering design of a land-based test facility and operation of a sea-based engineering test facility.
- The land-based facility is designed for continuing tests on heat exchanger designs and cleaning techniques.

Projects planned for the 1980's include:

- The design, construction, deployment and testing of proof-of-concept ocean thermal energy conversion systems.

Other Solar Energy R&D Activities 6

Research and development and financial incentives for the solar electric energy field are performed by government agencies in cooperation with DOE. A brief description of these complementary activities follows:

a. National Aeronautics and Space Administration *

- Manage the project to establish feasibility of low-cost silicon solar arrays.
- Manage projects on large experimental wind energy systems.
- Satellite Solar Power Systems Study.
- Parabolic dish thermal electric R&D.

*Reference to National Science Foundation activities deleted. 7

b. Department of Commerce

- Study feasibility of selected alternative materials for low-cost solar cells (for example, cuprous oxide).
- Provide ocean engineering support for OTEC R&D activities.
- Administer one-stop licensing for OTEC commercial plants (P.L.96-320).

c. Department of Defense

- Advanced Solar Cell Concept Evaluation.
- Purchase of solar cells for isolated stations.

d. Department of Agriculture

- Investigate farm and remote area wind energy applications.

e. Department of Transportation

- Administer mortgage loan guarantees for OTEC plants and plant-ships (P.L. 96-320).

f. Department of the Interior

- Solar/hydroelectric hybrid system feasibility studies.

g. Department of State

- Support of CESA I (Spanish central receiver pilot plant).

The following table is an updated version of Table S-4 in ERDA-1535:

Table 4

KEY DECISION POINTS - SOLAR ENERGY PROGRAMS

Energy System	Decision Points	Calendar Year
Wind Energy Conversion	Experimental units -	
	200-KWe	1977-1980
	MWe scale (1st generation)	1979
	MWe scale cluster (2nd generation)	1981
Solar Photovoltaic		
	Large Scale Production -	
	silicon arrays	1985
	thin - film cells	1990's
Solar Thermal Conversion	Central receiver plant - pilot	1981
	Distributed collector plant - field test	1979-1981
	Solar total energy system - pilot	1981
*Ocean Thermal Energy Conversion	40-MWe proof-of-concept experiments (100-MWe total)	1986
	Demonstration power plants (500-MWe total)	1989

*National goals stated in Public Law 96-310

REFERENCES FOR SECTION IV

1. Proposed Final Environmental Statement, LMFBR Program, WASH-1535, I, U.S.A.E.C. p. 3.5-3 (1974).

2. "LMFBR Conceptual Design Study; Phase I Summary Technical Report," CDS 500-1, U.S. Dept. of Energy, p. 4-29 (1980).

3. Final Environmental Statement Related to the Construction and Operation of The Clinch River Breeder Reactor Plant, Docket No. 50-537, February 1977, NUREG-0139; Site Suitability Report by the Office of Nuclear Reactor Regulation, USNRC, in the Matter of the Clinch River Breeder Reactor Plant, Docket No. 50-537, March 4, 1977.

4. "LMFBR Conceptual Design Study; Executive Summary," CDS 400-2, U.S. Dept. of Energy (1981).

5. Secure Automated Fabrication Preconceptual Design Report, HEDL Document TC-1831, Rev. 2, September 1981.

6. Environmental Assessment for the Fuels and Materials Examination Facility, DOE/EA-0116, July 1980.

7. DOE Memorandum, R. C. Clusen to G. W. Cunningham, "Environmental Assessment of the FMEF," dated July 17, 1980 (Approval).

8. DOE Memorandum, R. J. Stern, Director, NEPA Affairs Division to G. Sherwood, "Environmental Analysis of the Secure Automated Fabrication (SAF) Facility," dated October 30, 1981.

9. Nuclear Power Issues and Choices, results of a study sponsored by the Ford Foundation and administered by the Mitre Corp., Ballinger Publishing Co., Cambridge, Mass., p. 357 (1977).

10. Energy, The Next Twenty Years, results of a study sponsored by the Ford Foundation and administered by Resources for the Future, Ballinger Publishing Co., Cambridge, Mass., pp. 447-448 (1979).

11. Energy in Transition, 1985-2010, Final Report of the Committee on Nuclear and Alternative Energy Systems, National Research Council and National Academy of Sciences, W. H. Freeman Co., San Francisco, p. 70 (1979).

12. "Securing America's Energy Future, The National Energy Policy Plan," DOE/S-0008, U.S. Department of Energy, July 1981.

13. "National Energy Plan II," U.S. Department of Energy, May 1979.

V. Affected Environment

The affected environment remains unchanged from that discussed in WASH-1535 and ERDA-1535. For the case of radioactivity and other releases from model fuel cycle facilities (LMFBR power plant, fuel fabrication plant, fuel reprocessing plant, and various radioactive waste management facilities), the generic data on meteorology, hydrology, and populations within a 50 mile radius of these facilities has not changed. For transportation of nuclear materials, the population densities along shipping routes and the routes themselves are also unchanged. Thus in these cases the affected environment has not changed since ERDA-1535 was issued six years ago.

For the special case of releases of transuranics, the population of the north central and eastern U.S. has not changed significantly since the analyses of meteorological transport, deposition, resuspension, and resulting population intakes were completed (1974). Thus the resulting doses and health effects would have been unchanged as far as the affected environment is concerned. However, as discussed in Section VI.A (4) and Appendix D, these resulting dose estimates and health effects have been changed due to changes in dosimetric models and risk estimates. But, the affected environment, even in this case, was essentially unchanged.

VI. Environmental Consequences of the LMFBR Program and Alternatives

A. Environmental Impacts of the LMFBR Program

In his review of the Proposed Final Environmental Statement for the LMFBR Program (see ERDA-1535, Section IV A), the ERDA Administrator defined certain considerations for a determination on the acceptability of the technology for widespread deployment of breeder reactors. Among them he identified four significant environmental issues--reactor safety, waste management, safeguards, and health effects--that must be resolved before any decision on widespread commercial deployment of LMFBRs can be made. Although the Federal Government no longer plans to decide on the question of breeder deployment, the Department of Energy is charged with the responsibility for conducting a comprehensive breeder research and development program and plant demonstration program to establish the sound engineering basis for a decision by the nuclear industry to commercialize the breeder. Considerable progress on these matters has been made but additional work remains. The purpose of this section is to provide a status report on the progress made since ERDA-1535 was issued and a discussion of how results from the R&D programs, studies, and analyses bear on environmental impact analyses. None of the new information developed since ERDA-1535 indicates a significant change in the environmental consequences of the LMFBR Program over those analyzed in WASH-1535 and ERDA-1535.

From an environmental impact standpoint, the analyses in WASH-1535 and ERDA-1535 represent the best available information on a widely deployed breeder economy. This information also represents a conservative analysis of environmental consequences for all cases except the routine release of transuranics. For this special case, new analyses are presented in Section VI.A.(4).

The descriptions of model LMFBR fuel cycle facilities (fuel fabrication, reprocessing, and various waste management facilities) contained in WASH-1535 are still valid. The environmental control technologies (e.g., HEPA filters) and estimated routine and accidental releases are unchanged. Thus calculated radiation exposures (except for the case of transuranics) are also unchanged. However, health effects resulting from these calculated radiation exposures would be changed since risk estimates (used to convert exposure/dose estimates to health effects) have changed since completion of the WASH-1535 and ERDA-1535 analyses. Changes in dose estimates are presented in Appendix H for the convenience of reviewers of this supplemental EIS. The various risk estimates have not changed significantly and thus it was decided that no additional analyses were required in this supplement (except for the case of transuranics).

In addition, the only health effects calculated in WASH-1535 and ERDA-1535 (and thus the only risk estimates used) were for routine and accidental releases of transuranics. This was due to the controversy concerning the health effects of these transuranic releases. The risk estimates presented in Appendix H can be used to calculate health effects for the various radiation exposure estimates given in WASH-1535 and ERDA-1535 for radioactivity releases (other than transuranics).

(1) Reactor Safety

Introduction

Over the past three decades, an extensive set of safety-related LMFBR plant design requirements and corresponding sets of design and quality assurance principles and procedures have been developed and are being applied to guide the design and operation of LMFBRs. The safety-related design requirements and operating procedures take advantage of the many characteristics of LMFBRs which tend to make them intrinsically safe and also take cognizance of those characteristics which do not enhance safety. These are discussed in some detail in Section 4.2.7.4 of WASH-1535. It has been and remains the responsibility of the LMFBR Safety Program to translate an understanding of the safety characteristics of LMFBRs into safety-related design requirements and operating procedures. Past efforts within the Safety Program have been focused on providing the requisite safety-related technology for FFTF and CRBRP. The program is now focusing on the task of extending this safety technology so as to provide an adequate base for future large LMFBR plant projects, such as the LDP.

Three fundamental and related questions need to be answered regarding the safety implications of an LMFBR: (1) How safe is the plant? (2) What, if anything, can be changed in the design or operating procedures of the plant to make it safer? (3) Is the plant safe enough? These lead to consideration of a number of more specific questions: What external events or system failures could initiate a sequence of events that would lead to an accident? What is the probability of occurrence of each of these events or failures? Is the plant designed so that it can stop the sequence before the accident occurs or accommodate the consequences of the accident? Can the plant design be improved at an acceptable cost so as to improve the reliability of its systems and/or its ability to accommodate the consequences of system failures? All of these considerations have to be woven together using the concepts of risk assessment and risk reduction.

In order to provide adequate answers to these questions, the technology must be available to permit designers and safety analysts to determine the following information for a given plant: (1) failure modes and failure probabilities for its systems and structures; (2) reliability of the safety systems, given the range of events to which they must respond; (3) the scenario that each accident would follow, given safety system failure in the face of all credible challenges; (4) the extent of damage to the plant and the response of the reactor containment system in these various accident situations; and (5) the nature and cost of the various feasible design changes that could be made to the design to improve its overall reliability and its ability to contain the consequences of accidents.

A great wealth of LMFBR safety technology is available today as a result of past Safety Program efforts to obtain this information for present and future LMFBR plants. This technology is reviewed comprehensively in Section 4.2.7 of WASH-1535, and additional information is provided on selected safety issues in Section III.B of ERDA-1535. There are certain safety-related areas where the availability of additional information would permit the designers of future large LMFBR plants to provide more cost-effective designs while meeting all safety requirements. Present and future Safety Program efforts will concentrate on providing these elements of improved safety technology.

The balance of this section on safety concentrates on updating the safety questions which were addressed in ERDA-1535. Most of these questions were associated with postulated severe accidents that would lead to core disruption. It is essential to appreciate the massive efforts that have been devoted to assuring that LMFBRs can be and are designed, constructed, and operated to have an extremely low probability of occurrence of core disruptive accidents. The strategy that has been used to accomplish this objective is to provide a design that is sound, conservative, and intrinsically safe during normal operation, and has sufficient margin to safely accommodate anticipated, unlikely, and extremely unlikely events (the three levels of design safety approach discussed in Section 4.2.7.3 of WASH-1535).

The LMFBR Program has accumulated much valuable experience on how to design systems and structures in LMFBR plants so that they have the requisite safety-related design features and margins. Exhaustive lists of possible external events and system and structural failures which could fall in the three event categories (anticipated, unlikely, and extremely unlikely) have been prepared. Events within the anticipated category include loss of off-site power and small sodium leaks or spills. In the unlikely category, representative events include accidents involving radioactive waste treatment system failures, fuel handling accidents, small sodium fires, local fuel assembly faults, and steam generator failures. The more severe extremely unlikely events include natural phenomena such as seismic events, tornados and floods, large sodium fires, refueling accidents, and heat transport system failures. Sections 4.2.7.5 through 4.2.7.7 of WASH-1535 provide a comprehensive discussion of the implications of these events on LMFBR designs; this discussion remains valid today.

For each LMFBR plant designed in the U.S., an extensive range of systems and features has been included in order to assure that the plant can safely accommodate these events within the requisite damage levels and that any radioactivity releases are within the limits set in 10 CFR 100. The discussion of the design features included in CRBRP that is found in Section III.B.3 of ERDA-1535 remains applicable.

While some residual uncertainties remain as to how best to design these systems and features for future large plants, sufficient conservatism is employed in the design of present plants to ensure that they can meet safety requirements. This conservatism is provided by requiring that significant margins be provided in the design of these systems and features and by providing redundancy and diversity of systems and structures. Operation of FFTF and CRBRP will provide additional evidence of the adequacy of the design of these plants with respect to safety. As stated earlier, present and future efforts in the Safety Program are aimed at reducing uncertainties and further improving designs so that plant capital and operating costs can be reduced by eliminating excessive conservatisms while still meeting safety requirements.

In the material which follows, each subsection of ERDA-1535, Section III B, Safety Research and Development Program Information, is addressed in turn. First, subsection content is briefly summarized. Then, areas in which changes have occurred since ERDA-1535 was issued are identified. Finally, information explaining these changes and describing the current status of the particular topic is presented. These subsections are the following:

III B.1 Additional Information Relative to the RRD Development Plan for LMFBR Safety

III B.2 Additional Information on Energetic LMFBR Core Disruptions

III B.3 Additional Information on the Basis for Proceeding with the Design, Licensing, and Operation of LMFBRs While the LMFBR Safety Program Progresses

III B.4 Additional Information on LMFBR Risk Assessments Methods Development

I. The DOE LMFBR Safety Research and Development Program

I.A. Summary of Subsection III.B.1, ERDA-1535

The objective of the Safety Program was described as development of technology that could be applied in the design process to contribute to the safety of LMFBRs. The Program was planned to make timely contributions to the LMFBR plant design and development program, ranging from completion of documentation of the technical base for the FFTF FSAR and the CRBRP PSAR in June 1976 to establishment of the technical base for the Commercial Breeder Reactor (CBR) FSAR in January 1985. The necessary analytical and experimental work would continue to be performed by national laboratories, industrial contractors, and universities. For experimental work, existing and new facilities would be utilized. The need for a new Safety Research Experiment Facility (SAREF) was identified.

Past Safety Program activities resolved some significant issues and reduced the uncertainties associated with other issues. Important remaining open questions included: the quantitative reliability of plant shutdown and decay heat removal systems and plant structures; quantitative understanding of the movement of fuel from breached fuel pins, including fuel sweepout; the characteristics of the extensive and extended fuel motion associated with a postulated whole core meltdown; uncertainty in the upper limit which can be placed on the energetics of a potential whole-core accident recriticality; and uncertainties over the content and attenuation of radioactive aerosols that could be released from fuel and containment as the result of a severe reactor accident.

Plans of action to resolve these remaining safety uncertainties, along with milestones supportive of the LMFBR plant development program, were presented.

I.B. Areas of Change Since ERDA-1535 Was Issued

Substantial progress has been made in the resolution of issues related to the initiation and progression of major reactor accidents. This has been enhanced by completion of the FFTF safety review interaction with NRC, and by partial completion of the CRBRP licensing interaction with NRC.

A change in the timing for anticipated large-scale deployment of LMFBRs, coupled with progress in the accident energetics area, has warranted a reversal in the earlier position that a new, large reactor safety test facility (SAREF) is needed.

The Program work schedule and key milestones have changed to reflect the modified LMFBR plant design and development program.

I.C. Current Status

I.C.1. Safety Issues

I.C.1.A. Introduction

In the period since ERDA-1535 was published, Safety Program work, coupled with experience in the FFTF and CRBRP design and safety review activities, has significantly advanced our understanding of the safety-related behavior of LMFBR plants. Progress toward resolution of particular LMFBR generic safety issues is discussed in the remainder of this section. Background for these discussions is provided by the listing of Safety Program accomplishments, 1976-1981, included as Appendix E.

I.C.1.B. ERDA-1535 Issues

As stated in Section I.A., ERDA-1535 identified a number of important open questions on LMFBR safety (see pp. III B-24, -25, ERDA-1535). The first ERDA-1535 question related to the quantitative reliability of plant shutdown and decay heat removal systems and plant structures. Reliability is factored into LMFBR designs by application of basic quality assurance and reliability principles, which include independence, separation, redundancy, and diversity of systems, subsystems and components. Reliability is then demonstrated analytically, by laboratory testing, and by the accumulation of plant operating experience. While the quantification of reliability can be made with analytical methods using generic LMFBR component data at any stage of plant design, construction, or operation, confidence in these reliability assessments is strongly influenced by the quality and depth of data bases from testing and operating experience.

Extensive hardware testing programs have been conducted for both primary[1] and secondary[2] control rod systems and associated logic circuits. The testing programs with thousands of successful scram operations have demonstrated with high confidence that the probability of failure to scram due to hardware failures is extremely low. The reliability assessment for the CRBR shutdown system[3] estimates the failure frequency to be well below 10^{-6} per year.

A systematic identification of potential common-cause failures has also been carried out[4], and the reliability estimates still have margin for unlikely failure modes not yet identified.

The shutdown heat removal system for LMFBRs is also designed to be highly reliable. Emergency power supplies and alternate heat sinks are added to the normal heat transport system to provide redundancy in these critical areas. In addition, special redundant and diverse residual heat removal systems, such as the direct heat removal and air-cooled condenser systems, have been designed for CRBR, and alternative designs are being developed for large LMFBRs. Existing programs related to SHRS reliability include testing of CRBR SHRS components and large plant component development tests. The data gathered from these test programs, along with a more limited data base gathered from operating plant testing and operating experience (EBR-II and FFTF), support analysis which predicts an extremely low probability of CRBR SHRS failure, about 10^{-6} per year[5].

Recently, reliability analysis models and computer codes have been improved by the incorporation of models of such elements as test and maintenance periods, a greater spectrum of operating and failure modes, and capabilities to handle human errors and dependencies. These developments allow more realistic and comprehensive modeling, thereby increasing the confidence in results. Progress has also been made in the identification and qualitative analysis of common-cause failures[4], for which significant margin is allowed in current designs. Learning from operating experience also continues to be an important part of reliability and analysis data improvement.

A diverse means of shutdown heat removal was demonstrated at FFTF in March 1981 when a primary system natural circulation test from 100% power was successfully completed. This and earlier natural circulation tests confirmed that the FFTF has the capability to safely remove heat by natural circulation during postulated events such as loss of electrical power. Furthermore, the series of tests verified the ability of the analytic model IANUS to accurately predict system behavior from the pump coastdown phase to the steady state natural circulation condition.

The second ERDA-1535 question related to quantitative understanding of the movement of fuel from breached fuel pins, including fuel sweepout. Such an understanding is necessary to assess the likelihood that a transient overpower (TOP) or loss-of-flow (LOF) event with failure to scram would inherently terminate its progression prior to whole-core disruption. Experiments designed to provide observations of fuel motion under these accident conditions have been performed both out-of-reactor[6] and in-reactor,[7,8] and diagnostic tools for measuring fuel motion under test conditions[9] have provided important data for development and validation of computer codes.[10] These computer codes provide the analytical methods for a quantitative understanding of fuel motion under hypothetical core disruptive accident conditions.

The experimental data base and the computer codes extrapolating this data to prototypical conditions support the conclusion that an overpower event with failure to scram would most likely terminate inherently with limited core damage by fuel sweepout leading to a subcritical core. The data and codes also indicate that a loss-of-flow event with failure to scram would most likely progress to whole-core disruption because coolant would be voided from many subassemblies prior to extensive fuel disruption, leaving much of the core uncoolable. This conclusion on the loss-of-flow event has resulted from an extensive investigation conducted in 1978 and 1979 using the more sophisticated computer codes and more extensive data base then available.[11] The current approach to accommodating the loss-of-flow event with failure to scram is to demonstrate that the potential for it to result in energetics that would threaten the integrity of the primary system boundary is low.

Integral tests such as the TREAT L-series have demonstrated the dispersive capability of irradiated fuel subjected to elevated power levels under LOF conditions[12], minimizing concern for positive reactivity insertion in the early stages of the scenario. Phenomenological tests including the TREAT F-series[13,14,15] and the direct electrical heating (DEH) tests[16] have provided additional confirmation of the mechanisms which inhibit fuel compaction and promote fuel dispersion. Phenomenological guidance has been provided to analytical modeling efforts and the results have demonstrated the ability to predict successfully both the material redistribution patterns and their neutronic integral feedback effect as used in whole core analyses.[17] Post-test analyses of additional in-pile tests in the L-series and pre-test analysis and planning for upcoming unprotected loss-of-flow tests[18,19] is currently underway.

The third ERDA-1535 question had to do with the characteristics of the fuel motion associated with a postulated whole core meltdown. These characteristics must be understood in order to provide assurance that fuel motion associated with a melting or molten LMFBR core would be sufficiently dispersive to preclude an energetic power burst which would challenge the structural integrity of the primary system.

It was stated in Section III.B.2 of ERDA-1535 that substantial efforts within the Safety Program were being directed toward demonstrating that energetic recriticalities would be very unlikely to occur during the whole-core meltdown phase of postulated core disruptive accidents in LMFBRs. The existence of several fundamental physical phenomena was cited as the basis for believing that these efforts would be successful. In the years since ERDA-1535 was published, significant progress has been made toward realizing this objective. However, recriticality events during the whole-core meltdown phase still cannot be completely ruled out because the occurrence of phenomena such as collapse of boiling regions due to excessive heat transfer to boundaries,[20] partial separation of the molten fuel and boiling steel,[21] and reentry of large quantities of material previously ejected from the core and solidified in the above-core structure cannot be absolutely precluded. Because these phenomena are rate-limited and because of the nonuniform conditions that would exist under such scenarios, none of these phenomena, should they occur, are expected to result in reactivity insertion rates yielding large energetics.[22,23] Both in-reactor and out-of-reactor experiments now planned are intended to provide an expanded data base to support this position.[18,24]

A precise analysis of fuel motion under these accident conditions requires large computer codes capable of calculating the integrated effects of neutronics, multi-phase fluid dynamics, and thermodynamics. Such codes (TRANSIT[25] and SIMMER[26]) are under development and are being validated with out-of-reactor experiments which attempt to simulate accident conditions.[27,28]

The fourth ERDA-1535 question, uncertainty in the upper limit which can be placed on the energetics of a potential whole-core accident recriticality, is addressed in Section II, Energetic LMFBR Core Disruption.

The last ERDA-1535 question related to uncertainties over the content and attenuation of reactor accident-produced radioactive aerosols. Resolution of these uncertainties will permit improved assessment of the consequences of postulated severe accidents. Since 1975, improved understanding of aerosol behavior has been obtained as a result of extensive out-of-reactor testing[29,30,31,32] and advances in analytical methods.[33,34] The major advancement has been the generation of new test data which broadens and extends the data to higher sodium aerosol densities ($\sim$1000 μgm/cc in the High Temperature/Concentration Aerosol experiments[30,31]) and recent test data for UO_2 aerosols.[32] Use of these data for code validation will reduce conservatisms in radiological assessments and allow analysts to take credit for inherent depletion mechanisms which limit the quantity of fuel and sodium aerosols that can be transported from a breached primary system or reactor containment building following a postulated core disruptive accident. Although a substantial data base exists,[34,35] additional out-of-reactor tests are planned to refine computer codes and to better characterize aerosol behavior under special accident conditions. These tests include a steam-sodium aerosol test to form the basis for a code comparison study, a test of the efficiency of a turbulent agglomeration concept, and additional tests of high density UO_2 aerosol agglomeration and settling.

I.C.1.C. Additional Safety Issues

Safety Program work and other events occurring since ERDA-1535 was published have focused attention on additional safety issues.

FFTF and CRBRP safety review activities highlighted the need for more research on core debris accommodation. The purpose of this research is to support improved assessments of the capability of LMFBR containments to withstand loadings from core meltdown accident debris and to develop design features for enhancing containment capabilities. Core debris accommodation work involves a broad range of technologies addressing issues associated with both in-vessel and ex-vessel core debris phenomena.[36] These phenomena include particulate core-debris behavior, sodium-concrete interactions, water release from heated concrete, hydrogen release and burning, and the response of structural concrete to elevated temperatures for long times. Experiments conducted in a variety of out-of-reactor facilities have provided substantial insight into the nature of these phenomena and have enabled integrated computer codes which model containment response, such as CACECO[37] and HAA-3B,[38] to be validated. The current technology base supports the position that the CRBRP has the core debris accommodation capabilities necessary to meet licensing requirements associated with core disruptive accidents.[39] At the same time, a number of issues in core-debris accommodation technology must be studied further in order to assure that questions on optimal containment designs and licensing concerns for large plants can be adequately resolved.[40] These questions arise for large plant designs due to the much larger fuel inventory and the associated decay heat loads. Questions regarding the distribution of debris over the cross section within the reactor vessel and within the reactor cavity, the carryover of debris into the piping, the performance of in-vessel and cavity structures in contact with molten core debris, the structural behavior of concrete at high temperatures, sodium natural convection and the reliability of long-term decay heat removal systems under post-accident conditions must be studied further to assure that large plant designs can control accident progression and that, should a core-disruptive accident occur, radiological releases will remain within prescribed limits.

The Three Mile Island accident highlighted the safety importance of the man-machine interface. The initial efforts within the nuclear industry to address this issue were focused on light water reactors, but it became clear that the LMFBR program would be able to apply much of the new technology developed for such reactors. Nonetheless, in order to advance understanding for LMFBRs, research and development on the LMFBR man-machine interface was initiated in selected areas. Progress to date includes the development and initial operation at FFTF of an automated system for control of plant maintenance work.[41] This system is designed to provide plant operators with real-time information as to which plant components and systems are unavailable because of maintenance operations, and information on the functional relationship between plant subsystems and on the relationship of equipment to plant safety functions. It is intended that this body of information, presented in a clear, organized way, will enable plant operators to make better-informed decisions on when and how to change the operational condition of the plant for maintenance or other reasons. Demonstration of operational safety improvement produced by use of this system is currently underway at FFTF.

Another recent man-machine interface R&D product is the completion of a comprehensive study[42] to establish, for a future large LMFBR plant, the optimum set of parameters that should be displayed to plant operators for the purpose of monitoring plant safety status and initiating necessary corrective actions. This effort is analogous to the safety parameter display system efforts of the LWR industry.

In parallel with these early LMFBR man-machine interface R&D activities, an overall plan[43] for continued work in this area has been prepared. This plan provides a task structure, perceived priorities for execution of these tasks, and near-term and long-term plans based on these priorities. In preparing this plan, it was recognized that the LWR man-machine technology which is expected to apply in large part to LMFBRs is itself still in an evolutionary phase, so that the degree of this applicability and any special LMFBR needs for new technology cannot be firmly established early on. Thus, a major task within the program is to develop and maintain familiarity with ongoing man-machine technology developments in the LWR and other areas, and to appraise these for applicability to LMFBRs. The appraisal function will be closely coordinated with LMFBR project design activities.

Another Three Mile Island-related issue is that of the adequacy of provisions for emergency response in the event of a serious reactor accident. Because this matter is both plant- and site-specific, and requires interaction with local government entities, it is addressed by particular LMFBR plant projects. CRBRP has considered all applicable emergency preparedness requirements, and envisions no difficulty in implementing these requirements. Emergency preparedness facilities and arrangements for CRBRP will be similar to those for a light water reactor. Emergency response capabilities of future LMFBRs will likely be substantially the same as those for LWRs and will meet NRC regulatory requirements.

I.C.2. Safety Test Facilities

ERDA-1535, on pages III B-45 through -49, described major facilities used or anticipated to support the LMFBR Safety Program. Of these facilities:

- TREAT, in use since ERDA-1535 was issued, continues to be the principal test facility for advancing understanding of initiating phase accident phenomenology and validating integral accident analysis codes. Coolant dynamics, pin failure, and fuel relocation have been investigated for oxide fuel under LOF and TOP conditions, and integral experiments and phenomenological tests have investigated the effects of parameter variations, such as fuel pin fission gas release, on accident sequences. In 1983, TREAT will be shut down for completion of the TREAT Upgrade modification to permit testing of larger bundle sizes, to investigate scale-dependent phenomena such as fuel sweepout during a TOP accident and provide a more prototypic thermal-hydraulic environment to validate extrapolation of the current data base.

- SLSF experiments were conducted in the ETR from 1975 to 1981. These experiments addressed fuel disruption and relocation under LOF conditions, fuel pin response and relocation under LOF conditions, slow ramp rate TOPs, fuel pin survivability under sodium boiling and detection and propagation of fuel bundle local faults. Experimental data have been used for model development and validation of accident analysis codes.

- PBF has not been used for Safety Program experiments, because it was determined that the use of this reactor would not be cost-effective as compared to SLSF/ETR.

- FFM, renamed THORS, and OPERA both have used electrically heated fuel pin simulators for out-of-reactor safety experiments. The combined program has addressed inlet and heated zone blockages, steady state and transient boiling behavior, and normal thermal-hydraulic characteristics of test assemblies up to 61 pins. These data have been used for assessing applicability of one-dimensional and multi-dimensional coolant behavior codes.

The last major facility called for by ERDA-1535, SAREF, would have provided in-reactor capability for experiments much larger than possible in any other facility, including TREAT Upgrade, in a highly prototypic LMFBR reactor environment. The experiment size capability, up to the equivalent of four full-length LMFBR subassemblies, each consisting of 217 fuel pins within a hexagonal structural housing, was considered necessary "...to permit understanding of controlling size dependent phenomena within a subassembly during the progression of postulated accident sequences" (page III B-36, ERDA-1535). Table III B-1 in ERDA-1535 uses the name "Safety Test Facility" to represent SAREF.

Acquisition of the Safety Test Facility has not been implemented, because:

- In contrast to the situation that existed when ERDA-1535 was issued, it is now anticipated that the late 1990's would be the most likely period for a utility commitment to large-scale deployment of LMFBRs. This schedule permits the Safety Program to proceed to address the safety issues that the Safety Test Facility was intended to resolve along a lower-cost path that does not include the construction of major new in-reactor facilities beyond TREAT Upgrade. If the early results of this program disclose significant safety uncertainties for the deployment of a family of commercial LMFBRs, time would be available to redress the shortcoming.

- Significant improvements have been made in the understanding of key accident-related phenomena as the result of an aggressive program of analysis, out-of-reactor experiments, and experiments in TREAT. It is believed that the combination of planned analytical and out-of-reactor experimental activities and larger-scale in-reactor tests in TREAT Upgrade will be successful in bringing about the required further reduction in uncertainty in the understanding of accident-related phenomena on a schedule consistent with the needs of the current LMFBR plant development program.

- It is now believed that only a marginal additional reduction in uncertainty could be gained from testing in the Safety Test Facility, given the current understanding of the relationship between test bundle size and uncertainties introduced in the scaling of results to a commercial-sized LMFBR.

I.C.3. Program Milestones

The LMFBR plant development program includes construction and operation of CRBRP. Also, the program contemplates the future design, construction, and operation of a near-commercial size LMFBR plant, the Large Developmental Plant (LDP). This project would be carried out in cooperation with the private sector. Experience gained from CRBRP and LDP would be used in decisions on LMFBR commercialization.

The CRBRP design and Preliminary Safety Analysis Report (PSAR) are essentially complete; the Final Safety Analysis Report (FSAR) is to be submitted in early CY 1987. The latter event provides the basis for a major Safety Program milestone: completion of the safety technology base for the CRBRP FSAR by late CY 1986. Similar milestones would be developed from key LDP Project events such as start of preliminary design, PSAR submittal, and FSAR submittal. It is expected that these events would occur in the period from the mid 1980's to the early 1990's.

The LMFBR Safety Program Plan[44], prepared in 1980, is the principal basis for ongoing safety R&D planning. The R&D work plans contained in this document will be revised to achieve consistency with the major milestones discussed above.

II. Energetic LMFBR Core Disruption

II.A. Summary of Subsection III B.2, ERDA-1535

It was stated that R&D directed toward identification and elimination of accident initiators and toward provision of design characteristics and engineered features to mitigate accident consequences, coupled with conservative design, construction and operation, provides high assurance of LMFBR plant safety relative to energetic hypothetical core disruptive accidents (HCDAs). It was also stated that it should be possible to demonstrate that HCDAs in large LMFBRs would not result in damaging energy releases.

II.B. Areas of Change Since ERDA-1535 Was Issued

Since 1975, there have been substantial improvements in the understanding of HCDA phenomena through extensive out-of-reactor and in-reactor experiments, and in the analytical methods for predicting HCDA consequences through advances in computer code technology. These improvements have led to significant reduction in uncertainties in HCDA energetics assessments and have substantially increased confidence that licensing requirements associated with HCDAs can be met. While the state-of-technology in 1975 was adequate to support qualitative arguments for the benign nature of HCDAs, the current technology base provides much greater confidence in the ability to quantify HCDA energetics consequences and thus to address HCDAs in the perspective of quantitative risk assessment. For example, in determining the range of consequences of HCDAs, analyses were performed which parametrically varied phenomenologically based parameters which affect fuel motion.[45] In homogeneous cores with moderately large sodium void coefficients, loss-of-flow scenarios involving prompt critical excursions and resulting in several hundred megajoules of work-energy in expansions to one atmosphere were calculated. Transient overpower and loss-of-flow driven overpower (LOF/TOP) scenarios were also calculated in this parametric fashion, resulting in similar concerns about energetics potential.

Since the time of that assessment, experimental information has been obtained and incorporated in more sophisticated analytical tools which now tend to confirm the position of early dispersion and minimal energetics. Integral tests such as the TREAT loss-of-flow tests L6 and L7[12] provide a data base for minimizing concern about initial fuel compaction and for predicting dispersion under overpower conditions. Such tests provided preliminary confirmation of the ability of retained fission gas to provide the dispersive mechanism. Additional confirmation was provided by phenomenological overpower tests in the F-series in TREAT.[13,14,15] By analyzing the coolant and fuel motion reactivity effects in the LOF/TOP simulation in the L8 TREAT tests with the new PLUTO 2 module of SAS4A, it has also been demonstrated that energetics enhancement by within-pin compactive fuel motion was overestimated in previous parametric analyses[46]. Such analyses provide a rational basis for substantially limiting the positive fuel motion feedback and suggest that the LOF/TOP scenario may be of small concern in low to moderate void worth LMFBRs. Material motion information in the transient overpower scenario has also been extended by both in-pile tests such as the TREAT J1 slow TOP test,[47] and the out-of-pile CAMEL TOP fuel-sweepout tests.[48] Such information is being used in the continuing validation of modules of the SAS4A Code, and confirm the hydraulic sweepout potential in this scenario.

In addition to the advances that have been made in developing more sophisticated analytical tools and acquiring experimental information to validate the models and support the application of these tools, an improved understanding has been gained of the relationship between certain LMFBR core design features and the predicted behavior of LMFBR cores under HCDA conditions. It has long been known that the level of energetics predicted for the LOF accident in an LMFBR was somewhat sensitive to the sign and magnitude of the overall sodium void reactivity worth of its core. A scoping study of the response of a preliminary heterogeneous core design for CRBRP under HCDA conditions conducted in 1976[49] revealed that the potential for energetic power excursions during the initiating phase of the LOF accident for CRBRP with this core seemed to be markedly reduced compared to that predicted for CRBRP with a homogeneous core. It was subsequently determined that a number of characteristics associated with these heterogeneous core designs, including the reduced overall sodium void worth and the fact that a significant portion of the void worth is tied up in the internal blanket subassemblies which would not experience voiding until much later than the fuel subassemblies, contributed to the predicted reduced energetics potential. This conclusion has subsequently been reinforced for CRBRP with its current reference heterogeneous core[50] and confirmed for commercial-sized LMFBRs.[51] For this reason, the reference design for LDP now includes a heterogeneous core.

II.C. Current Status

HCDAs are treated as accidents beyond the design basis for containment systems because of their extremely low probablity of occurrence. However, HCDAs still receive a great deal of attention because of their potentially severe consequences.* For CRBRP, NRC has required that the primary system be capable of accommodating an energetic HCDA, and that analysis supported by experimental data be performed to demonstrate this capability. The major issue associated with such requirements is the magnitude of energetics which must be accommodated. The related Safety Program objective is to demonstrate that the likelihood of large energetics is so low that the magnitude of energetics which must be accommodated to meet safety requirements is not large enough to adversely impact the design. For a CRBRP-sized core, the current technology base is adequate to meet this objective. The results of hypothetical core disruptive event analyses for the CRBRP heterogeneous reactor core have been reported.[50] The analytical results cover a large number of parametric cases including variations in design parameters and phenomenological assumptions. Reactor core configurations at both the beginning of cycle one and end of cycle four were evaluated. The energetic consequences were evaluated based upon both fuel expansion thermodynamic work potential and a relative probability assignment. It was concluded that the structural loads which result from

*NRC's Final Environmental Statement for the CRBRP (NUREG-0139, February 1977) included a discussion of the consequences of HCDAs for that plant. More recently, NRC has started to include similar information in LWR environmental statements (e.g., NUREG-0769, August 1981, for Enrico Fermi Unit 2). It is anticipated that environmental statements for large LMFBRs such as LDP and future commercial breeders will also address this subject.

101 megajoules of available expansion work at sodium slug impact on the reactor closure head (equivalent to 661 megajoules of fuel expansion work to one atmosphere), are an adequate energetic consequence envelope for use in specifying the Structural Margin Beyond the Design Base. Analyses and supporting model experiments reported in Reference 52 indicate that the CRBRP reactor coolant boundary would accommodate these structural loads without loss of integrity and with limited leakage of radioactive materials to the reactor containment building.

For LMFBRs larger than CRBRP, such as LDP, it is believed to be prudent to obtain additional confirmation that practical primary system boundary designs provide adequate capability to accommodate HCDA energetics. Several factors combine to make the HCDA energetics accommodation problem a more difficult one to treat in large LMFBRs. The larger cores generally have larger positive void worths, meaning that more positive reactivity is available for insertion during the voiding phase of a loss-of-flow accident. The larger fuel inventory means that a larger mass of fuel could be vaporized and serve as a source of work-energy in the improbable event that an HCDA would lead to a sustained superprompt critical transient. In addition, it is more difficult to provide a given structural capability in the larger diameter primary vessels and vessel heads these large plants would have. Programs involving the validation of current-generation accident analysis codes such as SAS4A,[53] TRANSIT,[25] and SIMMER[26] through analysis and the conduct of in-reactor experiments in TREAT and out-of-reactor tests in a variety of facilities are in progress or soon to be implemented.[19,24] These programs are expected to provide the necessary confirmation.

III. Basis for Proceeding with the LMFBR Plant Program While the Safety Program Progresses

III.A. Summary of Subsection III B.3, ERDA-1535

It was asserted that while the knowledge gained from LMFBR safety R&D is not without gaps and uncertainties, conservatism in design, construction, and operation provide a satisfactory basis for proceeding with LMFBR projects. The "three levels of design" approach then being taken by CRBRP was discussed as a specific example of such conservatism.

III.B. Areas of Change Since ERDA-1535 Was Issued

Ongoing Safety Program R&D has reduced the uncertainties over LMFBR safety.

Continued application of the "three levels of design" approach has strengthened confidence in the safety of CRBRP.

III. C. Current Status

The Safety Program has made substantial progress toward resolution of LMFBR safety issues. The current status of these issues is given in Sections I.C.1 and II.

The CRBR Project has continued to take a conservative approach to design, with particular attention to application of experience from other related activities. An example is the Project's program to apply experience from the design, construction, and operation of DOE's Fast Flux Test Facility (FFTF) at Richland, Washington. This program, formally initiated in 1976 and still active, has resulted in CRBRP review and analysis of experiences at FFTF; many were found to apply to CRBRP and appropriate action was taken. Beneficial information transfer has taken place on subjects such as the performance of the Plant Protection System, the need to modify large sodium check valve design as the result of hydraulic testing, and inoperability of sodium level indicators due to moisture in wiring insulation.

A second example of application of experience is the work of the CRBRP Key Systems Design Review Task Forces. The design reviews addressed decay heat removal systems, containment isolation systems, systems to mitigate the consequences of hypothetical core disruptive accidents, the control room system, and others. Event tree and fault tree methods were used to search for unforeseen events or interactions that could lead to unsafe conditions. The Three Mile Island experience was fully considered.* The reviews concluded that the systems are designed to permit safe operation with a minimum possibility of serious plant accidents. However, a number of system and procedural changes to enhance operational safety were recommended. Several of the recommended changes are being implemented in the CRBRP design, including the relocation of some of the gaseous radwaste processing system equipment into containment (mainly for plant operating staff protection), a redesign of the main control room panel to enhance the man-machine interface aspects for plant operation, incorporation of emergency response facilities into the design, and procurement of a simulator for operator training.

*The CRBRP Project has closely followed the developments that resulted from the 1979 incident at Three Mile Island, including the findings of the NRC Lessons Learned Task Force, the Kemeny Commission, and the Rogovin Report. New regulatory requirements emanating from these findings are contained in NUREG-0718, Rev 1, "Licensing Requirements for Pending Applications for Construction Permits and Manufacturing License (August 1981)." While the requirements of NUREG-0718 were written specifically for application to light water reactors, there are many underlying engineering principles which may be applicable to the LMFBR. Consequently, the CRBRP Project has reviewed all of the NUREG-0718 requirements to determine the requirements which CRBRP should consider. All those which were found have a degree of applicability to LMFBR technology have been applied to CRBRP.

IV. LMFBR Risk Assessment Methods Development

IV.A. Summary of Subsection III B.4, ERDA-1535

It was stated that exploratory R&D on risk assessment methodology was underway, aimed toward development of credible methodology by the mid-1980's. An important companion objective was to gain understanding of the level of confidence that can be placed in the results of application of this methodology. When available, risk assessment methodology would verify and quantify our belief in the safety of LMFBRs; it may also enable plant design improvements and guide R&D program selection. The safety approach described was to take advantage of the inherent safety features of the LMFBR, to use conservative design practices, and to apply probabilistic risk assessment when appropriate.

IV.B. Areas of Change Since ERDA-1535 Was Issued

Soon after the publication of ERDA-1535, a comprehensive risk assessment was carried out for CRBRP.[54]* The objective of this risk assessment was "to provide a realistic evaluation of the risk to the public from the Clinch River Breeder Reactor Plant, to place that risk in perspective relative to other societal risks, and to provide a basis for asssessing the comparability of the risk from the CRBRP with risks associated with previously licensed reactors." This study concluded CRBRP risks are comparable to those from light water reactors of the then-current generation as characterized by the Reactor Safety Study[55] and that the risk associated with postulated accidents in the CRBRP is negligible when compared with non-nuclear risks to which the local population is already exposed. Additional information on the CRBRP risk study is

*Comparable assessments have not been performed for nonreactor facilities of the LMFBR fuel cycle.

given in Appendix C. This study is being revised to account for changes in plant design and improvements in risk assessment methodology, and to address earlier comments. Although changes in the detailed results of the earlier study are likely, the overall conclusion on comparability with light water reactors is not expected to change. It should be understood that the detailed results of a risk analysis for an LMFBR plant larger than CRBRP are likely to differ from those for CRBRP because of differences in plant size, design, and siting.

The role of probabilistic risk assessment has been enlarged since the CRBRP Safety Study was completed in that it is now used as an aid in the design of LMFBRs. A risk allocation model[56] has been developed which allows a comparison of design alternatives in terms of reduction in risk and cost of implementation. This model has been used to date primarily to examine safety design tradeoffs concerning prevention and mitigation of accidents which involve severe core damage. The application of this model to the LDP in the CDS phase provided the basis for determination of safety-related reliability goals and the screening of available safety alternatives. The comparison of design options indicated that accident prevention features are generally more cost-effective than accident mitigation features. It was determined that the most significant design-related contributor to risk reduction is enhancement of the reactor shutdown system and shutdown heat removal system reliabilities. Mitigation features required to minimize total energy generation costs and satisfy safety objectives were identified as a core design with a low probability of high energetics and a strong containment building. A containment vent/filter scheme also appeared desirable. The study developed the reliability goals of 1×10^{-5} and 3×10^{-5} mean failures per year for the LDP reactor shutdown and shutdown heat removal systems to obtain a total value of 4×10^{-5} severe core damage events per reactor year. This total value satisfied the risk allocation results which indicated that the mean frequency of severe core damage events should be limited to no higher than about 1 x 10^{-4} events per reactor year to protect the plant investment.

IV. C. Current Status

A large breeder reactor risk model was developed in FY 1980 and has been improved since that time. The current status of this risk model and approach is described in Reference 57. The single plant risk model provides a sound risk evaluation capability for application to large LMFBR plants. It provides for the quantification of input data uncertainties as probability density functions for both initiating event frequencies and safety system failure frequencies. The input uncertainties are propagated by the model to the risk estimate outputs to provide a measure of output uncertainty. Further improvement of credible risk assessment methods requires a reduction of uncertainty in risk analysis input data. The integrated test programs for LMFBR safety systems (RSS and SHRS) and the LMFBR data base development activities (CREDO and SACRD)* will contribute to the reduction of these uncertainties.

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*CREDO[58] (Centralized REliability Data Organization) was established by DOE at Oak Ridge National Laboratory as a national center for the collection, evaluation, and dissemination of reliability/availability data on advanced reactors. The system operates by first collecting and storing comprehensive engineering (design and operational) data on reactor components and then tracking the performance (operating hours/cycles, failures, maintenance along with other parameters) of the components thoughout their lifetime. A versatile computerized system makes it possible to search the stored records, extract and compile different types of data, and prepare varied output reports to serve users.

SACRD[59] (Safety Anlysis Computerized Reactor Data) is a data base of material properties and other handbook data needed in computer codes used for fast reactor safety studies. Data are available in the thermodynamics, heat transfer, fluid mechanics, structural mechanics, aerosol transport, meteorology, neutronics, and dosimetry areas. Tabular, graphical, and parameterized data are provided.

References

1. "Assessment of LMFBR Primary Control Rod Systems Test Program," T-SCT-LHC-80-20, Westinghouse Advanced Reactors Division, August 29, 1980.

2. "Integrated Test Program Plan for the Large Breeder Reactor Secondary Control Rod Unit," GEFR-00519(DR), General Electric Company, Advanced Reactor Systems Department, Revision 1, November 1980.

3. "Reliability Assessment of CRBRP Reactor Shutdown System," WARD-D-0018, November 1975.

4. W. S. Woodward and R. J. Baloh, "Common-Cause Failure Assessment Specification for the CRBRP Reactor Shutdown System," WARD-D-0195, Westinghouse Electric Corporation, March 1978.

5. "An Update of the Preliminary Reliability Prediction for CRBRP Shutdown Heat Removal System," NEDM-14082, General Electric Company, January 1976.

6. D. H. Cho and G. M. Hauser, "An Analysis of CAMEL C2 Single-pin Fuel Sweepout Test," ANL/RAS 78-33, June 1978.

7. R. Simms, "An Interpretation of Fuel Motion in Recent TREAT Experiments with LMFBR Fuel," ANL-79-88, October 1979.

8. R. Simms, et al., "Fuel Motion in Experiments Simulating LMFBR Loss-of-Flow Accidents," ANL/RAS 80-25, November 1980.

9. A. DeVolpi, et al., "Fast Neutron Hodoscope at TREAT: Methods for Quantitative Determination of Fuel Dispersal," ANL/RAS 80-17, August 1980.

10. J. M. Kramer, "Comparison and Evaluation of Transient Fuel Pin Behavior Codes," ANL/RAS 80-22, September 1980.

11. D. R. Ferguson, et al., "A Study of the LOA-2 Termination Potential for the LOF Accident in LMFBRs," Proceedings of the International Meeting on Fast Reactor Safety Technology, Seattle, WA, August 19-23, 1979.

12. R. Simms, et al., "TREAT Experimental Data Base Regarding Fuel Dispersals in LMFBR Loss-of-Flow Accidents," ANS Reactor Safety Aspects of Fuel Behaviour Topical Meeting, Sun Valley, Idaho, August 1981.

13. R. G. Palm, et al., "F1 Phenomenological Test on Fuel Motion: Final Report," ANL-78-50, May 1978.

14. R. G. Palm, et al., "F2 Phenomenological Test on Fuel Motion: Final Report," ANL/RAS 80-24, October 1980.

15. R. G. Palm, "LOF-Initiator experiments F3 and F4," in USDOE Fast Reactor Safety Program Progress Report, Oct-Dec, 1980, ANL/TMC 81-1.

16. G. R. Fenske and G. Bandyopadhyay, "Summary Report on Direct Electrical Heating Experiments with Irradiated Mixed-Oxide Fuel," ANL/MSD 81-2, 1981.

References (Continued)

17. A. M. Tentner and H. U. Wider, "LEVITATE - A Mechanistic Model for the Analysis of Fuel and Cladding Dynamics Under LOF Conditions for SAS4A," Proc. Int. Mtg. Fast Reactor Safety Technology, Seattle, Wash., August 19-23, 1979.

18. "ANL Safety Experiments Program Plan," ANL/RAS 80-3, June 1980.

19. A. E. Klickman, et al., "TREAT Experiment Plan for U.S.-DOE LMFBR Safety Program," Transactions ANS/ENS Topical Meeting: Reactor Safety Aspects of Fuel Behavior, Sun Valley, Idaho, August 1981.

20. F. J. Martin, "Bottled Transition Phase Analysis-Preliminary Report," HEDL-TME-78-64, April 1980.

21. M. Epstein, et al., "Incipient Stratification and Mixing in Aerated Liquid-Liquid or Liquid-Solid Mixtures," Chemical Engineering Science, Vol. 36, pp. 784-787, 1981.

22. W. R. Bohl, et al., "An Analysis of Transient Undercooling and Transient Overpower Accidents without Scram in the Clinch River Breeder Reactor," ANL/RAS 75-29, July 1975.

23. E. E. Morris and T. Y. C. Wei, "An Assessment of the Unprotected LOF Accident in the CDS Phase II Heterogeneous Core Design," ANL/RAS 81-1, December 1980.

24. A. Padilla, Jr. and F. J. Martin, "Transition Phase Issues," HEDL-TC-1865, December 1979.

25. S. J. Hakim, et al., "TRANSIT: A Multi-Field, Multi-Phase Computer Code for the Analysis of the Transition Phase in an FBR," ANL/RAS 78-28, August 1978.

26. L. L. Smith, et al., "SIMMER-II: A Computer Program for LMFBR Disrupted Core Analysis," NUREG/CR-0453, October 1978.

27. B. W. Spencer, et al., "Reactor-Material Fuel-Freezing Experiments Using Small-Bundle, CRBR-Type Pins," ANL-80-22, February 1980.

28. M. Farahat, et al., "Experimental Simulation of Boiled-up Fuel Pools," ANL/RAS 78-24, June 1978.

29. J. D. McCormack and R. K. Hilliard, "Aerosol Measurement Techniques and Accuracy in the CSTF," HEDL-SA-1981 FP, November 1979.

30. H. A. Morewitz, et al., "Experiments on Sodium Fires and their Aerosols," Nuclear Engineering and Design, Vol. 42, 1977.

31. H. A. Morewitz, et al, "Attenuation of Airborne Debris from Liquid-Metal Fast Breeder Reactor Accidents," Nuclear Technology, Vol. 46, December 1979.

References (Continued)

32. "Annual Technical Progress Report-Reactor Safety-Government Fiscal Year 1979," ESG-DOE-13294, Rockwell International Energy Systems Group, April 15, 1980.

33. A. K. Postma and R. K. Owen, "Comparison of Aerosol Behavior During Sodium Fires in CSTF with the HAA-3B Code," HEDL-SA-1982 FP, March 1980.

34. "Nuclear Aerosols in Reactor Safety," OECD Nuclear Energy Agency, June 1979.

35. "Proceedings of the CSNI Specialists Meeting on Nuclear Aerosols in Reactor Safety," NUREG/CR-1724, Oak Ridge National Laboratory, October 1980.

36. E. L. Gluekler and L. Baker, Jr., "Post-Accident Heat Removal in LMFBR's," Symposium on the Thermal and Hydraulic Aspects of Reactor Safety, Vol. 2: Liquid Metal Fast Breeder Reactors, Edited by O. C. Jones, Jr. and S. G. Bankoff, 1977, p. 285-324.

37. R. D. Peak, "Users Guide to CACECO Containment Analysis Code," HEDL-TME 79-22, June 1979.

38. R. S. Hubner, et al., "HAA-3 User Report," AI-AEC-13038, Atomics International Division, March 1973.

39. "Hypothetical Core Disruptive Accident Considerations in CRBRP--Vol. 2: Assessment of Thermal Margin Beyond the Design Base," CRBRP-3, March 1980.

40. L. Baker, et al., "Core Debris Accommodation Program Plan," USDOE, July 1981.

41. S. E. Seeman, "MIDAS Documentation," TC-2073, Hanford Engineering Development Laboratory, September 1981.

42. S. M. Divakaruni, et al., "Safety Status Information System: A Critical Parameters Display Study," GEFR-00569(DR), General Electric Company, Advanced Reactor Systems Department, August 1981.

43. "Man-Machine Interface Program Plan," Fast Reactor Safety Technology Management Center, Argonne National Laboratory, September 1981.

44. "LMFBR Safety Program Plan," Office of Reactor Research and Technology, U.S. Department of Energy, August 1980.

45. W. R. Bohl, et. al., "An Analysis of the Unprotected Loss-of-Flow Accident in the Clinch River Breeder Reactor with an End-of-Equilibrium-Cycle Core," ANL/RAS 77-15, May 1977.

46. H. U. Wider, et. al., "The PLUTO2 Overpower Excursion Code and a Comparison with EPIC," Proc. Int. Mtg. Fast Reactor Safety Technology, Seattle, Wash., August 19-23, 1979.

47. R. J. Page, et. al., "Preliminary Data Report for TREAT Test J1," ANL/RAS 79-27, 1979.

48. B. W. Spencer, et. al., "Fuel Motion in the CAMEL TOP-Simulation LMFBR Safety Tests," Int. Mtg. Fast Reactor Safety Technology, Seattle, Wash., August 19-23, 1979.

49. R. J. Henninger, et al., "An Analysis of Selected Transient Undercooling Accidents Without Scram for the Clinch River Breeder Reactor with a Parfait Core," ANL/RAS 77-16, May 1977.

50. "An Assessment of HCDA Energetics in the CRBRP Heterogeneous Reactor Core," CRBRP-GEFR-00523, December 1981.

51. J. E. Cahalan, "Homogeneous/Heterogeneous LMFBR Core Design Safety and Licensing Trade-offs," ANL/RAS 80-2, February 1980.

52. "Hypothetical Core Disruptive Accident Considerations in CRBRP--Vol. 1: Energetics and Structural Margin Beyond the Design Base (Rev. 3)," CRBRP-3, August 1981.

53. J. E. Cahalan, et al., "The Status and Experimental Basis of the SAS4A Accident Analysis Code System," Proceedings of the International Meeting on Fast Reactor Safety Technology, Seattle, Wash., August 19-23, 1979.

54. "CRBRP Safety Study--An Assessment of Accident Risks in the CRBRP," CRBRP-1, March 1977.

55. "Reactor Safety Study," Main Report, WASH-1400 (NUREG-75/014), October 1975.

56. J. A. Hartung, "Risk Allocation Status Report," N323TI000056, Rockwell International Energy Systems Group, July 1980.

57. "Single Plant Risk Model Development and Application," GEFR-00573(DR), Advanced Reactor Systems Department, General Electric Company, August 1981.

58. T. F. Bott, et al., "Development of the Centralized Reliability Data Organization (CREDO)," Proceedings of the Third European Reliability Data Bank Seminar, NCSR-R24, July 1980.

59. N. M. Greene, et al., "SACRD: A Data Base for Fast Reactor Safety Computer Codes - General Description," ORNL-5477/V1, January 1979.

(2) Safeguards

Introduction

Historically, the Munich incident of 1972 marked the start of a period of increasing concern with the external adversary, particularly the terrorist, that would threaten or assault institutions of society. It was clear that at least some terrorist groups were and are sufficiently well trained, well financed, and well organized to engage in a limited number of sophisticated paramilitary operations. Thus over the last 6 years the development of safeguards and security systems to deter, prevent, and respond to such threats has been a major, although certainly not exclusive, focus of research and development. A variety of other adversaries with varying objectives and capabilities have also been identified. Development of sensors, hardening of sites, and effective training of guards, have all been part of this response to the threat of armed assault.

However, it is important to put these concerns in perspective. While a recent study[1] found actions against nuclear facilities have occurred, mostly during the last 10 years, these have been relatively low level acts.[2,3] Even the more violent acts in Europe, such as bombings in Spain, have occurred at reactors in construction. Thus, it is important not to exaggerate their significance. There is an important difference between low level actions and those designed to produce vast casualties through sabotage or utilization of special nuclear material (SNM). The latter would be an escalation fraught with grave implications. It should be observed that political terrorists generally have not engaged in mass destruction.

A few additional, initial overall points need to be made:

- No attempts to quantify risk were made. Although acts with serious consequences can be identified, the vulnerability techniques and threat characterization analyses do not lend themselves to accurate probabilistic estimates of success or failure needed for a quantified societal risk projection; i.e.,

  Risk = Threat (probability of occurrence) x vulnerability (probability of success) x consequences

  Attempts at quantifying intentional acts in terms that could be used for comparison with other societal risks would be misleading rather than fruitful.

- The discussion of consequences and vulnerabilities is general. Specific vulnerability or consequence evaluations are in many cases classified and thus cannot be discussed in detail in a public document of this type.

- The discussion presents the state of the art in safeguards and security technology and approaches. Its purpose is to provide to a decision-maker a clear picture of the applicable safeguards technology and approaches, illustrating that sufficient reliable safeguards-related information relevant to a DOE decision on the acceptability of the LMFBR for future commercial use is available.

With this brief overview, the remaining discussion describes the type of technology and analytical methods applicable to the LMFBR that have been developed over the last 6 years (since ERDA-1535 was issued).

Forward

A primary mission of the DOE safeguards program is to provide overall support in terms of development and design of components and systems that can be effectively utilized to safeguard DOE fuel cycle facilities and transport. However, to apply the technologies and methodologies which evolve from the safeguards development program requires firm information on the characteristics of future fuel cycle facilities, in particular the reactor plants and the fuel fabrication and reprocessing facilities. Given this kind of information, feasible safeguards systems can be designed, their effectiveness can be evaluated, and a management decision can be made with respect to the acceptability of the systems.

Safeguards development includes consideration of measures which can be taken to minimize or reduce the harmful consequences of postulated successful adversary actions against a fuel cycle. Section III C of ERDA-1535 discusses a number of such measures, and indicates an approach to determining their effectiveness in reducing overall risks.

Existing safeguards capabilities presently provide the basis to develop a system to minimize the effectiveness of adversary actions. However, it is anticipated that the R&D program will continue to generate safeguards systems and components adaptations in support of the developing LMFBR requirements. These changes would improve cost effectiveness and further reduce the possibility of adversary actions associated with such considerations as changing threat patterns and advancing technologies.

Section 7.4.8.1.3 of the PFES described the future safeguards program in terms of a number of general interrelated activities performed by the research and development and regulatory arms of the AEC (now DOE and NRC). Since then, ongoing implementation, development and planning activities have resulted in an improved and more specific description of the DOE safeguards program, which follows. For completeness, general information on NRC safeguards activities is also provided, since safeguards comparability between DOE and NRC is one of our major objectives.

The DOE safeguards program includes the development of capability to make improved threat predictions and system effectiveness evaluations, and the design and demonstration of balanced, flexible safeguards components and systems and operations for application to future fuel cycles.

Before describing the safeguards program for the LMFBR fuel cycle, it should be stated that the DOE safeguards program relates to all nuclear fuel cycles. In general, the policies and techniques developed to protect nuclear material in one facility or shipment are applicable in a generic sense to protection of the same kind of nuclear materials in other facilities or shipments. Physical protection systems, whether for a light water reactor or an LMFBR fuel fabrication facility, employ technology based on the same principles of defense-in-depth, although the particular mix of elements will depend on the specific type of facility and its location. For example, in such facilities as reactors where special nuclear material (SNM)* is contained in large, heavy subassemblies (fuel elements), and either positioned in the operating reactor core or stored under molten sodium, the risk of diversion is less than in other facilities where material is being processed for the fabrication of fuel elements. Accordingly, a baseline of experience and capabilities has already been developed which is applicable to the LMFBR.

Supplemental Information on the Future Safeguards Program

The following sections are related to the subtopics as presented in PFES Section 7.4.8.1.3, pages 7.4-61 through -64.

*Special nuclear material means (1) plutonium, uranium-233, uranium enriched in the isotope-233 or in the isotope-235, or (2) any material artificially enriched.

(a) Improvement of Threat Definition

A safeguards system is designed to successfully counter a set of defined threats. Consequently, threat analysis must be based on an understanding of the properties of nuclear materials which an adversary might seek to exploit, and inferences as to the motivation and characteristics of possible adversaries drawn from adversary activities in other fields.

Studies completed or currently underway involve identifying the motivations, resources, and other attributes of potential adversaries;[4] identifying the range of credible threats;[1] and considering the types of actions a particular adversary might choose against a nuclear target.[5] These and related studies are designed to provide information regarding the range of threats and adversary behavior which might be encountered. Studies provide a basis for understanding the range of threats which present or future safeguards systems should be designed to counter. Experience indicates that the threat is dynamic and will evolve and change with time--requiring systematic review.

(b) Improvement of Safeguards System Design and Evaluation Capability

Safeguards system design is an iterative process which includes: assessment of threats, assessment of the capability of existing safeguards to effectively counter the threats, and improvement of the system to remedy existing or anticipated weaknesses.

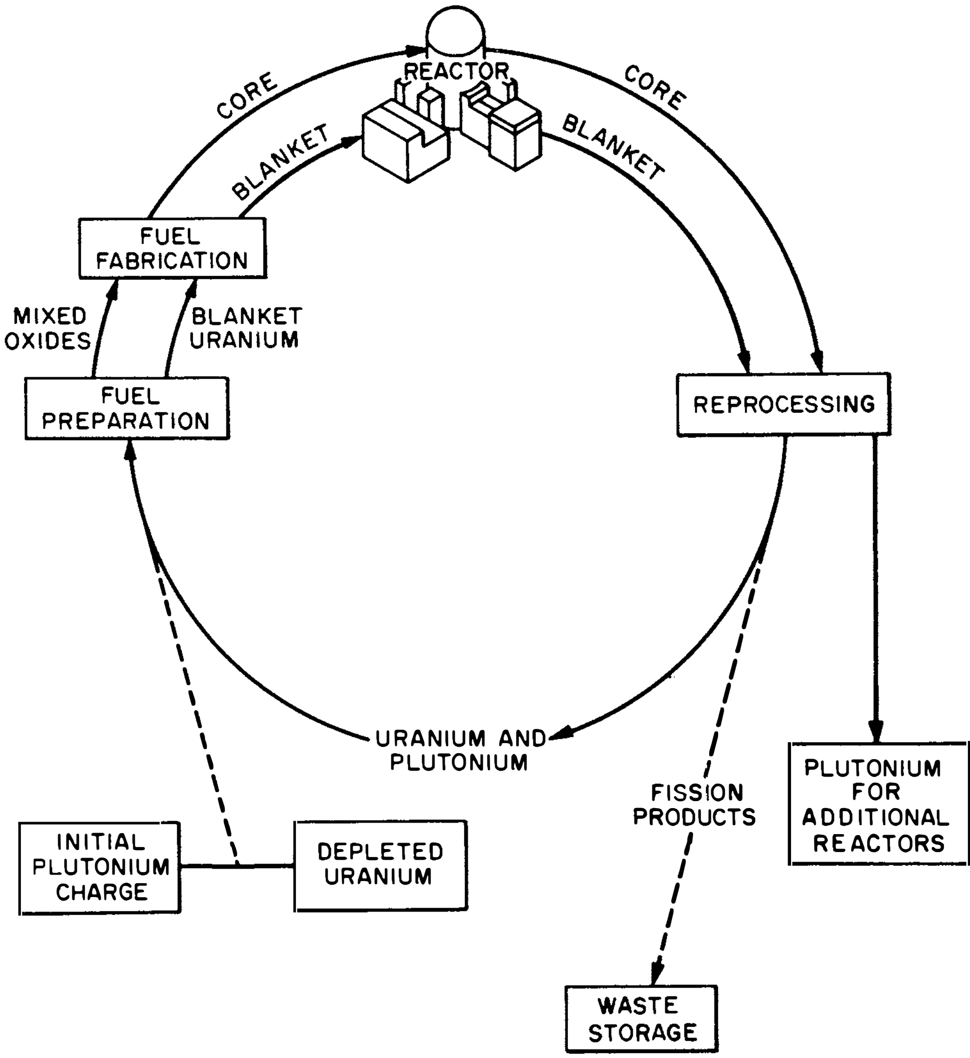
The methodology for estimating the public and occupational health consequences of events of concern is well defined, primarily as the result of extensive DOE and NRC (formerly AEC) experience in nuclear safety design and accident and weapons effects evaluation. Thus, work in this area consists of application of existing analytical techniques to specific instances.[6,7,8,9,10]

With respect to methodology for evaluating the vulnerabilities of safeguards systems, several analytical methods have been developed for this purpose. These include: diversion path analysis, developed under contract with the National Bureau of Standards; "black hat" techniques, developed by Sandia Laboratory to evaluate protection systems for weapons materials; and computer-aided systems to evaluate facility protection plans, developed at the Lawrence Livermore, Sandia (ASM, SVAP, SAFE, SNAP, FESEM, ISFM) and Brookhaven National Laboratories.[11,12] These efforts are directed toward identifying as exhaustively as possible the range of vulnerabilities of a safeguards and security system. Some focus on the insider, others the outsider, and others can be used for a variety of adversary problems.

The analytical methods mentioned above have been applied to determine the strengths and weaknesses of existing safeguards systems at specific DOE facilities. The application of these analytical methods themselves is being continually refined and improved.

(c) Application of R&D to the LMFBR Fuel Cycle

As shown in Figure 3, the LMFBR fuel cycle contains a number of elements: fuel preparation and fabrication; the reactor; reprocessing; plutonium storage; waste storage; and associated transportation. Each component of the cycle creates specific demands for safeguard capabilities. However, certain



LMFBR NUCLEAR FUEL CYCLE

Figure 3

aspects of (a) physical protection (including guard forces); (b) personnel access/monitoring; and (c) materials accountability and control technologies have general application to all fuel cycle elements.

General Safeguards Applicable to LMFBR

Physical Protection (including guard forces)

Over the last 6 years, there has been a concerted effort to improve the performance of physical protection components, such as barriers, interior and exterior intrusion sensors, closed circuit television (CCTV) for surveillance and assessment, personnel identifiers, and automatic protective mechanisms and guard force performance. All of these developments are designed to limit the effectiveness of adversary actions, particularly external assaults.

A number of sensors, such as microwave, ultrasonic, and buried cable motion detectors, have been tested and proven effective at identifying intrusions while producing low false alarm rates. Effective systems of sensors for surveillance and evaluation of an incident (assessment) have also been developed, as opposed to 6 years ago.

Combinations of these technologies have been used at various commercial and government facilities, such as at Pantex at Amarillo, Texas and at the FFTF at Hanford, Washington. Protection against forceful intrusion by vehicles, such as embankments and reinforced fencing, has been improved and tested. Demonstrations of a variety of barriers, sensors, and automatic protective mechanisms have been conducted at Sandia's test laboratory and various DOE sites. Thus, an extensive data base presently exists and is available for design, installation, operation, and maintenance of effective, in-depth, physical protection systems in support of the LMFBR Program.[13,14,15,16,17]

In addition, technology to improve the performance of guard forces during an incident has been implemented and utilized extensively in training within the DOE system. A sophisticated system for simulating actual combat, initially developed by the military and called the Multiple Integrated Laser Engagement System (MILES), is available for use.

Other developments that can improve guard response and performance are the use of technologies to improve central communication and incident evaluation. In particular, a Sandia system to allow a central guard communication station to more effectively evaluate an incident, called Experimental Computerized Alarm Display System (ECADS), is being developed as a design tool. The focus of the system design is to account for the problems of man-machine interaction. This was one of the problems identified as contributing to confusion during the emergency at Three Mile Island (TMI), i.e., the organization and physical design of the control panels. The ECADS system is an attempt to "human engineer" this interface to minimize those types of problems during a threatening safeguards incident.

Transportation of nuclear materials has been considered an area of critical concern, because of perceived vulnerability. When plutonium is transported, a variety of protective techniques can be used. DOE now has substantial experience with its Safe Secure Transportation (SST) system. This includes vehicles with immobilization devices, hardened driver cabs, and penetration resistance features in the trailer where plutonium is stored. In addition, DOE has accumulated several years of experience in utilizing technologies for effective emergency communication, and the use of mobile guard forces. Thus, technology and operational approaches to secure plutonium in transit are available and currently being employed in the field.

Finally, LMFBR spent fuel and high level waste should not present any different problems than light water reactor (LWR) spent fuel and high level waste. Theft is not considered a common threat. Experimental studies[18] of the seriousness of sabotage will be completed by FY 1983. Capabilities to protect spent fuel and high level waste should be less demanding than those already in place for the protection of plutonium in transit.

Personnel Access/Monitoring

Another focus of concern is the control of access into sensitive parts of LMFBR facilities. Reactors, reprocessing plants, plutonium storage facilities, and fuel preparation and fabrication facilities all have sensitive areas which must be protected from sabotage or SNM losses. It is necessary to assure: (1) that only those who have a need to have access can enter these areas, (2) that contraband (such as explosives or weapons) cannot be brought into the area, nor SNM taken out, and (3) finally that those that have access can be monitored to detect and help prevent a hostile or malevolent act from occurring.

With regard to the control of access not only will the present badge or card key identification systems be available but technologies that would include more sensitive indicators of identity such as hand geometry (physical dimension of the hand) have been tested. These technologies would be available for application in the future. To prevent the removal of nuclear material from a facility, or the introduction of contraband, personnel portal monitors have been developed and are now commercially available (in contrast to 6 years ago) which can detect gram quantities of plutonium (unshielded), as well as metallic objects. Sensitive instruments have also been developed to search for nuclear materials in vehicles and other hiding places. Commercial explosives detectors are available and R&D is underway to further increase the detection sensitivity of such devices.

Finally, motion detectors that can monitor movements, particularly unusual ones, within, or into or out of, sensitive areas have been demonstrated. CCTV surveillance and assessment can also be used, in contrast to 6 years ago, and the two man rule (no single individual allowed in a sensitive area) can be implemented to assure increased protection against an "insider" adversary.

To deal with potential "insider" sabotage involving manipulation of equipment or operational controls, tamper-indicating devices and time delays on critical components such as switches can be developed and implemented with existing technology. An alarm signal and override control in a central location could be part of an effective system.

A variety of design tools to minimize such problems have been developed over the last 6 years at Sandia National Laboratory. These techniques or technologies can prevent an individual having access to materials and facilities from engaging in criminal acts, making it exceedingly difficult and thus undesirable to attempt the theft of plutonium or engage in acts of sabotage. Thus, the likelihood of a successful malevolent act is small, although not zero.

Materials Accountability and Control

Another important component of the overall safeguard system for the LMFBR will be accounting for plutonium moving throughout the system. The critical points of potential accessibility are in fuel fabrication, plutonium storage, and spent fuel reprocessing.

With regard to fuel fabrication, a variety of automated destructive and nondestructive instruments for assay of uranium and plutonium have been installed and successfully tested. Data from the instruments can be fed into a computer-based accountability system. Several commercial and DOE facilities have similar systems in operation. The Los Alamos plutonium processing facility (TA-55) contains an automatic computerized measurement system designed to detect immediately small diversions from the process lines.[19,20,21,22] Other systems are designed or in operation. By use of these automated devices, direct personnel access can be reduced or eliminated.

Systems are being developed for operation of plutonium storage vaults with increased security and to facilitate the performance of inventories which will rapidly detect material discrepancies. These have been demonstrated at the Rockwell International Plutonium Storage Facility in Hanford, Washington, and at Sandia and LANL (Los Alamos National Laboratory).

For reprocessing plants, material accounting procedures for separated plutonium are well developed. On-line non-destructive analysis (NDA) techniques are being developed to give near real time analyses that are comparable in precision and accuracy to more time consuming wet chemistry methods. Similar techniques will be used for the storage and accounting of PuO_2 in process lines.

The generic type studies, applications and demonstrations mentioned above, together with other safeguards measures in place and under evaluation at DOE facilities, will provide an increasingly extensive inventory of technology which can be drawn upon to design safeguards systems for application to a future commercial LMFBR industry. Additional details are given in Table 5 (a revised version of Table III C-1 in ERDA-1535).

Demonstration of reprocessing plant advanced safeguards systems will initially be implemented in a breeder head end reprocessing facility, coupled with an LWR safeguards demonstration. In a joint effort, Allied General Nuclear Services (AGNS) and the Oak Ridge National Laboratory have been cold testing safeguards instrumentation and procedures at the Barnwell Nuclear Fuel Plant (BNFP).

Specific Aspects of LMFBR Safeguards

The above three main categories of safeguards, i.e., Physical Protection (including guard forces); Personnel Access/Monitoring; and Materials Accountability and Control, are applicable in varying degrees to the following elements of the LMFBR fuel cycle. The general safeguards discussed address most needs of these fuel cycle activities. Some safeguards aspects of specific LMFBR facilities and functions are summarized in the following paragraphs.

Table 5

DOE SAFEGUARDS PROGRAM FOR LMFBR--ACTIVITIES AND MILESTONES

	CY
(a) Threat Definition	
o evaluate criminal adversary capabilities	78**
o evaluate adversary motivations and intentions	80**
o match adversaries to generic nuclear criminal actions	81**
o continuing review	into 80's
(b) System Design and Evaluation Capability	
o design near-real time material accounting system for TA-55[19]	77**
o develop comprehensive system evaluation program[11]	80**
o establish operation of near-real time material accounting system at TA-55[20,21,22,23,24]	81**
o complete integrated system design for TA-55[25,26,27]	81**
o begin application of comprehensive system evaluation to DOE facilities	81**
o continue comprehensive systems evaluation and development of cost-effective approaches for DOE facilities[28]	into 80's
(c) Interruption and Consequences Reduction Capability (Generic System Demonstrations)	
o Prototype computerized Pu accountability system at Los Alamos facility	80**
o Physical protection at Sandia Test Reactor[29]	78**
o Pu storage protection system at Atlantic Richfield facility	79**
o Physical protection system technology	into 80's
o Demonstration of prototype SNM measurement instruments/system	into 80's
(d) LMFBR System Evaluation	
o Synthesis and comprehensive evaluation of future LMFBR safeguards systems[30]	78-84*
o Start long-term demonstrations	
FMEF (SAF)	84(87)
CRBR	83
Breeder Reprocessing Head End	early 1990's

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* Based upon availability of LMFBR facility design information per the following schedule:

o Clinch River Breeder Reactor (CRBR)	complete in 83
o Secure Automated Fabrication (SAF) Line in FMEF	complete in 83
o Hot Experimental Facility (HEF) [conceptual design study]	completed in 81

** Completed milestones

Reactors

The Hanford Engineering Development Laboratory, which includes the Fast Flux Test Facility, initiated a construction line item for safeguards improvements in FY 1979 which is to be completed in FY 1982. The improvements include construction of new fences, electronically-monitored fence alarms, lighting, additional guard stations, personnel monitoring, closed-circuit television monitoring, door alarms, and an emergency control center.

At the Test Reactor Area (TRA) at the Idaho National Engineering Laboratory, construction of a nuclear material inspection and storage facility was completed in 1981 in order to provide upgraded safeguards capability for nuclear material storage, accountability assay, measurements, and quality assurance functions. In addition, guard facilities protecting the TRA were hardened.

At Argonne National Laboratory (ANL)-East and ANL-West, an overall upgrade project was completed in 1981 that included addition of nondestructive assay equipment, installation of area intrusion detection systems, fencing, alarms, lighting, access control systems, and construction of a security building.

The safeguards aspects of the Clinch River Breeder Reactor Plant (CRBR) are in accord with applicable regulations for nuclear power plants; i.e., 10 CFR 73, Parts 1 and 55.

As directed by the regulations, the CRBR plant area is apportioned into the requisite owner controlled, protected, and vital areas defined as follows:

1. An owner-controlled area which is the area contiguous to the protected area with limited control for security purposes. The perimeter of this area shall be marked by signs or other means to ensure that persons entering the area are aware that they are on private property. Existing roads will facilitate locating and removing persons from this area.

2. A protected area which is an area within the controlled area. This area shall be enclosed by a security barrier through which access shall be strictly controlled. An isolation zone shall be maintained on both sides of the barrier with sufficient illumination for monitoring and observation at night. Employee and visitor parking areas shall be located outside the outer isolation zone.

3. Vital areas (as defined by ANSI N18.17) which shall be located within the protected areas, and shall be protected by building walls, roofs and floors, which constitute a second physical barrier. Vital equipment and facilities shall be isolated from non-vital equipment and facilities to the maximum extent practical. The second physical barrier enclosing vital equipment shall be capable of deterring intrusion by unauthorized persons and shall provide reasonable resistance to penetration.

Security measures incorporated include, as a minimum, a perimeter physical security barrier enclosing the protected area and all vital areas, intrusion-detection systems, closed-circuit television systems, lighting systems adequate for effective surveillance, patrol roads, buildings designed to resist forced entry and fire bombing, and a card-key system for access control to certain sensitive and vital areas of the plant. Guard forces trained to meet the requirements of 10 CFR 73, Appendix B, are integrated into the system. It is anticipated that the safeguards features of the Large Development Plant (LDP) will be generally similar to those of the CRBR.

Reproducing Plants (with regards to Safeguards)

An LMFBR fuel reprocessing plant will reprocess and recycle fuel for several reactors and will handle relatively large amounts of plutonium. Safeguards measures which will be needed for LMFBR fuel reprocessing will include physical protection systems, which are similar to those in use and planned for other nuclear facilities, and material control and accounting measures which rely largely on technology well-demonstrated in past reprocessing operations. These will be supplemented by the latest measurement and control technology and advanced safeguards concepts, which are now under development.

One place where these systems have been developed is the Barnwell Nuclear Fuel Plant (BNFP). A plant reprocessing Fast Breeder Reactor (FBR) fuel will differ only in some details from those required at an LWR fuel reprocessing plant. BNFP provides a base of experience in material control, accounting, and physical protection systems developed during the past 6 years including near-real-time accounting, voice ID check, all-around television surveillance, remote monitoring of all access to separated Pu-nitrate product and elaborate physical protection capability.[31,32,33,34]

The variety of physical and chemical forms of fuel, and the various process vessels and flow paths in a reprocessing plant require the use of several unique safeguards measures. However, the economic incentives for high operating efficiency in LMFBR reprocessing plants will cause extensive use of process instrumentation, and that same instrumentation will provide valuable information for safeguards measurements and control.

Therefore, standard process monitoring and control data will be available to provide expanded safeguards protection of nuclear fuel cycle facilities. The methodology identifies process events by recognizing significant patterns of changes in on-line measurements. The goal is to provide information on process status useful to other facility safeguards operations. Use of such information to supplement safeguards has been demonstrated at the BNFP, and the feasibility of the concept was established. The process monitoring concept is being expanded and further demonstrations are planned.

Penetration monitoring is a material control strategy that involves monitoring penetrations of containment boundaries to detect anomalous movements of material through the boundaries. The concept has been extensively developed and documented, and one detailed study was done for a conceptual plant design.[35]

Each of the safeguards measures which can be used in reprocessing plants involves large amounts of data and requires complex decision analyses. Consequently, future safeguards systems for reprocessing plants will rely on extensive use of computers. Considerable effort is planned to achieve the reliability and security needed for safeguards applications. Also, many of the instruments which may be needed for some of the safeguards measures are not fully developed, and additional effort is planned.

Fuel Preparation and Fabrication Facilities

The area requiring special attention in fuel fabrication is the integration of availabile safeguards accounting technology with measurement information generated by the requirements of remote fabrication. Successful meshing of these elements should provide real time accountability of special nuclear material.

The Fuels and Materials Examination Facility (FMEF) will be a fuels facility with supporting laboratories to develop and demonstrate LMFBR fuel fabrication processes, equipment, and related technology. The Secure Automated Fabrication Facility (SAF) will be installed in the FMEF at Hanford, Washington. The SAF line incorporates the capability to control processes in this manner and to demonstrate near real time accountability. SAF will provide the technical base for development of the necessary long-term commercial manufacturing capability for LMFBR fuels. Safeguards demonstration will be preceded by analysis of vulnerability to overt and covert access to SNM, as well as sabotage; design of countermeasures to suitably strengthen desired areas; and design of the physical security system. Safeguards design will also involve application of advanced techniques for materials control and accountability and protection of plutonium inventory. Process operations and vaults will be designed to resist diversion and will incorporate alarms, warning systems, and tamper-safing features, as well as make extensive use of on-line nondestructive assay methods, on-line inventory, and highly automated and protected process operations minimizing access to SNM. A systematic design of the total system, interfacing with the requirements of a highly automated, high through-put process line operation, will achieve maximum protection. Development of design principles and criteria for this system is underway. Installation of SAF is scheduled to start in 1984 and the line is scheduled to begin operation in 1987, at which time the safeguards system will be operating as an integral part of the facility and will be subject to further evaluation.

Nuclear Waste Management

The safeguards applied to reactors and special nuclear materials are sufficient for radioactive waste considerations. Storage of spent fuel at reactor sites is within the physical protection systems for each reactor. High level radioactive waste is stored in underground tanks and bins within the physical boundaries and protection systems at DOE sites. Similarly, transuranic (TRU) wastes are packaged in DOT approved shipping containers and transported from points of origin to retrievable storage facilities, where they are handled and processed within existing physical security systems. The TRU operation now exists only within the DOE system. Once commercially generated TRU waste exists, the technology employed by DOE will be available to the commercial sector. No special safeguards measures need to be developed or employed for low level radioactive waste.

Physical transportation of spent nuclear fuel is accomplished using DOT and NRC approved shipping casks. These specially designed casks provide radiation and thermal protection and are designed and tested to survive transportation accidents. Shipment of spent nuclear fuel is performed in accordance with existing DOT and NRC regulations. Movement of solidified high level waste will be accomplished in similar fashion using approved shipping containers specially designed for the solidified high level waste. Existing transportation systems satisfy current requirements and will be adapted to satisfy future requirements for the safe and secure transport of spent nuclear fuel and high level radioactive waste.

(d) Coordination with NRC and Other Organizations

The Energy Reorganization Act transferred the licensing and inspection operations for privately-owned nuclear facilities from the regulatory arm of AEC to the Nuclear Regulatory Commission. Responsibility for promulgation of safeguards requirements and inspection of Government-owned nuclear facilities was transferred from the AEC to DOE (except for new demonstration power reactors and nuclear waste disposal sites, which are subject to NRC licensing and inspection).

DOE is charged to develop and to demonstrate the effectiveness of safeguards for new fuel cycles. NRC is conducting confirmatory research to determine whether the safeguards plans submitted to NRC by DOE for facilities subject to NRC licensing, and plans submitted by private facilities, satisfy NRC criteria.

Since the CRBRP is subject to NRC license requirements and inspection, ongoing activities and design have been, and will continue to be, closely coordinated with NRC. To facilitate this endeavor, the NRC has established a Program Office specifically for the CRBRP Project. Progress to date includes the preparation of an essentially completed conceptual design for the CRBRP safeguards system which is in full compliance with NRC requirements as set forth in the Code of Federal Regulations (e.g., 10 CFR 73, 10 CFR 70) and applicable Regulatory Guides. The safeguards for this facility are expected to further demonstrate the high standards of protection capabilities applicable and available to future facilities to assure that LMFBR commercial power plant safeguards will be highly effective.

While the regulatory responsibilities of NRC and the developmental responsibilities of DOE must be clearly separated, the activities of the two agencies toward improved safeguards are being coordinated. To the extent that safeguards measures applied to DOE facilities also apply to licensee facilities (which is usually the case), DOE has the responsibility not only to optimize such systems but also to make safeguards system design and operating experience available to the nuclear industry and to NRC.

DOE continues to cooperate with NRC and other Government agencies in those aspects of nuclear safeguards which transcend individual agency responsibilities. DOE will assist in the development of plans and procedures for deterrence, interdiction and response and recovery where nuclear materials are involved. DOE technical capabilities will be developed and maintained as required to support interagency emergency preparedness plans covering nuclear sabotage, dispersal, or explosion and to support any search and recovery procedures conducted by or with other agencies. DOE considers that it has a responsibility to insure the development and maintenance of all interagency programs that relate to safeguarding of nuclear materials.

DOE is the lead U.S. Government Agency for providing U.S. support to the International Atomic Energy Agency in developing and implementing an effective safeguards system for nuclear materials and equipment as required by the Nuclear Non-Proliferation Act of 1978, among others. The objective of the international safeguard system is the timely detection of any diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons or for other purposes. Early detection is a significant deterrent to diversion by an individual nation. DOE supports R&D to develop instrumentation, equipment and procedures for safeguarding all phases of the nuclear fuel cycle which include uranium enrichment, nuclear reactors and chemical reprocessing of spent nuclear fuel. Specifically, the products of the R&D include approaches and instrumentation that will assure the control and accountability of significant quantities of uranium and plutonium.[36] Included are non-destructive assay instruments and techniques for near real-time accountability as well as equipment for containment and surveillance of nuclear material and facilities. The hardware developed includes advanced radiation detectors, closed circuit television, security seals which indicate tampering, personnel identification devices, and nuclear material monitors. The Department of Energy through its Office of Safeguards and Security works closely with international organizations (IAEA, EURATOM) and other governments (Canada, UK, Japan, Germany, etc.). DOE exchanges technical safeguards information with the IAEA and provides technical experts in the areas of materials control and accounting and containment and surveillance. The objective and results of this work are the establishment of an effective safeguards system for the prevention or detection of the unauthorized diversion of nuclear materials.

(e) Nonproliferation

The subject of international safeguards has been studied intensively in recent years as part of an overall examination of the issue of nuclear nonproliferation. The fundamental premise of this issue is that the real and perceived risks of nuclear proliferation constitute a serious threat to international peace and stability. The concern with regard to civilian nuclear power systems is that as the reactors, fuel cycle facilities, and supporting civilian research and development activities become more widespread, their abuse may provide an alternate route for nuclear weapons capability.

The U.S. LMFBR program was influenced significantly by the nonproliferation policies of the previous administration. Exhaustive studies of possible means of reducing the risk of nuclear proliferation without jeopardizing the development of nuclear energy for peaceful purposes were conducted. The Nonproliferation Alternative Systems Assessment Program (NASAP)[37] and the International Nuclear Fuel Cycle Evaluation (INFCE)[38] were both directed at providing the basis for ensuring that nuclear power programs and systems, as they evolved here and abroad, did not present an attractive route or make significant contributions to a nuclear weapons capability. Moreover, these studies considered many alternative fuel types and techniques to make reactor fuel a less desirable material for input to a weapons-acquisition effort. But, as concluded by Smith and Rathjens[39], the hope of finding a "technical fix" to the proliferation problem proved illusory:

> "But to the surprise of few in the technical community, neither NASAP nor INFCE came up with realistic fuel-cycle alternatives that would permit reprocessing and reuse in reactors while making access to weapons materials difficult for nations (as distinct from terrorists)."

The INFCE concluded[40] that: "...technical measures have a powerful influence on reducing the risk of theft, but only a limited influence on reducing the risk of proliferation." INFCE participants formally recognized the importance of international safeguards and institutional measures, and judged these activities more effective in reducing proliferation risks than technical measures.

With regard to technology, the NASAP study concluded that while a combination of light water reactor fuel-utilization improvements and tails assay reduction appeared adequate to support U.S. power needs through at least the first decade of the 21st century, breeder reactors may become desirable and necessary before the first quarter of the next century is over. Of the breeder systems that could be commercially available by then, none was found to be more proliferation-resistant than the liquid metal fast breeder fueled with uranium and plutonium. This system, of which the Clinch River Breeder Reactor Plant is the forerunner, is also of interest because of its technical feasibility, commercial potential, and economic and resource use aspects.

The INFCE study concluded that, with certain improvements, complete fuel cycles with reprocessing, recycle, and breeder reactors can be used without undue risk and are essential to adequate energy supplies for the world. With regard to the fast breeder, INFCE concluded that the diversion risk encountered in the various fuel cycle stages presented no greater difficulties than in the case of the light water reactor with the uranium-plutonium cycle, or even in the case of the once-through cycle, in the long term.

The President's Nuclear Nonproliferation Policy Statement of July 16, 1981, proclaims the critical importance of preventing the further spread of nuclear explosives to other countries. In regard to nuclear reactor matters, it proposes to improve the effectiveness of the pursuit of these objectives by strongly supporting and continuing to work with other nations to strengthen the International Atomic Energy Agency (IAEA) to provide for an improved international safeguards regime. Further, current policy is that unless the U.S. acts as a predictable and reliable partner for peaceful nuclear cooperation, its support to deal with proliferation problems will be reduced. Development of LMFBR technology is consistent with these policies.

References

1. Bass, G. et al, "Motivations, and Possible Actions of Potential Criminal Adversaries of U.S. Nuclear Programs," Rand, February 1980, R-2554-SL.

2. "Nuclear Incidents Abroad," Rand, Santa Monica, California, 1980, WD 809.

3. Nuclear Regulatory Commission, "Safeguards Summary Event List (SSEL)," NUREG-0525, Rev. 4, Sept. 1981.

4. DeLeon, P., Jenkins, B., Kellen, K., and Krofcheck, J.: Attributes of Potential Criminal Adversaries of U.S. Nuclear Programs. Rand, February 1978, R-2225-SL.

5. Bass, G. et al, "Motivations, Capabilities, and Possible Actions of Potential Criminal Adversaries of U.S. Nuclear Programs" (DRAFT), Rand, May 1981, R-2703-SL.

6. Glasstone, S. and Dolan, P.J., "The Effects of Nuclear Weapons." U.S. Department of Defense and U.S. Department of Energy. 1977.

7. "Reactor Safety Study, An Assessment of Accident Risk in U.S. Commercial Nuclear Power Plants," U.S. Nuclear Regulatory Commission, WASH-1400, NUREG75/014, October 1975.

8. "Safeguarding a Domestic Mixed Oxide Industry Against a Hypothetical Subnational Threat." U.S. Nuclear Regulatory Commission, NUREG-0414, May 1978.

9. Cohen, B.L., "Hazards from Plutonium Toxicity," Health Physics, Pergamon Press, 1976.

10. Finley, N.C., et al, "Transportation of Radionuclides in Urban Environs: Draft Environmental Assessment." Sandia National Laboratories for the U.S. Nuclear Regulatory Commission. NUREG/CR-0743, SAND79-0369, July 1980.

11. "A Review of Safeguards and Security Systems Effectiveness Evaluation Methodologies" (Draft), E. J. Dowdy (Los Alamos) and D. L. Mangan (Sandia), January 1980.

12. "Current Methods for Evaluation of Physical Security System Effectiveness," R. B. Davidson and J. W. Rosengren (R&D Associates), RDA-TR-179200-001/DNA-TR-81-18 (May 1981).

13. <u>Intrusion Detection Systems Handbook</u>, Sandia National Laboratories, SAND76-0554, November 1976, (Revised October 1977).

14. <u>Entry Control Systems Handbook</u>, Sandia National Laboratories, SAND77-1033, September 1978, (Revised September 1980).

15. <u>Barrier Technology Handbook</u>, Sandia National Laboratories, SAND77-0777, April 1978.

References (Continued)

16. Safeguards Control and Communications Systems Handbook, Sandia National Laboratories, SAND78-1785, May 1979.

17. John L. Darby and Frederick L. Crane, Access Control Technology for Nuclear Power Plants, Sandia National Laboratories, SAND80-1046, January 1981.

18. Sandoval, A.R., Weber, J.P., and Newton, G.J., "Safety Assessment of Spent Fuel Transportation in Extreme Environments," Vol. I, Waste Management, pp. 427-441; ANS Topical Meeting, Proceedings of the Symposium on Waste Management at Tucson, Arizona, Feb. 23-26, 1981.

19. "DYMAC Demonstration Program: Phase I Experience," R.H. Auguston (Los Alamos), LA-7126-MS (February 1978).

20. "Implementation of the DYMAC System at the New Los Alamos Plutonium Processing Facility--Phase II," compiled by J. J. Malanify and D. C. Amsden (Los Alamos), to be published.

21. "An Evaluation of the DYMAC Demonstration Program, (Phase III Report)," compiled by J. J. Malanify and R. C. Bearse (Los Alamos), LA-8953-MS (September 1981).

22. "An Operational Advanced Materials Control and Accountability System," J. J. Malanify, et al. (Los Alamos), INMM Journal IX (4), pp. 30-44 (1980).

23. "Systems Concepts for DOE Facilities: PF/LASS Data Analysis" (Draft), R. C. Bearse, et al. (Los Alamos), unnumbered report (September 1981).

24. "Systems Concepts for DOE Facilities: Research and Development Needs" (Draft), R. C. Bearse, et al. (Los Alamos), unnumbered report (October 1981).

25. "Los Alamos Plutonium Facility Applied Systems Integration Project Status Report for Period Ending August 31, 1981" (Draft), D. G. Shirk, et al. (Los Alamos), unnumbered report (September 1981).

26. "Baseline Safeguards Analysis of the LASL TA-55 Plutonium Facility," S. D. Chester (Sandia) and C.E. Nordeen (Los Alamos), SAND 79-1831

27. "Concepts on the Integration of Physical Security and Material Accountability Functions in a Safeguards System," D. A. Reynolds (Sandia), INMM Proceedings (July 13-15, 1981) San Francisco, CA.

28. "Integrated Safeguards Systems: Design, Evaluation, and Application--Interim Report" (Draft), J. T. Markin, et al. (Los Alamos and Sandia), unnumbered report (September 1981).

29. SAND 78-1148, "Sandia Pulsed Reactor Safeguards Alarms and Assessment Systems," October 1978 (CNSI) Phase I; August 1979 (CNSI) Phase II.

References (Continued)

30. "Conceptual Design for Safeguarding the LDP Liquid Metal Fast Breeder Reactor," SAND 81-0142, S. H. Scott, et al. (Sandia and Los Alamos), prepared for the USDOE LMFBR Conceptual Design Study (September 1981).

31. Joseph, C., "Inspection--A Cost Effective Approach," INMM, Vol. X, Proceedings Issue, 1981, p. 52.

32. Ehinger, M. H. et al, "In Process Inventory Estimation in a Reprocessing Facility for Near Real Time Accounting," INMM, Vol. X, Proceedings Issue, 1981, p. 108.

33. Ellis, J. H., "Development and Testing of a Near Real Time Accounting System at the Barnwell Reprocessing Facility," INMM, Vol. X, Proceedings Issue, 1981, p. 402.

34. King, R. W. et al, "Advanced Access Control System," INMM, Vol. IX, Proceedings Issue, 1980, p. 362.

35. "Report of Subgroup on Containment/Surveillance to the International Working Group for Reprocessing Plant Safeguards," Appendix 2, T. A. Sellers, Sandia National Laboratory, August 7, 1981.

36. Christopher P. Cameron and Mark E. Bleck, International Safeguards for a Light-Water Reactor Fuels Reprocessing Plant: Containment and Surveillance Concepts, Sandia National Laboratories, SAND80-0160, December 1980.

37. DOE/NE-0001, "Nuclear Proliferation and Civilian Nuclear Power, Report of the Nonproliferation Alternative Systems Assessment Program," 9 Volumes, U.S. Department of Energy, June 1980.

38. "International Nuclear Fuel Cycle Evaluation," 9 Volumes, International Atomic Energy Agency, Vienna, 1980.

39. G. Smith and G. Rathjens, "Reassessing Nuclear Nonproliferation Policy," Foreign Affairs, p. 885 (Spring 1981).

40. INFCE Summary volume, op. cit., p. 38.

(3) Waste Management

The major waste management issue has been selection of a generally accepted method for removing and segregating high-level and transuranic radioactive wastes from man's environment for the long time periods required for these wastes to decay to safe levels. Because of this, it has been suggested by some that nuclear reactors be shut down, and the LMFBR Program be delayed, until a definitive method for permanent disposal of high-level radioactive wastes has been demonstrated. The problem of waste disposal is not unique to the LMFBR fuel cycle, but also must be resolved for the LWR or other nuclear fuel cycles and for the wastes resulting from defense programs. Furthermore, the quantities of LMFBR high-level and transuranic wastes will be considerably smaller than the quantities of such wastes from the LWR fuel cycle or from defense programs until well into the twenty-first century. For purposes of the waste management program, LMFBR and LWR wastes are essentially the same.

The major waste management issue of how to dispose of high-level and transuranic wastes has been addressed. There is general agreement among the technical community, government agencies, elected leaders, and the public that mined
geologic disposal is the preferred disposal method at this time.[5] DOE care- 21
fully considered the environmental impacts and concluded that mined geologic disposal was preferred at this time above all other methods. DOE documented this decision in its Record of Decision in the Federal Register on May 14, 1981.[1]

Waste Management Program

The key element of the waste management program which has a bearing upon the LMFBR fuel cycle is the availability of a geologic disposal facility for high-level and transuranic wastes. Programs are underway to develop such facilities in the 1990s. Included in this program effort is the Test and

Evaluation facility that allows for emplacement of several hundred canisters of high-level waste in geologic media at proposed depths. The T&E facility will be used to develop waste emplacement technology, methods for handling large quantities of waste packages, and to demonstrate on a practical basis that high-level radioactive waste can be handled and stored safely. The T&E facility is scheduled to be operational by 1989. Selection of the site for the first licensed repository is scheduled for 1988 and full-scale operation by as early as 1998, to meet the requirements associated with the LWR fuel cycle. This is well in advance of waste disposal needs of the LMFBR Program. Based upon the schedule for the repository program (see following Figure 4), there does not appear to be any constraint on the LMFBR Program imposed by disposal requirements for high-level or transuranic radioactive wastes. Repositories will be designed to accept solidified high-level waste (HLW) and transuranic (TRU) waste from commercial power reactors and from the Department of Energy (DOE) programs, and would also be capable of accepting unreprocessed spent fuel, if disposal of such materials were deemed appropriate.

Geologic disposal has been selected for the isolation of HLW and TRU waste from the commercial fuel cycle. The reference option for HLW and TRU waste from DOE programs is immobilization and disposal in a geologic repository. This approach for disposal of commercial waste has been suggested and reconfirmed by several groups, as described below.[1]

In 1955, the Atomic Energy Commission (AEC) asked the National Research Council, an advisory committee of the National Academy of Sciences (NAS), to assess the use of geological formations in the United States for HLW disposal. The Academy published a report of their findings in 1957[2] and concluded that "wastes may be disposed of safely at many sites in the U.S., but conversely

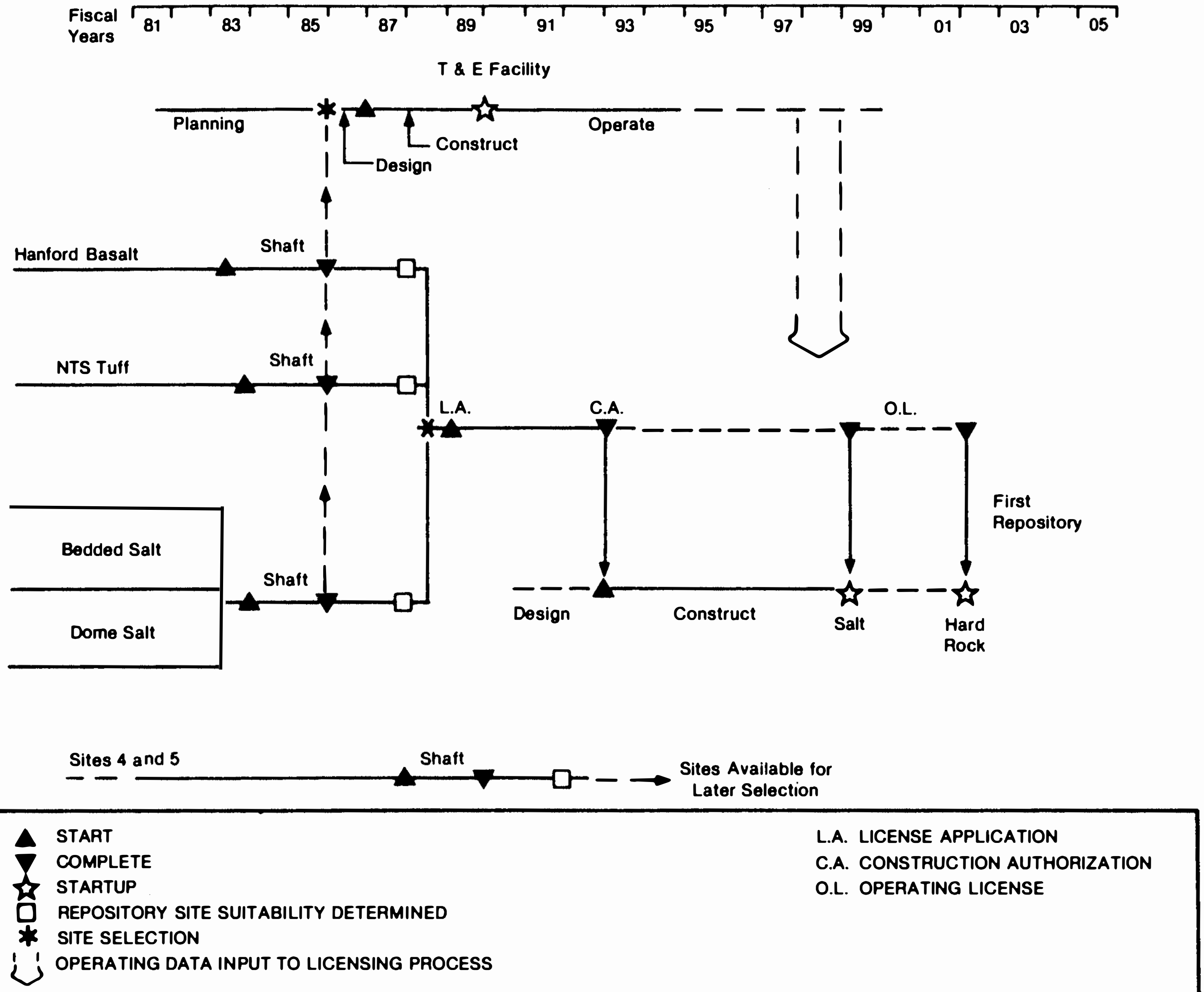


Figure 4
Reference Schedule of Activities
Leading to Geologic Repository Operation

there are many large areas in which it is unlikely that disposal sites can be found."[2] The report went on to state: "the research to ascertain the possibility of disposal has for the most part not yet been done. Disposal in cavities in mined salt beds and domes is suggested as possibly promising the most practical immediate solution of the problem."[2] The Academy also recommended that liquid waste be transformed into a solid stable form prior to emplacement in a geologic repository. Subsequent reviews by NAS in the 1960's and 1970's duplicated these initial recommendations.

In 1965, the AEC conducted a series of experiments involving emplacement of spent nuclear fuel elements in an abandoned salt mine near Lyons, Kansas to determine the feasibility of waste emplacement in salt. The experiment was ended and the spent fuel was removed in 1967. Following the analysis of the Project Salt Vault data and a number of other design studies, the Atomic Energy Commission in June 1970 announced its intention of establishing a Federal demonstration waste repository adjacent to and encompassing the inactive Lyons mine provided that subsequent geological investigations confirmed the suitability of that site. Those investigations over the next two years encountered technical difficulties associated with past and (then) present mining methods as well as strong political opposition. For those reasons, investigations of the Lyons, Kansas, site as a possible repository ceased in 1972. After the investigations at Lyons, a number of broad geological surveys of several underground salt formations in the country were undertaken as the first steps in evaluation of their suitability for waste disposal. In the mid-1970's, the Energy Research and Development Administration (ERDA) undertook an extensive review of its nuclear waste management program. As a result of this review, ERDA developed and undertook a program to locate sites and develop the related technology.

In 1978, an American Physical Society study group published a report[3] which focused in considerable detail on disposal in a geologic repository. The consensus of the study group was that "we recommend emplacement of high-level and transuranic wastes in a geologic repository. If reprocessing were to be deferred for the long term, we recommend that provision be made for the storage of spent fuel in a geologic repository. We expect that many waste repository sites with satisfactory hydrogeology can be found in the continental U.S. in a variety of geological formations, including bedded salt."[3]

A DOE Task Force was formed in late 1977 to analyze the overall Federal waste management program and to consider the methods for final disposition of radioactive waste. Its draft report, published in February 1978, highlighted the need for a comprehensive Federal approach to waste management. The Interagency Review Group (IRG) was established in response to this recommendation and released its report in March 1979[4], as a basis for formulating policy for radioactive waste management. A key recommendation of this report was that planning activities in the near term should be based on the assumption that the first disposal facilities for HLW will be in mined geologic repositories. Along with this recommendation, however, the IRG recognized "that a much more broadly based program which addresses fundamental scientific questions with a systems concept is needed."[4] Based on its findings, the IRG also made specific recommendations that nuclear waste disposal should proceed on a step-wise basis in a technically conservative manner, and that a systems approach should be used to select the geologic environment, repository site, and waste package combination.

As a part of assessing the overall program strategy, a Draft Environmental Impact Statement (EIS) on Management of Commercially Generated Radioactive Waste was published for review and comment in April 1979. Following review and revision to reflect comments received, it was issued as a Final EIS in October 1980.[5] This EIS evaluates waste disposal alternatives and concludes that there appear to be no environmental issues that would reasonably preclude a program strategy favoring disposal in mined geologic repositories. Based on this EIS, a Record of Decision was issued by the Department of Energy in May 1981[1] adopting the mined geologic repository strategy for disposal of commercially-generated high-level and transuranic radioactive wastes.

In 1977, the U.S. Geological Survey (USGS) published a critique of the status of the technology for radioactive waste disposal[6] and identified many areas in which it was felt more emphasis should be placed. Following publication of this review, a joint technical working group from DOE and the U.S. Geological Survey (USGS) was formed to define the major technical issues related to permanent isolation in mined geologic repositories. This working group reviewed the USGS report and also a report issued by the EPA.[7] The resulting report[8] reviewed ongoing earth science research and plans and reached the following major conclusions:

- A review of all earth science research found no major areas in which research was lacking.
- The current technical plans should result in a resolution of major technical issues concerning repository development.
- Available technology is adequate to proceed with identification and characterization of potential sites.

The Nuclear Regulatory Commission (NRC) is conducting a rulemaking proceeding for the purpose of assessing "generically the degree of assurance now available that radioactive waste can be safely disposed of, to determine when such disposal or off-site storage will be available, and to determine whether radioactive wastes can be safely stored on-site past the expiration of existing facility licenses until off-site disposal or storage is available." This rulemaking was initiated in response to the decision of the United States Court of Appeals in State of Minnesota v. NRC, 602F. 2d 412 (1979), but it also is a continuation of previous proceedings conducted by NRC in this area (42 FR 3491, July 5, 1977). A Notice of Proposed Rulemaking was published in the Federal Register on October 25, 1979.[9,13]

The national strategy for permanently isolating high-level radioactive waste contains the following major elements:

- The repository system will undergo a rigorous regulatory review since it is required to be licensed.
- A technically conservative approach to development and evaluation of the repository will be followed to compensate for perceived repository system performance uncertainties. This approach includes the following:
  - A "step-wise" approach to repository development will be implemented, which means proceeding cautiously through each phase of development and operation by taking advantage of information, data, and experience gained in previous phases.
  - The concept of a multi-barrier system (developed since ERDA-1535) for isolation of the waste will be used. This system, composed of several man-made and natural-barrier components, provides "defense in depth" against the release of radionuclides to the environment.
  - Conservative design and operating margins will be utilized to compensate for residual uncertainties in the repository system.
  - The capability to retrieve all emplaced wastes for a limited period of time will be designed into the repository system.
- Throughout all phases of the program, approaches will be subjected to a continual review. This will be accomplished through regularly scheduled technical and non-technical reviews.
- The repository will be capable of handling and disposing of either immobilized HLW or unreprocessed spent fuel, and TRU wastes, thus providing a firm basis for licensing regardless of any future decision on reprocessing.

- Repositories will be regionally sited to provide for equitable distribution of the impacts of disposal including minimization of transportation risks.
- Multiple geologic environments will be considered prior to selecting a site for any repository.
- The program is committed to providing an effective role for States, local governments, and Indian Tribes in the decisionmaking process. States and Indian Tribes will have a timely and continuing role in the Federal decisionmaking process on the siting, design, and construction of repositories.

Additional details concerning the waste management program are given in Appendix B.

Status of Technology for Isolating Nuclear Wastes

A report on the status of technology relevant to long-term isolation of high-level and transuranic wastes in a mined geologic repository has been issued.[10] This report identifies and evaluates additional information and identifies topics where work is underway or needed to reduce uncertainties. The major findings and conclusions follow.

1.1 Importance of the Systems Approach

The fate of radionuclides over thousands of years in a geologic repository will be determined by the cumulative effect of geohydrologic, geochemical, and tectonic characteristics of the repository environment and by human activities in the future, as well as by the physical and chemical properties of the rock chosen for waste emplacement, the waste form, and other engineered aspects of the repository. Because no single property, characteristic, or human action alone will determine the fate of the radionuclides, the waste package, the repository, and the geologic environment of the repository are analyzed as a system.[11]

Adoption of a systems approach implies that:

(a) To the extent that they are independent, natural barriers to radionuclide migration can provide significant assurance of waste isolation and to some degree can compensate for imperfect predictive ability of engineered barriers.

(b) The waste form and other engineered components of the repository system can also provide significant barriers to radionuclide migration, but only to the extent that they are tailored to be compatible with the repository environment.

(c) Geologic environments and formations heretofore not considered could prove to be suitable for repository sites.

Scientific and technological knowledge is adequate to identify potential repository sites for further investigation.[4] No scientific or technical reason is known that would prevent selecting and characterizing sites that would be suitable for a repository, provided that the systems approach is used to evaluate the suitability of the sites and the repository designs. A suitable site is one at which a repository would meet predetermined criteria and which would provide a high degree of assurance that radioactive wastes can be isolated from the biosphere for periods of thousands of years. General guidance on program objectives, functional requirements, performance criteria, and specifications intended to ensure that the program is consistent with national policy and that it results in the safe and environmentally acceptable disposal of radioactive waste has been established.[12] These, plus site specific criteria, are intended to follow the approach of the proposed NRC regulatory criteria for a licensed repository (10 CFR Part 60).

Successful isolation of radioactive wastes appears feasible for periods of thousands of years. A thousand years is sufficient to permit decay of most of the fission products that represent the largest fraction of the radioactivity of the waste. Beyond a thousand years, and during the time in which actinides and a few long-lived fission products remain, the ability to predict repository behavior, and therefore, the assurance of successfully meeting isolation criteria diminishes.

Some uncertainties can be bounded or compensated for and, therefore, need not be resolved in detail before selecting a site or constructing a repository; other uncertainties can be resolved during repository construction. The status of technology for site selection and characterization is adequate to meet the requirements for selecting a site to dispose of radioactive wastes in a mined geologic repository.[13] Current mathematical models[14] adequately represent the more important processes involved in radionuclide transport; they aid technology development by identifying factors most important to waste isolation, and can be used in site selection and in preliminary performance assessments of site-specific repository designs. Verification of modeling of flow in fractured rock and of waste/waste package/host rock interactions remains to be achieved. Transportation and emplacement of spent fuel have been demonstrated. Although evaluation of potential metal barrier materials is not complete, available data indicate that several alloys are capable of maintaining their integrity for long periods under anticipated repository conditions. The current research and development program is expected to provide the remaining technical data needed for the design, licensing, and operation of a waste repository as required.[10]

Isolation Barriers. Extensive design, testing, and development studies[15] on individual components of the waste package system under expected repository conditions have been in progress for several years. These studies, conducted in universities as well as in industrial and national laboratories, indicate that some of the available components of the waste package system can prevent or minimize release of radionuclides to the natural system by functioning as effective chemical and physical barriers.

Experiments that simulate repository conditions and integrate the behavior of waste package components and the geological environment are in progress.[16] Laboratory efforts are being directed toward more complex tests, including testing to meet long-term requirements.

Various aspects of required testing have been described by the Department of Energy (DOE) and the U.S. Geological Survey (USGS) in the "Earth Science Technical Plan" which discusses the types of data required and the needed sequence of laboratory, large scale engineering, field, and in situ tests.[8]

A Waste Package Design, Development, and Test Plan has been formulated to direct the development of improvements in the waste package. An integral part of this plan is the development of coordination among, and standards to be followed by, researchers and waste management organizations with respect to testing procedures and materials certification. Newly created organizations have been charged with supporting waste package design, development, and testing programs to produce suitable packages that meet established requirements.

Performance Assessment. Current work in refining and coupling individual models is in progress to develop a more complete and more versatile system of models to describe complex phenomena. These advanced models[8] will be available in late 1981, and their coupling will be completed in 1982 (with the exception of thermomechanical and hydrologic models which will be coupled by 1985). Insights gained from sensitivity and uncertainty analyses will be used to plan further development; verification by laboratory and in situ tests will continue throughout the process. In the meantime, analysis of the response of the hydrologic system to thermomechanical effects will be conducted using uncoupled models with more conservative parameters to compensate for the added uncertainty that is involved.

The use of these continually improving models, along with the improving body of experimental data, will permit more complete performance assessments to be made. These assessments will contribute to site selection and verification of repository design, and confidence in the safety of the repository system.

Models have also predicted the consequences of releases of radionuclides from repositories in the distant future.[17,18,19] The majority of credible release scenarios would not deliver any significant doses to people. The only studies that have predicted large doses to people have been based on what seem to be unrealistic assumptions, such as the occurrence of highly unlikely breaching phenomena or the omission of engineered barriers from the repository system.

Site Selection and Characterization. Site selection and characterization include all the exploration and testing that is required to determine the acceptability of a site for a waste repository. Current technology is available to pursue testing during the excavation of the repository; continuing examinations will develop information in ever increasing detail.

Characterization of a repository site is interdisciplinary in its approach and includes many aspects of earth sciences, engineering, safety analysis, health physics, biology, and the social sciences. These studies include theoretical, laboratory, field, and in situ research, with each step designed to confirm the preceding one, as the emphasis shifts from the general to the specific. A national screening process has been established to examine successively smaller units of land. A detailed plan for national site characterization and site selection has been prepared to describe these activities.[20]

Potential Host Rocks. The DOE program leading to site selection in 1985 for the Test and Evaluation Facility, described earlier, is currently considering salt (both bedded and dome), basalt, and tuff as potential host rocks. Of these rocks, the level of scientific knowledge is highest for salt. Any of these rocks can prove to be acceptable for a mined geologic repository; however, no rock type, on strictly technical grounds, is a first choice at this time.

Investigations of other potential host rocks, such as granite, anhydrite unsaturated rocks, and shale and related rocks are being conducted with a smaller effort. Additional rock types may be identified through screening of geologic environments that will be conducted by the DOE and the USGS. However, for budgetary reasons, granite, anhydrite unsaturated rocks, shale, and other rock types not yet identified, are not expected to be involved in the 1985 selection of a site for the Test and Evaluation facility.

Specific LMFBR Radioactive Wastes

Section 4.6 of WASH-1535 discussed facilities and techniques for handling specific LMFBR wastes (contaminated sodium wastes, plutonium contaminated wastes and noble gases). These facilities and the environmental impacts associated with their operation are unchanged.

Low Level Wastes

Low level wastes from LMFBR program activities will be sent to existing commercial or DOE burial grounds, as appropriate.

REFERENCES

1. Federal Register, Vol. 46, pp. 26677 and 26678, May 14, 1981.

2. National Academy of Sciences/National Research Council. 1957. The Disposal of Radioactive Waste on Land. Division of Earth Sciences, Committee on Waste Disposal. Report, Pub. 519.

3. Study Group on Nuclear Fuel Cycles and Waste Management. January 1978. Report to the American Physical Society by the Study Group on Nuclear Fuel Cycles and Waste Management. Reviews of Modern Physics 50 (1) Part II.

4. TID-29442, Report to the President by the Interagency Review Group on Nuclear Waste Management, Washington, D.C., March 1979.

5. DOE/EIS-0046F, Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste, U.S. Department of Energy, October 1980.

6. U.S.G.S. Circular 779, 1977, "Geologic Disposal of High-Level Radioactive Wastes - Earth Science Perspectives."

7. "The State of Geological Knowledge Regarding Potential Transport of High-Level Waste From Deep Continental Repositories, U.S. Environmental Protection Agency.

8. DOE/TIC-11033, Earth Science Technical Plan for Disposal of Radioactive Waste in a Mined Repository, U.S. Department of Energy and U.S. Department of the Interior, Geological Survey, 1980.

9. U.S. Nuclear Regulatory Commission, "10 CFR Parts 50 and 51, Storage and Disposal of Nuclear Waste: Notice of Proposed Rulemaking," Federal Register 44FR208:61372-61376, October 25, 1979.

10. Office of Waste Isolation, DOE (Klingsberg, C.) and Office of Nuclear Waste Isolation, Battelle (Duguid, J.), 1980. Status of Technology for Isolating High-Level Radioactive Wastes in Geologic Repositories, DOE/TIC-11207 (Draft).

11. Interagency Review Group on Nuclear Waste Management, 1978. Subgroup Report on Alternative Technology Strategies for the Isolation of Nuclear Waste, TID-28818, Washington, DC, draft, October.

12. U.S. Department of Energy, NWTS Program Criteria for Mined Geologic Disposal of Nuclear Waste, DOE/NWTS-33(1), April 1981, Washington, DC.

13. U.S. Department of Energy, 1980. Statement of Position of the U.S. Department of Energy in the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (Waste Confidence Rulemaking), DOE/NE-0007, Washington, DC.

14. Office of Nuclear Waste Isolation, Tabulation of Waste Isolation Computer Models, Vols. I and II, ONWI-78, December 1979.

15. Office of Nuclear Waste Isolation, 1979. Waste Package Design, Development, and Test Plan, ONWI draft, Battelle Memorial Institute, Columbus, OH.

16. International Atomic Energy Agency, 1980. Site Investigations for Disposal of Solid Radioactive Waste in Deep, Continental Geological Repositories, January.

17. Logan, S. E., and M. C. Berbano, 1978. Development and Application of a Risk Assessment Method for Radioactive Waste Management, EPA 520/6-78-005, U. S. Environmental Protection Agency, Washington, DC.

18. Arthur D. Little, Inc., 1979. Technical Support of Standards for High-Level Radioactive Waste Management: Vol. C, Migration Pathways, EPA-520/4-79-007C, prepared for U. S. Environmental Protection Agency, Washington, DC.

19. Stottlemyre, J. A., G. M. Petrie, and G. L. Benson, A Conceptual Simulation Model for Release Scenario Analysis of a Hypothetical Site in Columbia Plateau Basalts, PNL-2892, Pacific Northwest Laboratory, Richland, WA, draft.

20. U.S. Department of Energy, National Site Characterization and Selection Plan, DOE/NWTS-4, February 1982, and Environmental Assessment*, DOE/EA-151, February, 1982.

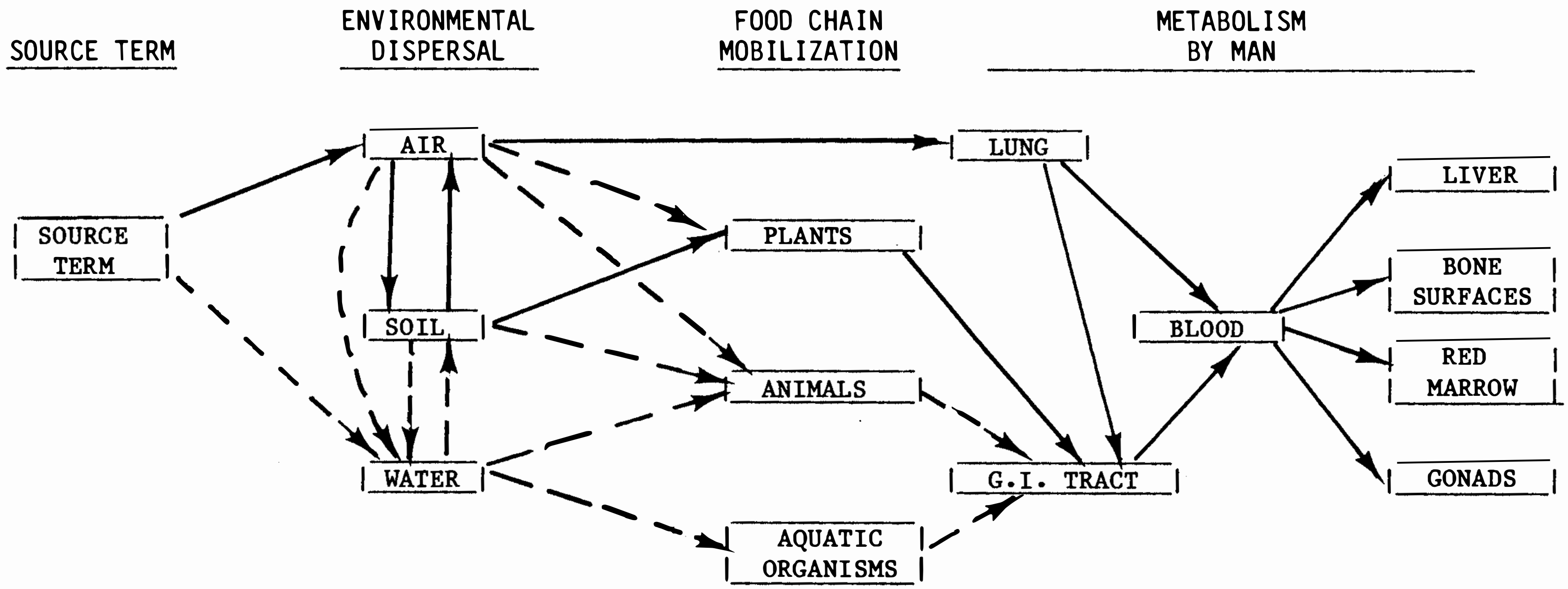
*Same title.

(4) Health Effects

INTRODUCTION

The purpose of this section is to describe information and uncertainty regarding the human health effects from plutonium and other transuranic elements released to the environment during the operation of an LMFBR fuel cycle. This risk is an unfamilar one, with certain unusual features, and for this reason it is a cause of public concern and deserves the special attention provided in this section. Among the unusual features of this risk are the following: (1) large quantities of radioactive materials will be produced, and their containment will have to be rigorously insured; (2) radioactive half-lives are long, so that some risk may persist for over a hundred thousand years; (3) although the toxicity of these materials is well demonstrated in experimental animals, there is no direct knowledge of effects in man; and (4) such effects as might conceivably occur will be indistinguishable from the normal ills of mankind.

This effort to estimate the health consequences of exposure to plutonium and other transuranic elements released during operation of the LMFBR fuel cycle is somewhat modified from that employed in WASH-1535, in light of more recent developments. However, it still follows the general model portrayed in Figure 5. The model starts with an input of radionuclides, the source term, from the LMFBR fuel cycle; there has been no reason to change this source term. These radionuclides are dispersed to air, soil, and water, and then follow along pathways leading to man. After inhalation or ingestion by man, there is a distribution to organs of concern, in which the radionuclides decay to produce a radiation dose.



SCHEMATIC DIAGRAM SHOWING PRINCIPAL PATHWAYS FOR ACCUMULATION OF TRANSURANIC ELEMENTS BY MAN (The heavy lines indicate pathways and compartments evaluated in this section. The dashed lines indicate pathways which are considered in the text or in Appendix D, but deemed insignificant for the purposes of this risk evaluation.)

TRANSURANIC PATHWAYS
Figure 5

The model of Figure 5 simplifies the real-life processes and, as described in the caption, is even further simplified in its application by neglecting certain pathways. Justifications for this simplication, and for the choice of values assumed in the quantitative application of the model, are summarized in this Section and supported by more detailed information in Appendix D.

The choice of values for the many parameters involved in the quantitative application of the model is often difficult. Several changes have been made from values employed in WASH-1535. Where data are not available to support the choice of a "most probable" value, estimates have been made that are
clearly "conservative." This approach leads to conservative estimates of 11
transuranic deposition in man, which must be kept in mind in considering the final results.

The estimation of health consequences, based on the model's prediction of radionuclide accumulation in the environment and in man, is also an uncertain procedure because of the total lack of direct experimental data on effects at these low exposure levels. Recognizing this uncertainty, predictions of risk have been made, based on comparison of predicted radiation doses in man with the dose-response data from animal experiments with plutonium, at much higher dose levels, and with the dose-response data from human exposure to other sources of radiation, also at much higher dose levels. Risk comparisons involving fewer extrapolation uncertainties have been made between the predicted doses due to releases from the LMFBR fuel cycle, and occupational exposures to plutonium, exposure to particulate plutonium from weapons test fallout, and exposure to natural background radiation. These comparisons of health consequences are summarized in this section and considered in greater detail in Appendix D.

SOURCE TERM

A release of 0.36 mCi of alpha-emitting transuranic elements is assumed for each 1000 MWe-year of LMFBR operation (Table 6). The derivation of this source term is described in detail in WASH-1535. The major fraction of the release occurs from the fuel reprocessing operation. The release is airborne and predominantly particulate in nature, with an assumed activity median aerodynamic diameter (AMAD) of 0.3 μm. Although relatively high releases may result from an individual accident, such accidents are predicted to occur so infrequently that they contribute insignificantly to the total source term; this conclusion is supported by detailed discussion in WASH-1535 (in Appendix II.G). WASH-1535 also discusses the source term that might be associated with deliberate acts of sabotage or of enemy attack.

ENVIRONMENTAL DISPERSAL

For this generic consideration, all of the source term was assumed to be released to the atmosphere. The initial release to the aqueous system, as well as all subsequent transfers from air to water or from soil to water, was ignored. While such a simplification might not be appropriate if one were concerned with the siting of a specific plant, it seems justified for treatment of the general case, because of the small fraction initially released to water, the low solubility of most transuranic compounds, and the great dilution volume ultimately provided by the world's oceans. Any small risk neglected by this approach should be more than counterbalanced by the conservative assumption that terrestrially deposited transuranic elements are not depleted in the soil, but remain for their total radiological lifetime, fully available for root-uptake by plants.

Table 6

QUANTITIES OF TRANSURANIC ELEMENTS RELEASED TO THE ATMOSPHERE PER 1000 MWe-YEAR[a]

Radionuclide	Half Life (years)	β-Activity (mCi)	α-Activity (mCi)	Mass (μg)
Pu-238	86.4		0.18	10
Pu-239	24,400		0.04	650
Pu-240	6,600		0.05	220
Pu-241[b]	13.2	5.4[b]		48
Am-241[b]	458		0.01[b]	3
Cm-242	0.44		0.07	0.02
Cm-244	17.6	___	0.01	0.01
Total		5.4	0.36	930

[a] The quantities enumerated for each radionuclide are estimates of the routine release from fuel reprocessing operations. Quantities released in other operations or in accidents make a comparatively insignificant contribution to the total.

[b] In evaluating health consequences, the β-radiation from Pu-241 is insignificant compared to the α-radiation from other transuranic elements. However, the 5.4 mCi of Pu-241 decays to produce an additional 0.16 mCi of Am-241, which is included as a part of the source term, where appropriate.

Atmospheric Dispersal: For modeling the dispersal of the source term within the atmosphere and its deposition from the atmosphere, a single point of release in the North Central United States was assumed. As described in WASH-1535, this choice was based on the availability of a model developed for, and the availability of actual data from, this site. There is a relatively large population downwind from this site, such that the population density considered is higher than the average U.S. population density by about a factor of 10. In the light of this conservatism, it was not considered necessary to revise WASH-1535 calculations to account for 1980-census changes or for refinements in our understanding of meteorological processes.

Application of the meteorological model, as detailed in WASH-1535, results in the prediction that a fraction of 4×10^{-6} of the source term will be inhaled by the exposed population of the United States before the material reaches the ground. After reaching the ground, the material may be resuspended, and it is estimated that an additional fraction of 9×10^{-6} of the activity released will eventually be inhaled as a consequence of this resuspension, about one-fourth of this within 2 years following the initial release. A total fraction of about 1.3×10^{-5} of the source term is therefore predicted to reach the exposed population via inhalation, half of this during the first 2 years following release and the remainder at later times, extending for the lifetime of the radionuclides involved.

This estimate of the total fraction of the source term inhaled by the total exposed population of the United States is, of course, sensitive to the point of release; it will be higher for points of release closer to downwind population centers and lower for sites located upwind of sparsely populated areas.

It is based upon average meteorological conditions and upon somewhat uncertain theory, particularly as regards the resuspended fraction. As considered in Appendix D, a smaller fraction of the fallout plutonium from weapons tests seems to have been inhaled by man. While the behavior of this fallout plutonium cannot be assumed to exactly match that of the transuranic releases from LMFBR operations, it does provide a check on the calculations which suggests that these calculations may overestimate the fraction inhaled.

Terrestrial Dispersal: A simpler model than that employed for atmospheric dispersal was employed for the transport of transuranic elements via food chains. In this case the entire source term was assumed to be uniformly distributed over the surface of the United States, and uniformly dispersed in the soil to a depth of 20 cm, where it remains for the lifetime of the radionuclides involved. There is assumed to be no downward movement in the soil beyond the root zone of plants and no loss due to runoff. This is a very conservative assumption, since, as discussed in Appendix D, fallout plutonium from weapons tests has already penetrated to soil depths of greater than 20 cm. The assumption of uniform distribution over the United States will, of course, underestimate the deposition immediately downwind from the source; and, if this area is used extensively to produce food crops, may underestimate the transuranic elements reaching man via food chains. An opposite effect will occur if the heavier deposition occurs on land unsuitable for agricultural use. Such uncertainty is inevitable in generic evaluations and would need to be considered in evaluations of specific sites.

TRANSPORT VIA FOOD CHAINS

Transuranic elements in soil may reach man via a number of food chain routes, the more important of which are indicated in Figure 5. Of these, the most significant is the direct pathway involving absorption of the radionuclide from the soil by plants (or external contamination of the plants by soil) and ingestion of the plants by man. For estimating ingestion by man, it is assumed that plant-derived food will include transuranic elements at a concentration that is 1 percent (plant wet-weight basis) of the concentration of these elements in the soil. This is lower than the 10% concentration assumed in WASH-1535, but, in light of accumulating data on the uptake of plutonium in agricultural crops, is still considered a conservative estimate (see Appendix D).

Because of the conservative assumption of permanent plutonium retention within the root-zone of soil, and 1 percent plant uptake, no attempt was made to model the finer points of food chain transport to man. It was assumed that all plant-derived food ingested by man will have a concentration of LMFBR-released transuranic elements equal to 1 percent of the concentration of these elements in the top 20 cm of soil. This leads to a total ingestion by the U.S. population, over the lifetime of the radionuclides involved, of about 10^{-3} of the released activity. This total quantity ingested will contribute significantly to human exposure in comparison with the contribution via inhalation.

METABOLISM AND DOSIMETRY IN MAN

Since the publication of WASH-1535, the International Commission on Radiological Protection (ICRP) has recommended new models for the behavior of transuranic elements in man and for the calculation of radiation doses to organs.[1] These new ICRP procedures are employed in this document; the details of their application are described in Appendix D.

For the case of inhaled radionuclides, the ICRP Lung Model distinguishes between various solubility categories; plutonium oxide falls in its least soluble category (Class Y), other plutonium compounds in an intermediate solubility category (Class W); all compounds of americium and curium are considered as Class W. For calculating dose to lung, the LMFBR plutonium particles are assumed to fall in the least soluble class, thus maximizing retention in lung and thoracic lymph nodes, and maximizing radiation dose to these organs. For calculating dose to other organs, an intermediate solubility is assumed for the plutonium particles, which results in more rapid clearance from lung to blood and somewhat larger doses to bone surfaces, red marrow, liver, and gonads. This insures that dose to a specific organ will not be underestimated because of uncertainty as to the chemical nature of the plutonium inhaled. But, since the same material is sometimes assumed to be in two places at the same time, these assumptions conservatively overestimate the combined dose to all organs.

For more soluble plutonium compounds, a fraction of 10^{-4} of ingested plutonium is assumed by the ICRP to be absorbed from the gastrointestinal tract to blood. For americium and curium the ICRP absorption fraction is 5×10^{-4}. Recent data from studies in animals suggest that these absorption fractions may be too small for very low concentrations of transuranics, or transuranics incorporated in organic foodstuffs.[2,3] Thus a conservatively higher absorption fraction of 10^{-3} was used for plutonium, americium and curium. Transuranic elements reaching the blood, whether absorbed from the lung or from the gastrointestinal tract, are assumed to deposit 45% on bone surfaces and 45% in liver; the transuranics in bone are retained with a half-time of 100 years and the transuranics in liver with a half-time of 40 years. A deposition from blood of 0.035% in the testes and 0.011% in the ovaries, with total retention, is also assumed.

Employing the dose calculation procedures of the ICRP, estimates were made of the 50-year dose commitment to organs significantly irradiated as a result of ingestion or inhalation of the calculated fractions of the initial source term release. These procedures are described in Appendix D. Briefly, they take account of the physical decay and biological retention of the radionuclide, including daughter radionuclides where pertinent, and sum the dose over 50 years following initial deposition. The 50-year period was chosen by the ICRP as a conservative interval of dose accumulation for occupationally exposed persons. It is less conservative for a member of the general public, who may be exposed at any age, but will still overestimate total exposure. These dose estimates for the organs and tissues of critical concern, lung, bone surface, red marrow, liver, and gonads, are shown in Table 7, expressed in units of organ-rem. These represent the total cumulative dose equivalent, from transuranic elements released per 1000 MWe-year* of LMFBR operation.

ESTIMATES OF HEALTH EFFECTS

The various estimates of exposure to transuranic elements released from the LMFBR fuel cycle are summarized in Table 7. Relating these estimates of exposure to health effects must necessarily be done indirectly, since there have been no observed life-threatening effects in man that can be uniquely related to transuranic exposure. The relationship must also be quite uncertain, since the estimated levels of exposure are far lower than can be studied experimentally, and because no principles, mechanisms, or established models exist to support the prediction of radiation effects at such levels. A number of comparisons can be made, however, which give an indication of the possible magnitude of effects.

* Equivalent to a 1000 MWe LMFBR power plant (and supporting fuel cycle) operating for a year at an 80% capacity factor.

Table 7

SUMMARY OF PRINCIPAL MODEL ASSUMPTIONS AND PREDICTIONS
(per 1000 MWe-YEAR)

Transuranics Released to Air (Ci)	0.36×10^{-3}
Initial Transuranic Concentration in Soil (Ci/g - all in top 20 cm)	1×10^{-22}
Initial Transuranic Concentration in Food (Ci/g)	1×10^{-24}
Transuranics Ingested by U.S. Population (Ci)	4×10^{-7}
Absorbed from G.I. Tract (Ci)	4×10^{-10}
Transuranics Inhaled by U.S. Population	
Directly Inhaled (Ci)	1.4×10^{-9}
Inhaled After Resuspension	
During First 2 Years (Ci)	0.8×10^{-9}
After First 2 Years (Ci)	2.5×10^{-9}
Total Inhaled (Ci)	5×10^{-9}
Radiation Dose to U.S. Population from Transuranics	
To Lung (organ-rem)	9
To Bone Surface (organ-rem)	86
To Red Marrow (organ-rem)	7
To Liver (organ-rem)	18
To Gonads (organ-rem)	1.1

Comparison With Current Levels of Exposure to Alpha-Emitters: Table 8 compares the exposure estimated to result per 1000 MWe-year of LMFBR operation with various measures of exposure from (1) natural background radiation, (2) naturally occurring alpha-emitting radionuclides, (3) fallout plutonium present in our environment as a result of nuclear weapons tests, and (4) human plutonium depositions resulting from occupational exposures. The data of Table 8 are considered in greater detail in Appendix D.

The numbers in Table 8 afford many interesting comparisons. The most extensive comparisons are those which can be made with the fallout plutonium from weapons tests. The amount of fallout plutonium exceeds by a factor of about 50 million the estimated LMFBR release per 1000 MWe-year; 1000 LMFBR's each rated at 1000 MWe and operating for 50 years would release only 1/1000 of the plutonium deposited from past weapons tests. The measured concentration of fallout plutonium in plant-derived foods is 400,000 times the estimated initial contamination of such foods per 1000 MWe-year of LMFBR operation. The estimated dose equivalent to a single generation from fallout is a million times greater than the dose equivalent to all future generations from a 1000 MWe-year of LMFBR operation.

Radiation doses from the naturally occurring alpha-emitting radionuclides dwarf those from either fallout plutonium or estimated LMFBR releases. The distribution of this natural dose in bone and lung may not be exactly comparable to that from the transuranic elements. However, the differences are so large that this factor becomes relatively unimportant. It should be noted also that the doses shown for naturally occurring radiation sources are doses calculated for a single generation, while the LMFBR doses are distributed over many generations.

Table 8

COMPARISON OF ESTIMATED EXPOSURES FROM LMFBR TRANSURANIC ELEMENT RELEASES WITH EXPOSURES FROM OTHER SOURCES

	Units	1000 MWe-Year of LMFBR Operations	Plutonium Exposed Workers[a]	Fallout Plutonium from Weapons Tests[a]	Naturally Occurring α-Emitters[a]	Total Natural Radiation[a]
Total Released to Air	10^{-3} Ci	0.36		16×10^{6}		
Concentration in Soil	10^{-22} Ci/g	1		4×10^{7}		
Concentration in Plant-Derived Food	10^{-24} Ci/g	1		4×10^{6}		
Total Inhaled by U.S. Population	10^{-8} Ci	0.5	--	8×10^{5}		
Total Retained in U.S. Population	10^{-8} Ci	--	500	6×10^{4}		
Dose Equivalent to U.S. Population[b]						
Lung	organ-rem	9		17×10^{6}	9×10^{9}	11×10^{9}
Bone Surface	organ-rem	86		88×10^{6}	2×10^{9}	3.2×10^{9}
Red Marrow	organ-rem	7		7×10^{6}	0.5×10^{9}	1.8×10^{9}
Liver	organ-rem	18		19×10^{6}		
Gonads	organ-rem	1		1×10^{6}	0.3×10^{9}	1.3×10^{9}

[a] Numbers derived in Appendix D.

[b] Dose equivalent from LMFBR release is a 50-year dose commitment to a constant U.S. population exposed for all time.
Dose equivalent from natural radiation is calculated for a 70-year exposure of U.S. population.
Dose equivalent from fallout plutonium is a 50-year dose commitment to the U.S. population from exposure during the period 1954-1975.

It is of interest that the estimated total amount of plutonium deposited in a few thousand plutonium workers is 1000 times the estimated deposition that would result from 1000 MWe-year of LMFBR operation. These workers were exposed, mostly via inhalation, to forms of plutonium that may closely simulate the LMFBR release. Thus far, no effects attributable to the plutonium deposition have been seen in these people.

The comparisons of Table 8 provide no measure of the absolute risk of health effects from transuranic releases from the LMFBR fuel cycle. They indicate, however, that such effects will be small compared to whatever effects may result from fallout plutonium. They also suggest that any effects from LMFBR releases (or from fallout plutonium) would be totally obscured by the much larger incidence of effects to be expected from natural background radiation, if, indeed, any effects are to be expected from any of these sources.

Comparison With Animal Toxicity Studies: Direct information on the toxicity of transuranic elements is available only from studies in experimental animals. The radiobiological literature suggests that the biological effects observed in such animal experiments will approximate those that would occur in man exposed under the same conditions. For this reason, it is justifiable to look to the results from extensive animal experimentation for guidance in estimating the health risks from exposure to transuranic elements. These studies suggest that bone and lung cancers are the most important effects of exposure to the lowest levels of transuranic elements thus far studied. Despite the relatively high radiation doses to pulmonary lymph nodes, there is no indication from animal studies of significant tumor production in the lymphatic system. For this reason we have followed the practice of the ICRP and included pulmonary lymph node deposits as part of the lung deposit for dose calculations.[1]

The exposure levels employed in animal studies are necessarily very much higher than the estimated exposures from LMFBR releases. One is also aware that extrapolation of animal results to man is uncertain under any conditions. Estimates have nevertheless been made, based on these animal studies, relating cancer risk to radiation dose. The range of these estimates is given in Table 9; a more detailed consideration of their origin will be found in Appendix D. The reasonable agreement among cancer risk estimates from the extensive animal data, and the limited and indirect data from human exposures to other alpha-emitters, strengthens our confidence in the general magnitude of the estimates.

Comparison With Human Cancer Risk Data: The human cancer risk data employed in WASH-1535 was that gathered by the National Academy of Sciences -- National Research Council Advisory Committee on the Biological Effects of Ionizing Radiations, and published in 1972 (BEIR I).[4] Since then, a revised assessment of the human data has been published by the successor to this Committee (BEIR III),[5] and other estimates of dose-effect relationships have appeared from other authoritative sources.[6,7] The more significant of these risk estimates, as they apply to transuranium element exposure, are summarized in Table 9, and are discussed at greater length in Appendix D. Also listed in Table 9 are the conservatively chosen cancer risk estimates employed in this document. Some confidence in these numbers may be engendered by the extent of agreement between the estimates from various groups. It must be remembered, however, that all of the groups had access to the same data, which was limited to exposures at relatively high dose levels, and the extent of agreement largely reflects the necessity of making the same kinds of assumptions in the extrapolations required.

Table 9

SUMMARIZED RISK ESTIMATES FOR EXPOSURE TO TRANSURANICS EXPRESSED AS EXCESS CANCER DEATHS OR MAJOR GENETIC DEFECTS

Per 10^6 organ-rem[a]

Organ	Source of Risk Estimates: Animal Studies	BEIR III	ICRP	UNSCEAR	Chosen for Use in This Documents
Lung	1-80	--	20	25-50	35
Bone Surface	0.5-10	1.4	5	2-5	5
Red Marrow		23	20	15-25	25
Liver		15			15
Gonads (for number of generations indicated)		15-225 (1) 180-3300 (all)	300 (2) 600 (all)	189 (1) 555 (all)	1,000 (all)

[a] The derivation of these risk estimates is discussed in Appendix D.

Comparison With Genetic Risk Data: The BEIR Committee,[5] the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR),[6] and ICRP[7] have published recent estimates of the risk of serious genetic defects. These risk estimates were all derived from data obtained with low-LET radiation exposures, and in accord with BEIR-III recommendations, have been multiplied by a factor of three for this application to high-LET alpha-radiation. These adjusted risk estimates are summarized in Table 9 and are discussed at greater length in Appendix D.

LMFBR Estimated Health Effects: The estimates of organ dose to the U.S. population per 1000 MWe-year of LMFBR operation, taken from Table 7, and the cancer and genetic risk estimates taken from Table 9, are combined in Table 10 to produce estimates of excess cancer deaths and serious genetic effects attributable to a 1000 MWe LMFBR operating for 1 year, and occurring over the lifetime of the released radionuclides. The estimates for total cancers and genetic effects, being very much smaller than 1, must be thought of as a probability of occurrence. Thus, there is an estimated probability of about one chance in one-thousand that a cancer death will result, and a somewhat smaller probability of a serious genetic defect. For example, an electrical generating system employing 1000 LMFBR's, each of 1000 MWe rated capacity, would be estimated to cause about one cancer death for each year of operation and about one serious genetic defect for each 2 years of operation.

DISCUSSION OF UNCERTAINTIES IN HEALTH EFFECTS ESTIMATES

In arriving at the estimates of health effects just presented, it was necessary to make many simplifying assumptions. While these assumptions have been designed to err in the direction of overestimating effects, it is important to the understanding of these estimates to have some feeling for the magnitude of the uncertainties involved. The more critical of these uncertainties are considered in the following discussion and in greater detail in Appendix D.

Table 10

ESTIMATE OF HEALTH EFFECTS FROM TRANSURANIC RELEASES

Per 1000 MWe-Year

Irradiated Organ	Estimated[a] Population Dose[a] (organ-rem)	Risk Factor[b] (per 10^6 organ-rem)	Estimated Excess	
			Cancer Deaths	Genetic Effects[c]
Lung	9	35	0.00032	
Bone Surface	86	5	0.00043	
Red Marrow	7	25	0.00018	
Liver	18	15	0.00027	
Gonads	1.1	1,000		0.0006
Totals			0.00012	0.0006

[a] From Table 2.
[b] From Table 4.
[c] The number of genetic effects was reduced by a factor of 2 to account for wasted radiation received beyond the average age of conception.

Problems of Averaging Activity and Dose: Throughout this document calculations have been made as though the radionuclide release was infinitely divisible, whereas, in fact, it is composed of particles with an assumed AMAD of 0.3 μm. These particles are not of a single diameter, but exhibit a distribution of sizes and shapes. There is no way of predicting particle sizes or composition. In fact, the particles originally released may contain uranium or other diluting material. Therefore, it would be unreasonable to attempt to employ a "particle model" for distribution of the source term beyond the initial atmospheric phase.

If the transuranic elements entering soils as particles remain in this form, transuranic availability would be diminished compared to the case where the particles are subdivided and dissolved by physical and chemical weathering processes. On the basis of present information, it is not possible to quantify the extent of particle subdivision and chemical dissolution which will occur as a function of the time periods of concern. It would appear likely, however, that entrance into the soil as an oxide particle would have the effect of reducing, at least initially, transuranic availability to plants below the levels assumed in this document.

Of greater interest are the possible consequences of inhaled particles. Is the intense radiation dose to tissue surrounding a particle more hazardous than the dose from the same quantity of radiation dispersed more uniformly throughout the lung? This question, the so-called "hot particle problem", has been addressed by several specially appointed groups and international bodies.[7,8,9,10] As referenced in greater detail in Appendix D, these groups have found neither 11
theoretical nor experimental grounds for confirming the extreme toxicity attributed to "hot particles" by Tamplin and Cochran.[11] The possibility of enhanced effects from particulate irradiation of specific tissue regions cannot be excluded, but

uniform exposure to total organs would generally be predicted to be more hazardous than exposure to "hot particles." The lack of any unusual incidence of health effects in workers that have inhaled plutonium (usually in particulate
11 form) also argues against any surprisingly large hazard due to these particles.[12] The use of an average lung dose in the estimation of health risks is therefore considered an appropriate procedure, which is not expected to underestimate risks.

PROBLEMS OF AVERAGING PEOPLE

Consideration of the number of particles available for inhalation, the fact that these particles will be released from a small number of fuel reprocessing plants, plus the fact that most of the direct inhalation of particles will occur within 50 miles of the release, combine to insure that LMFBR-derived transuranic element concentrations in the lungs of different people would be expected to vary widely. Whether this fact alters the acceptability of the very small total risk of health effects is a question pertinent, primarily, to decisions concerning the siting of individual fuel reprocessing plants.

Another type of people-averaging is implicit in the lack of separate consideration of the fetus, infant, or child. Data bearing on this problem are considered in WASH-1535, and it is concluded that risks to the very young are adequately covered by adult criteria.

PROBLEMS OF AVERAGING TIME

Estimates of health effects have been noted, as in Table 10, without regard to their distribution in time. It is important to have an estimate of the total effect over the lifetime of the radionuclides involved, but it is also important to know how these effects are distributed in time. About one-third of the estimated cancer deaths would be expected to occur to the generations alive during LMFBR operations. About one-third of the genetic effects would be expected to occur by the end of the first generation following LMFBR operation. The remaining two-thirds of the estimated health effects would be spread over subsequent generations, at a much diminished rate, decreasing with radioactive decay. Because of the greater conservatism reflected in the long-term aspects of the model, it is probable that considerably more than the predicted one-third of the total nongenetic effects will be evidenced in generations exposed directly to LMFBR releases.

Uncertainties in Environment Dispersal, Transport, and Metabolic Model Parameters: Thirty percent of the estimated inhalation of transuranics by man occurs during the primary phase of atmospheric dispersion (Table 7). The assumptions involved in estimating this initial inhalation will principally affect the pattern of dispersion. Since the areas downwind from the reference release site are rather uniformly populous, the quantity ultimately inhaled is relatively insensitive to these assumptions. It is therefore felt that the total quantity inhaled from the dispersed plume by the exposed U.S. population is a reasonable estimate for the site selected, but might vary over a 10-fold range depending upon the exact location of the release site with respect to population centers. This is primarily a matter to be evaluated in specific plant siting. The remaining 70% of the total estimated inhalation occurs as a result of resuspension, and is probably a substantial overestimate, since it assumes no loss of availability subsequent to an initial 2-year weathering.

The fraction of the LMFBR release that is estimated to be inhaled by the exposed U.S. population is about 30 times larger than the measured fraction of fallout plutonium inhaled (Table 8). It is reasonable that the LMFBR estimate should be larger, because of the higher population density of the heavy dispersal area for the LMFBR release, as compared to the U.S. average; and because the long-term inhalation of resuspended material is not reflected in the 20-year experience with fallout plutonium. These factors might not explain the total discrepancy; however, the agreement seems reasonably good.

About 0.1% of the LMFBR release is estimated to be ultimately ingested by the U.S. population (Appendix D). This value results from a combination of conservative assumptions necessitated by the absence of pertinent data. Thus, it is assumed that the transuranic elements remain available for root uptake or resuspension, in the upper 20 cm of the soil, for their lifetime; no sink is provided. It is further assumed that plant-derived food will contain a transuranic element concentration equal to 1% of the concentration of these elements in soil. This level of accumulation is about 10 times higher than that measured for fallout plutonium or americium.[13] The models employed indicate that cumulative organ radiation doses, over all time, from ingested transuranics are comparable to those from inhaled transuranics; the dose from inhaled transuranics will, however, predominate during the period of direct exposure to LMFBR releases, for which period the model parameters are most certain. For the case of gastrointestinal absorption, a higher absorption fraction was chosen than that recommended by the ICRP, in light of recent experimental results.[2,3]

With regard to the assumed absorption and distribution of the transuranic elements in man, the parameters employed in ICRP models are, in general, "best estimate" models. Some conservatism results from the duplication of exposure involved in maximizing both retention in, and movement from, the lung, and from the practice of assuming a 50-year period for accumulation of dose, regardless of age at deposition. These are minor factors, however, compared to those involved in the dispersal and transport models.

Uncertainties in Dose-Effect Extrapolations: A major uncertainty is that involved in translating estimates of dose to estimates of specific health effects. Without doubt, the most valid approach involves those comparisons which avoid the uncertainties of extrapolation to exposure levels far lower than can be experimentally studied. Thus, the most convincing comparisons are those in Table 8, which contrast the low levels of predicted LMFBR releases with the much higher levels of plutonium deposited in the U.S. from weapons tests; and with the even higher levels of naturally occurring alpha-emitters present in the exposed population.

The effort to place absolute numbers on specific risks must be looked upon as an exercise lending qualitative support to the conclusions implicit in Table 8. The numbers of cancers and genetic defects listed in Table 10 have no precise quantitative significance. They are based upon conservative estimates of exposure. Whether the actual risk approaches these numbers, or is zero, can in no way be inferred from our present knowledge.

REFERENCES

1. International Commission on Radiological Protection, Limits for Intakes of Radionuclides by Workers, ICRP Publication 30, Part 1, Pergamon Press, Oxford 1979.

2. M. F. Sullivan, "Absorption of actinide elements from the gastrointestinal tract of rats, guinea pigs, and dogs," Health Phys., 38, 159-171, 1980.

3. M. F. Sullivan, T. R. Garland, D. A. Cataldo, R. E. Wildung, and H. Drucker, "Absorption of plutonium from the gastrointestinal tract of rats and guinea pigs after ingestion of alfalfa containing ^{238}Pu," Health Phys., 38, 215-221, 1980.

4. U.S. National Academy of Sciences - National Research Council, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," Report of the Advisory Committee on the Biological Effects of Ionizing Radiations, Washington, DC, 1972.

5. U.S. National Academy of Sciences - National Research Council, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980," National Academy Press, Washington, DC, 1980.

6. U.N. Scientific Committee on the Effects of Atomic Radiation, "Sources and Effects of Ionizing Radiation," United Nations, New York, NY, 1977.

7. International Commission on Radiological Protection, "Recommendations of the International Commission on Radiological Protection," ICRP Publication 26, Pergamon Press, Oxford, 1977.

8. National Council on Radiation Protection and Measurements, "Alpha-emitting Particles in the Lung," NCRP Report No. 46, Washington, DC, 1975.

9. National Academy of Sciences - National Research Council, "Health Effects of Alpha-emitting Particles in the Respiratory Tract," Washington, DC, 1976.

10. U.S. Nuclear Regulatory Commission, "Natural Resources Defense Council - Denial of Petition for Rule Making," Federal Register 41(71), 15371-15379, 1976.

11. A. R. Tamplin and T. B. Cochran, Radiation Standards for Hot Particles, Natural Resources Defense Council, Inc., Washington, DC, 1974.

11 12. G. L. Voelz, J. H. Stebbings, Jr., J. W. Healy, and L. H. Hempelmann, "Studies on Health Risks to Persons Exposed to Plutonium," The Medical Basis for Radiation Accident Preparedness, pp. 419-430, Elsevier, New York, 1980.

13. B. G. Bennett, "Environmental Aspects of Americium," U.S.D.O.E. Document EML-348, 1978.

B. Environmental Impacts of Alternative Long-Term Technologies

Some qualitative comparisons* are possible for magnetic fusion[1,2], wind 21
energy conversion[3,4], solar photovoltaic conversion[5,6], solar thermal conversion[7,8], and ocean thermal conversion[9,10], using existing DOE Environmental Development Plans, Environmental Readiness Documents and related information.[11,12]

Comparative quantitative analyses of alternative long-term technologies are 21
difficult due to differences in types of impacts. However, all long-term technologies require land for generating facilities, transmission lines, etc. It would be expected that land use for the LMFBR and supporting fuel cycle would be roughly comparable to land use associated with magnetic and inertial fusion and wind energy conversion systems (on a unit electrical generation basis). However, land use for solar photovoltaic and solar thermal systems would be expected to be considerably greater, due to the large areas required for solar collectors. On the other hand, land area requirements for ocean thermal energy conversion systems would be expected to be considerably smaller, since only shore support facilities are required. Examples of comparable environmental impacts are given in the Table 11. These estimates, except for the LMFBR figures (taken from WASH-1535), are quite rough and subject to revision as additional information on alternative long-term technologies is obtained. Water use is seen to vary greatly.** 6,21

*Previous initial sentence deleted. 21
**Next-to-last sentence in this paragraph deleted. 6,21

Table 11

RELATIVE ENVIRONMENTAL IMPACTS*

Technology	Land Use (acres)	Water Use (ft^3/yr)	Construction Materials** (MT per GWe)
LMFBR			
fuel cycle	30*		
plant site	400	∿3 x 10^9	35,000 (steel)
transmission lines	1,050	(cooling towers)	730 (copper)
total	1,480		
Magnetic Fusion			
plant sites	∿400	∿3 x 10^9	∿50,000 (steel)
transmission lines	∿500	(cooling towers)	∿2,000 (copper)
total	∿900		
Wind Energy Conversion Systems			
plant sites	∿1,500		∿300,000 (steel)
transmission lines	∿500	----	∿3,000 (copper)
total	∿2,000		
Solar Photovoltaic			
plant sites	∿7,000		Not available
transmission lines	∿1,000	----	
total	∿8,000		
Solar Thermal			
plant sites	∿20,000	∿3 x 10^7	∿1,000,000 (steel)
transmission lines	∿1,000		∿20,000 (copper)
total	∿21,000		
Ocean Thermal			
plant sites (onshore)	∿50	∿4 x 10^{12}	∿200,000 (steel)
transmission lines	∿200	(sea water)	∿20,000 (copper)
total	∿250		

*Per 1000 MWe equivalent plant capacity.
**Generating facilities only.

Most other environmental impacts are different in kind and thus cannot be compared on the same basis. The major LMFBR environmental concerns--reactor safety, radioactive waste management, and health effects of radioactivity releases--are shared only by the fusion energy systems with the D-T cycle. Even here, there are likely to be significant quantitative differences between LMFBR and fusion energy systems. The major environmental issues for the wind energy conversion systems are likely to be safety (blade and/or tower failure), electromagnetic interference (TV and microwave), noise and aesthetics.

Environmental concerns associated with the development and deployment of photovoltaic systems have been identified in the following subject areas:

- Release of toxic gases during system operation or malfunctions;
- Inhalation of toxic gases and dusts by industry workers; and
- Solid waste disposal and effects of gases released during material mining, manufacture, and disposal.

Environmental concerns, other than land use, associated with solar thermal power systems are likely to be:

- Handling and disposal of system fluids and wastes;
- Heliostat reflections;
- Ecological effects of the heliostat field; and
- Potential microclimate alterations.

Environmental concerns associated with ocean thermal energy systems are expected to be:

- Ocean water mixing (alteration of water temperatures);
- Metallic discharges (toxic metals released from heat exchangers due to erosion and corrosion);

- o Effects of biocides;
- o Working fluid (ammonia) leaks; and
- o Potential climatological impacts.

The following material covers the environmental impacts of magnetic fusion powerplants, a situation where additional comparative information can be provided. There would be a wide range of uncertainty in the information, as discussed.

A general summary of the environmental impacts which would be anticipated as a result of the development and operation of fusion reactors has been presented in Section 6A.1.6.6 of WASH-1535. The purpose of the material contained in this supplement is to update, where appropriate, the discussions contained in that document.

Magnetic fusion powerplants would require several sets of very powerful magnets operating on or near the reactor vessel to confine the plasma in which the fusion reaction would occur. While the magnetic fields produced by these magnets would be concentrated inside the reactor vessel, significant magnetic fields would also exist outside of the vessel. These "outside" magnetic fields would have the potential to extend for substantial distances (several hundred meters) beyond the vessel before their intensity would be reduced to the earth's natural magnetic field strength (0.5 gauss). Although workers in certain areas of a fusion plant could be exposed to magnetic fields of several hundred gauss if shielding or other preventive measures are not used, exposure to the general population offsite would be negligible and potentially totally mitigatable by plant siting.

While the mechanisms of interaction that relate magnet field strength, field direction, field variability, and exposure time to effects on living organisms are not well known or well understood, research conducted by DOE since WASH-1535 was published have failed to identify any potentially harmful biological effects. Some earlier work had suggested potential effects may include long-term physiological problems, e.g., headaches and disorientation in humans and interference with migratory orientation in birds and insects.

Microwave (radio frequency) sources for supplemental plasma heating may be used in fusion powerplants. While microwaves are known to produce serious health effects in humans, control technology and effective shielding are readily available. Consequently, no major effects on humans from microwaves would be expected.

The most serious waste problems, especially with regard to public perception of hazard, would involve radioactive material. In addition, nonradioactive waste generated during fusion powerplant operation would require safe handling and disposal techniques.

While fusion reactors offer a potential for producing small amounts of the less long-lived radioactive wastes, a number of radioactive waste streams will exist. Among these are tritium, gaseous activation products generated in the plasma chamber, activation products produced in the structure that dissolve into the cooling system, activation products produced in the atmosphere within the confinement structure, and the activation products that remain trapped in the solid structure.

Tritium, present in the gaseous form in the plasma exhaust and in the purge gas used to collect tritium from the breeding blanket, would be relatively easy to recover from these gas streams for reprocessing as fuel. However, since tritium permeates through most metals readily, special procedures (e.g., low-permeability cladding on piping, double containment on process lines (plus the barrier of the building itself), and maintenance of negative pressure in all processing rooms) would be required to minimize losses.

For the systems utilizing a steam cycle, any tritium that diffused from the blanket system would interact with water in the steam cycle to form tritiated water (HTO) and would require isotope separation processes for recovery. The problems associated with maintenance and operation of steam cycles in fusion plants are expected to be identical with those encountered in present conventional steam-electric generating systems. The potential presence of HTO in the steam cycle is a factor that will require evaluation of the applicability of current steam cycle design, maintenance, and operational practices to fusion plants.

During the operation of a fusion powerplant, materials used in the construction of the machine would become activated through bombardment with the radioactive particles (neutrons) produced in primary nuclear reactions. The public hazard from this source depends on the total inventory of induced radioactivity and the potential for its volatilization and release outside the containment building. The inventory, in turn, depends on the construction materials used and, to some extent, the specific design of systems close to the reacting plasma.

Estimates based on reference designs of fusion machines indicate an operating inventory of radioactivity (including tritium) ranging from roughly equivalent to that for a comparable fission reactor (LMFBR or LWR) to many orders of magnitude less, depending on materials and design.

Activation of the atmosphere in the reactor building also could be an issue of concern. A number of radioactive isotopes having relatively short half-lives (tens of minutes), are produced by neutron bombardment of the constituents of air. These isotopes include argon 41 (^{41}Ar), carbon 11 (^{11}C), oxygen 15 (^{15}O), nitrogen 16 (^{16}N), and nitrogen 13 (^{13}N). The residual radioactivity from these isotopes after reactor shutdown is a consideration for on-site workers and removal of the isotopes from the reactor building atmosphere is possible.

The effects on public health and safety of release of part of the radioactive inventory depends on many details of the release conditions, including; portion released, chemical and physical form of compounds, population density and location, time between shutdown and release, warning time, energy of release, height of release, duration of release, and weather conditions at a specific site.

Depending on material selection, much of the radioactive material may be recyclable, and some of it is of relatively low activity. The primary source of higher level waste is the structural material used in the first wall and blanket. The average annual discharge rate per reactor of this material would range from being comparable to that expected from a typical fission breeder reactor to being several orders of magnitude less, depending on materials and design.

Several nonradioactive products may have to be disposed of either routinely or infrequently. Major materials may include lithium or lithium components, lead used as shielding and/or a neutron multiplier for breeding tritium, detergents for laundry and decontamination, and a large range of possible alloy materials including beryllium, nickel, bismuth, manganese, molybdenum, and chromium.

Lithium is routinely used in industry, and there is a long history of its mining, refining, and processing. Environmental quality standards have been defined, and adequate technology is available to permit design of waste treatment systems that assure compliance with applicable air and water quality regulations. The toxicity of lead is understood. Industrial controls for handling lead and lead compounds are adequate for control of the hazards from the lead used in magnetic fusion reactors. Nickel, bismuth, manganese, molybdenum, and chromium exhibit varying degrees of toxicity depending on type of contact, concentration, and the population at risk. The major potential environmental impacts from the use of these toxic metals will probably result from the mining, processing, fabrication, and methods by which they might ultimately be disposed of and would be identical for any powerplant using structural metals with these alloy materials.

Wind Energy Conversion Systems

WASH-1535 discussed land use and aesthetic impacts of wide scale use of wind energy systems, as well as concerns about weather modification. While the overall impacts of wind energy systems are relatively minor, additional concerns have also been identified in the areas of safety, electromagnetic interference, and noise.[13]

As with any type of large, moving machinery, there are several safety concerns associated with wind devices. The first of these is the danger associated with structural failures of the tower, rotor, or generator. These dangers could threaten both onsite personnel and nearby residents. However, system design features have been developed to minimize the occurrence of structural failures such as tower collapse, blade throw, and blade-tip throw. Another potential hazard associated with wind devices located in northern climates is that of ice loading and throw.

Another aspect of the safety problem is the potential occupational hazards to electric utility personnel when large or small-scale devices are interconnected with the utility network. Additional controls and disconnects are necessary to isolate a lineman, working on an otherwise dead line, from the shock potential of a local wind-powered generator that was still operating.

Although the tallest wind systems will not pose a hazard to aircraft in normal flight, potential interference could occur from systems located near airports or on terrain such as high hills or mountains where existing hazard potential would be enhanced. Federal Aviation Administration Regulations already govern structures in flight areas, and recommend safety lighting and marking procedures, which would mitigate potentially hazardous conditions.

A potential problem around large-scale wind generator sites is electromagnetic interference, particularly with television. The prime cause of this problem is the reflection of signals from the rotating metal blades. This amplitude-modulated interference affects only the picture (television sound is frequency modulated). Under certain conditions, large devices can cause severe picture bars, snow, and ghosts at distances up to 5 miles. Interference can be reduced by constructing blades of nonmetallic materials and mitigated through proper site selection.

Some noise has been reported from almost all wind generators, particularly the "swishing" noise associated with the rotor blade tips. Research groups currently investigating noises associated with experimental machines have linked them to site specific problems related to tower design, blade configuration, and mode of operation.[13]

Photovoltaic

A number of potential impacts of photovoltaic systems are noted in WASH-1535 (including land requirements, and impacts on ecosystems, microclimate, and aesthetics). More recently, concerns have been identified about outgassing of toxic gases in the event of overheating or fire, and about production worker exposure and waste disposal in connection with advanced photovoltaic materials containing cadmium, copper, arsenic, gallium, or other toxic substances.[15]

A salient feature of the photovoltaic technologies is the relative absence of hazardous residuals at the end use. However, the collector and storage subsystems can present some health and safety problems in the case of accidents or where collectors are exposed to extraneous fires.

Mining and cell manufacturing present more severe environmental problems, but the materials used are mostly byproducts of existing mining and extracting operations, which should limit the additional exposure from these sources. The potential exists for a variety of chemical and thermal releases during manufacturing, dependent upon the type of cell manufactured and the effectiveness of environmental control technology. Occupational concerns will become more significant as new photovoltaic cells using arsenic, cadmium, or other hazardous substances reach production scale.

Silicon cells are themselves believed to be inert, but polymeric concentrating materials (e.g., methyl methacrylate used in Fresnel lenses) are highly flammable. Off-gases and combustion products from these materials have not been characterized. Fires involving gallium arsenide cells may cause vaporization of the arsenic followed by oxidation to the highly toxic trioxide (As_2O_3).

These issues require ongoing research and mitigation efforts. Overall, however, photovoltaic technology appears to face only moderate environmental constraints.[5]

Satellite photovoltaic systems have been studied extensively since WASH-1535 was issued, and are not considered a viable alternative at this time. Major questions relating to microwave exposure remain to be answered.

Solar Thermal

Potential impacts of solar thermal electric power systems are discussed in WASH-1535, including land use impacts, microclimate alterations, and ecological impacts. Additional areas of concern include the handling and disposal of system fluids and wastes (touched on in WASH-1535) and impacts from misdirected solar radiation.

Accidental or emergency release or flushing of working and storage fluids such as liquid sodium, sodium hydroxide, hydrocarbon oils, and eutectic salts composed of sodium or potassium nitrates/nitrites could cause fires and explosions, contaminate drinking water supplies, increase soil salinity, impact terrestrial and aquatic communities, and reduce the effectiveness of sewage treatment systems. Resolution of these issues is important so that serious safety and pollution problems can be avoided during operation of solar thermal systems.

Heliostat reflections have the potential to cause severe burns, eye injury, and fires, as well as to create dangerous conditions for nearby ground and air traffic during all phases of heliostat fabrication and use. Because numerous heliostats may be used in solar thermal power systems (both central and dispersed), it is important to address and resolve this issue to ensure that safe procedures are used during heliostat manufacture and installation and that any necessary control strategies are incorporated into system design and operation procedures.[14]

It is believed that these potential impacts can be adequately controlled, and that solar thermal technology faces minimal environmental constraints.[15]

OTEC

Ocean thermal energy conversion (OTEC) technologies have been further studied since the issuance of WASH-1535. Major environmental concerns include ocean water mixing (alteration of water temperatures), metallic discharges (toxic metals released from heat exchangers due to erosion and corrosion), effects of biocides used to prevent fouling of pipes and heat exchange surfaces, leaks of working fluids such as ammonia, potential climatological impacts, and the impingement or entrainment of organisms.

References

1. DOE/EDP-0052, "Environmental Development Plan, Magnetic Fusion," September 1979.

2. DOE/EP-0014, "Environmental Readiness Document, Magnetic Fusion," March 1981.

3. DOE/EDP-0030, "Environmental Development Plan, Wind Energy Conversion," July 1979.

4. DOE/ERD-0006, "Environmental Readiness Document, Large and Small Wind Systems, Commercialization Phase III Planning," September 1978.

5. DOE/EDP-0031, "Environmental Development Plan, Photovoltaics," September 1979.

6. DOE/ERD-0008, "Environmental Readiness Document, Photovoltaics, Commercialization Phase III Planning," September 1978.

7. DOE/EDP-0004, "Environmental Development Plan, Solar Thermal Power Systems," March 1978.

8. DOE/ERD-0019, "Environmental Readiness Document, Solar Thermal Power Systems," August 1979.

9. DOE/EDP-0006, "Environmental Development Plan, Ocean Thermal Energy Conversion," March 1978.

10. DOE/ERD-0020, "Environmental Readiness Document, Ocean Thermal Energy Conversion," August 1979.

11. DOE/EV-0072, "Technology Characterizations, Environmental Information Handbook," June 1980.

12. ERDA-1547, Final Environmental Impact Statement, "Alternative Fuels Demonstration Program," September 1977.

13. DOE/EP-0026, "Energy Technologies and the Environment," June 1981.

14. DOE/EDP-0035, "Environmental Development Plan: Solar Thermal Power Systems," August 1979.

15. DOE/ERD-0022, "Environmental Readiness of Emerging Energy Technologies, Summary Report," January 1979.

VII. List of Preparers and Reviewers

The following table provides a listing of principal preparers and DOE reviewers of the draft supplemental EIS to the Final Environmental Statement, LMFBR Program (ERDA-1535). Biographical sketches, containing information on professional qualifications, are provided in the following paragraphs.

BIOGRAPHICAL SKETCHES

Dr. Roy C. Thompson is a Senior Staff Scientist in the Biology Department of Pacific Northwest Laboratory, Richland, Washington, which is operated for the U.S. Department of Energy by Battelle Memorial Institute. He has been associated with that laboratory for over 30 years and conducted his first studies with plutonium at the University of Chicago in 1944. Dr. Thompson's research has dealt with the metabolism and biological effects of internally deposited radionuclides, and he is the author of more than 50 publications in that field. He is a member of the National Council on Radiation Protection and Measurements, and of its Committee on Internal Emitter Standards; and of Committee 2 on Secondary Limits of the International Commission on Radiological Protection.

		Section												
								IV.D		VI.A				
Name	Organization	I	II	III	IV.A	IV.B	IV.C	(1)	(2)	(1)	(2)	(3)	(4)	VI.B
W. Kornack	DOE/NE	R	R	R	R	R	R	R	R	R	R	R	R	R
G. Sherwood	DOE/NE	P*	P*,R	R	R	R	R	R	R	R	R	R	R	P
G. Nardella	DOE/ER	--	--	--	--	--	--	P*[5],R	--	--	--	--	--	--
S. Barish	DOE/DP	--	--	--	--	--	--	P*[6],R	--	--	--	--	--	--
A. P. D'Zmura	DOE/NE	--	p*	--	--	--	--	--	--	P*,R	--	--	--	--
A. Katz	DOE/DP	--	p*	--	--	--	--	--	--	--	P	--	--	--
J. Zorn	DOE/NE	--	--	--	--	--	--	--	--	--	R	--	--	--
R. Loose	DOE/CE	--	--	--	--	--	--	--	P*,R	--	--	--	--	--
N. Evans	DOE/EP	R	R	R	R	R	R	R	R	R	R	R	R	R
E. Mastal[2]	DOE/NE	--	P*	--	--	--	--	--	--	--	--	P*,R	--	--
R. Thompson[3]	PNL	--	P*	--	--	--	--	--	--	--	--	--	P	--
B. Wachholz[3]	DOE/EP	--	--	--	--	--	--	--	--	--	--	--	R	--
D. Thomas[4]	DOE/NE	--	--	--	--	--	--	--	--	--	--	--	--	--
M. Lineberry	ANL	--	p*	P	P	P	P	--	--	--	--	--	--	--
H. McFarlane	ANL	--	p*	P	P	P	P	--	--	--	--	--	--	--
S. Brumbach	ANL	--	p*	P	P	P	P	--	--	--	--	--	--	--
H. Harper	ANL	--	p*	P	P	P	P	--	--	--	--	--	--	--
D. Ferguson[1]	ANL	--	--	--	--	--	--	--	--	P	--	--	--	--

R=Reviewer, P=Preparer, *=part, 1=Appendix E, 2=Appendix B, 3=Appendix D, 4=Appendix A, 5=Magnetic Fusion, 6=Inertial Fusion

Dr. Michael J. Lineberry is Associate Director of the Applied Physics Division at Argonne National Laboratory, Idaho Falls, Idaho. He is program manager at the Zero Power Plutonium Reactor (ZPPR) where critical experiments are conducted in support of fast breeder reactor design and licensing. Dr. Lineberry's research has dealt with the neutron physics of LMFBRs, and he has published over 30 papers in fast reactor physics. During 1977-79, Dr. Lineberry served on the U.S. team supporting the International Nuclear Fuel Cycle Evaluation. He is a member of the American Nuclear Society and is currently vice-chairman of the ANS Reactor Physics Division.

Dr. Harold F. McFarlane is head of the Analysis and Applications Section of the Applied Physics Division of Argonne National Laboratory. He has been employed by ANL since 1972, having been involved primarily with the planning, implementation and analysis of critical experiments. More recently, his work has been in investigating methodologies for applications of critical experiments to reactor design and in guiding research on the most persistent problems in fast reactor physics. He is a member of the American Nuclear Society and is on the Program Committee of the ANS Reactor Physics Division.

Dr. Stephen B. Brumbach is a physicist in the Applied Physics Division of Argonne National Laboratory, Idaho Falls, Idaho, which is operated for the U.S. Department of Energy by the University of Chicago. He is presently engaged in fast reactor critical experiments at the Zero Power Plutonium Reactor.

Dr. Henry A. Harper is a Nuclear Engineer in the Reactor Analysis and Safety and the Applied Physics Divisions of Argonne National Laboratory, Idaho Falls, Idaho, which is operated for the U.S. Department of Energy by the University of Chicago. During more than five years with Argonne, Dr. Harper's research has dealt with the operation and analysis of large scale, sodium cooled, breeder reactor safety experiments. With the Applied Physics Division he has worked with the operation and analysis of reactor critical experiments at the Zero Power Plutonium Reactor. Dr. Harper also served five years as a U.S. Naval Officer involved with the operation and maintenance of naval propulsion reactors. He is a member of the American Nuclear Society.

Dr. Donald R. Ferguson is a nuclear engineer on the staff of Argonne National Laboratory, which is operated for the U.S. Department of Energy by the University of Chicago. He is currently serving as Director of the Fast Reactor Safety Technology Management Center (FRSTMC) at Argonne. Dr. Ferguson joined Argonne in 1972 following the completion of his graduate studies in nuclear engineering at Massachusetts Institute of Technology. Before joining the FRSTMC in 1979, he served for five years as Manager of the Accident Analysis Section in the Reactor Analysis and Safety Division at Argonne. Dr. Ferguson is the author of numerous reports and technical papers on LMFBR safety-related subjects. He is a member of the American Nuclear Society and past chairman of the Mathematics and Computation Division of the ANS.

VIII. List of Agencies, Organizations and Persons to Whom Copies of this Environmental Impact Statement were Sent

Federal Agencies

Environmental Protection Agency
Department of Agriculture
Department of Commerce
Department of Defense
Department of Housing and Urban Development
Department of Justice
Department of Health and Human Services
Department of the Interior
Department of State
Department of Transportation
National Science Foundation
National Aeronautics and Space Administration
National Academy of Sciences
Central Intelligence Agency
Nuclear Regulatory Commission
Office of Management and Budget
Tennessee Valley Authority
Advisory Council on Historic Preservation
Council on Environmental Quality

States

All 50 states (and applicable clearing houses)

Environmental Groups

Natural Resources Defense Council, Inc.
Friends of the Earth
Sierra Club

Industrial Organizations

Atomic Industrial Forum

Atomics International Division, Rockwell International 5

American Nuclear Society

Electric Power Research Institute

Edison Electric Institute

Project Management Corporation

Bechtel Corporation

Burns and Roe, Inc.

Black and Veatch

Babcock and Wilcox Co.

C. F. Braun and Co.

Brown and Root, Inc.

Combustion Engineering, Inc.

Daniel Construction Co.

Ebasco Services, Inc.

Fluor Power Services

General Atomic Company

General Electric Co.

Gibbs and Hill, Inc.

Gilbert Associates, Inc.

J. A. Jones Construction Co.

Kaiser Engineers

Offshore Power Systems

Sargent and Lundy Engineers

Scientists and Engineers for Secure Energy

Stone and Webster Engineering Corp.

United Nuclear Corporation

United Engineers and Constructors

Westinghouse Electric Corporation

Utilities

Baltimore Gas & Electric Co.

Boston Edison Co.

Connecticut Yankee Atomic Power Co.
Consolidated Edison Co.
Duquesne Light Co.
Jersey Central Power & Light Co.
Long Island Lighting Co.
Maine Yankee Atomic Power Co.
Metropolitan Edison Co.
Niagara Mohawk Power Corp.
Northeast Utilities
Pennsylvania Power & Light Co.
Philadelphia Electric Co.
Power Authority of the State of New York
Public Service Co. of New Hampshire
Public Service Electric & Gas Co. (NJ)
Rochester Gas & Electric Corp.
Vermont Yankee Nuclear Power Corp.
Yankee Atomic Electric Co.
Cincinnati Gas & Light Co.
The Cleveland Electric Illuminating Co.
Commonwealth Edison Co.
Consumers Power Co.
Detroit Edison Co.
Illinois Power Co.
Indiana & Michigan Electric Co.
Iowa Power & Light Co.
Kansas City Power & Light Co.
Nebraska Public Power District
Northern States Power Co.
Omaha Public Power District
Public Service Indiana
Toledo Edison Co.
Union Electric Co.
Wisconsin Electric Power Co.
Wisconsin Public Services Corp.
Alabama Power Co.

Arkansas Power & Light Co.

Carolina Power & Light Co.

Duke Power Co.

Florida Power & Light Co.

Florida Power Corp.

Georgia Power Co.

Gulf States Utilities Co.

Louisiana Power & Light Co.

Mississippi Power & Light Co.

South Carolina Electric & Gas Co.

Virginia Electric & Power Co.

Arizona Public Service Co.

Houston Lighting & Power Co.

Public Service Co. of Oklahoma

Texas Utilities Generating Co.

Pacific Gas and Electric Co.

Portland General Electric Co.

Public Service Co. of Colorado

Pudget Sound Power & Light Co.

Sacramento Municipal Utility District

Southern California Edison Co.

Washington Public Power Supply System

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(See page xviii for list of comment letters received.)

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*The Supplemental Draft EIS was sent to all members of the public who provided comments on WASH-1535 or ERDA-1535. Mr. Dycus was the only individual from this group who provided comments on the Supplement.

IX. INDEX

1. Page numbers (this supplement).
2. WASH-1535 (starting page numbers).
3. ERDA-1535 (starting page numbers).
4. Appendix E also (this supplement).
5. Appendix C also (this supplement).
6. Appendix B also (this supplement).
7. Appendix D also (this supplement).
8. Appendix A also (this supplement).

X. APPENDICES

Appendix A

ASSESSMENT OF U.S. URANIUM RESOURCES

1. The National Uranium Resource Evaluation (NURE) Program

ERDA-1535 discussed the NURE Program, started in 1974, for comprehensively assessing the uranium resources in the United States. The program was designed to enhance the data pertaining to uranium deposits in order to improve uranium resource assessment and to reduce the uncertainties in estimates of the resources. A tremendous amount of information was developed by the NURE program. The program was terminated at the end of FY 1981, although much of the information developed during the program will be evaluated over the next two years. DOE will continue to develop reliable and timely estimates of U.S. uranium resources by using the data from NURE and commercially confidential data supplied voluntarily by industry.

Of the 621 2-degree National Topographic Map Series quadrangles in the conterminous U.S. and Alaska, 162 entire quadrangles were fully evaluated and assessed by the NURE program through the end of FY 1981. These quadrangles contain all uranium resources in the reserves and probable classes as well as other geologic environments favorable for uranium deposits.

NURE aerial radiometric and magnetic surveys covered over 3.4 million square miles involving 1.2 million flight-line miles of data acquisition. This included all of the conterminous U.S. and two-thirds of Alaska. Over seven hundred thousand geochemical samples of stream sediments and surface and ground waters, covering more than 1.8 million square miles, were collected. This included two-thirds of the conterminous U.S. and four-fifths of Alaska. More than 450,000 feet were drilled and cored in 23 project areas which provided subsurface information in specific favorable uranium environments. Moreover, about 2.2 million feet of gross-gamma and spectral-gamma logging was performed. In addition, about 1.7 million feet of gamma-ray logging was performed to gain additional subsurface data on non-uranium industry holes drilled for water, petroleum and mineral commodities other than uranium.

2. Latest Assessment of U.S. Uranium Resources

In October 1980, the most comprehensive assessment to date of U.S. uranium resources was issued in GJO-111(80), "An Assessment Report on Uranium in the United States of America." An improved method for the estimation of potential resources was developed and utilized for the first time in this report, which also provided estimated confidence levels. Table A-1 provides updated reserve data as of January 1, 1981, and other resources data as of October 1, 1980.

A substantial amount of the above-mentioned NURE data was developed since GJO-111(80) was issued. All of the data will be analyzed together with the voluntarily supplied industry data, and a major assessment report on the U.S. uranium resources will be issued by the end of 1983.

3. Comparison of Uranium Resource Estimates

Table A-2 provides an approximate comparison of the current U.S. uranium resource estimates with those presented in ERDA-1535. The average ore grade of 0.19 percent U_3O_8 for the \$10-per-pound-U_3O_8 ERDA-1535 estimate is about the same as the average grade for current \$30-per-pound-U_3O_8 estimates, a reflection of increased costs. At this grade, the current reserve and potential resources, all classes combined, total 2,012,000 tons U_3O_8, about 1.5 times the ERDA-1535 level of 1,320,000 tons at the same grade. Similarly, the \$15-per-pound-U_3O_8 estimate of 2,040,000 tons has increased by about

1.6 times to 3,336,000 tons for essentially the same grade; however, this amount is now in the \$50-per-pound-U_3O_8 cost category, again because of increased costs. Likewise, the \$30-per-pound-U_3O_8 estimate has increased by about 1.4 times to 4,815,000 tons for nearly the same grade, but because of increased costs this amount is in the \$100-per-pound-U_3O_8 cost category.

4. Use of Imported Uranium

Beginning in 1977, U.S. utilities were permitted to use imported uranium in their power reactors.[1] In that year, 10 percent foreign uranium could be used, which increased to 15 percent in 1978, 20 percent in 1979, 30 percent in 1980, and 40 percent in 1981, and which will increase to 60 percent in 1982, 80 percent in 1983, and finally no limit in 1984 and thereafter. However, the actual use of foreign uranium in domestic power reactors has been low. In over 4 1/2 years of actual experience, only 7.2 percent foreign uranium has been used, compared with an allowable weighted average of 21.0 percent. Based on market surveys, the future use of imported uranium should remain low as domestic utilities continue their preference for U.S. uranium.[2,3]

TABLE A-1

U.S. URANIUM RESOURCES[1/]
RESERVES AS OF JANUARY 1, 1981
OTHER RESOURCES AS OF OCTOBER 1, 1980

Cost Category	Short Tons U_3O_8 Probability Distribution Values		
	95th Percentile[2/]	Mean	5th Percentile[2/]
$30/pound U_3O_8			
Reserves	421,000	470,000	528,000
Probable	659,000	885,000	1,161,000
Possible	194,000	346,000	530,000
Speculative	155,000	311,000	600,000
	1,562,000[4/]	2,012,000	2,568,000[4/]
$50/pound U_3O_8 [3/]			
Reserves	700,000	787,000	900,000
Probable	1,102,000	1,426,000	1,802,000
Possible	346,000	641,000	973,000
Speculative	251,000	482,000	890,000
	2,628,000[4/]	3,336,000	4,158,000[4/]
$100/pound U_3O_8 [3/]			
Reserves	902,000	1,034,000	1,180,000
Probable	1,646,000	2,080,000	2,573,000
Possible	521,000	1,005,000	1,526,000
Speculative	378,000	696,000	1,225,000
	3,792,000[4/]	4,815,000	5,962,000[4/]

1/ Uranium resources are estimated quantities recoverable by mining. Losses due to processing may range from 5 to 15 percent. In addition to the above resources, uranium that could be recovered by the year 2000 as a byproduct of phosphate and copper mining is estimated at 120,000 short tons U_3O_8.

2/ The 95th percentile indicates a 95-percent confidence in the existence of at least the amounts shown. The 5th percentile indicates a 5-percent chance of the existence of more than the amounts shown.

3/ Includes lower cost resource categories.

4/ The values for resources at the 95th and 5th percentiles are not directly additive because the estimates are only moderately correlated.

TABLE A-2

COMPARISON OF URANIUM ESTIMATES

Approximate Average Ore Grade, in Percent U_3O_8	Current Estimates[1/]		ERDA-1535 Estimates[2/]	
0.19	$30/Pound U_3O_8	Tons U_3O_8	$10/Pound U_3O_8	Tons U_3O_8
	Reserves	470,000	Reserves	315,000
	Probable	885,000	Probable	440,000
	Possible	346,000	Possible	420,000
	Speculative	311,000	Speculative	145,000
		2,012,000		1,320,000
0.13	$50/Pound U_3O_8[3/]		$15/Pound U_3O_8[3/]	
	Reserves	787,000	Reserves	420,000
	Probable	1,426,000	Probable	655,000
	Possible	641,000	Possible	675,000
	Speculative	482,000	Speculative	290,000
		3,336,000		2,040,000
0.08	$100/Pound U_3O_8[3/]		$30/Pound U_3O_8[3/]	
	Reserves	1,034,000	Reserves	600,000
	Probable	2,080,000	Probable	1,060,000
	Possible	1,005,000	Possible	1,270,000
	Speculative	696,000	Speculative	590,000
		4,815,000		3,520,000

1/ In addition to the above estimates, the uranium that could be recovered by the year 2000 as a byproduct of phosphate and copper mining is estimated at 120,000 tons U_3O_8.

2/ In addition to the above estimates, the uranium that could be recovered by the year 2000 as a byproduct of phosphate and copper mining was estimated at 90,000 tons U_3O_8.

3/ Includes lower cost resource categories.

REFERENCES

1. Federal Register, Vol. 39, No. 208, page 38016, October 25, 1974.

2. Statement of Shelby T. Brewer, Assistant Secretary for Nuclear Energy, U.S. Department of Energy before the Committee on Energy and Natural Resources, Subcommittee on Energy Research and Development, United States Senate, September 25, 1981.

3. Department of Energy report, "The Domestic Uranium Industry and Imports of Uranium," February 23, 1981.

Appendix B

ADDITIONAL INFORMATION ON U.S. NUCLEAR WASTE MANAGEMENT PROGRAM

Roles of Federal Agencies

The repository development process involves interactions between several Federal agencies, State and local governments, and Indian Tribes. DOE has the lead role for the development and implementation of the disposal system, with support from DOI. EPA will set generally applicable standards that the disposal system must meet. NRC will set regulations to ensure that the EPA standards are met and will review DOE's application to construct and operate a repository, based upon compliance with those standards. These roles and responsibilities are expanded upon in this section and summarized in Table B-1.

Department of Energy (DOE)

DOE has the lead role among the Federal agencies for the management and disposal of radioactive wastes. Legislation authorizes DOE to provide the facilities for permanent isolation of highly radioactive wastes from the biosphere. Therefore, DOE is responsible for the following activities that will ultimately provide these facilities:

- Site characterization, selection and acquisition.
- Development of geologic repositories and supporting ancillary facilities.
- Development of supporting technology.
- Development of a timely, continuing, and meaningful dialogue with affected States and Indian Tribes.
- Applying for the repository license.
- Coordination of supplementary concepts, such as subseabed disposal.

Nuclear Regulatory Commission (NRC)

NRC is responsible for regulating the disposal of radioactive wastes in a manner that ensure the protection of public health and safety. NRC has developed proposed regulations (10 CFR 60) for disposal of HLW in a geologic repository (U.S. Nuclear Regulatory Commission, 1981g). These proposed regulations implement the environmental standards to be established by EPA. If DOE satisfies the NRC requirements (as demonstrated through a licensing proceeding), NRC will grant DOE a license to conduct activities relating to the disposal of radioactive wastes in the repository. As a basis for its licensing decisions, NRC also conducts an independent assessment of the technology by performing confirmatory research and development (R&D) and by exchanging information with DOE on a continuing basis.

Table B-1

ACTIVITIES OF FEDERAL AGENCIES IN THE DEVELOPMENT OF A GEOLOGIC REPOSITORY

ORGANIZATION	ACTIVITIES
DOE	• Site Characterization and Selection • Land Acquisition • Technology Development • Application for License • Repository Design, Construction, Operation and Closure • Interactions with State/Indian Tribes
NRC	• Regulation Promulgation • Siting Review • Licensing Proceedings • Technology Review • Interactions with State/Indian Tribes
EPA	• Standards Promulgation
DOI	• Site Characterization Support • Land Access • Land Withdrawal

Environmental Protection Agency (EPA)

EPA is responsible for developing and establishing generally applicable radiation protection standards for radioactive waste disposal. These standards will provide the basis for NRC's licensing regulations.

Department of the Interior (DOI)

DOI, through the USGS, is providing support to DOE in its site characterization activities, specifically in the areas of geophysical surveys, geohydrologic mapping, and geologic/hydrologic evaluation of potential sites throughout the United States. In addition, the Bureau of Land Management (BLM), within DOI, may provide access to public lands under its authority for siting evaluations and support the acquisition of such lands through administrative or Congressional withdrawals under the Federal Land Policy and Management Act of 1976 (FLPMA).

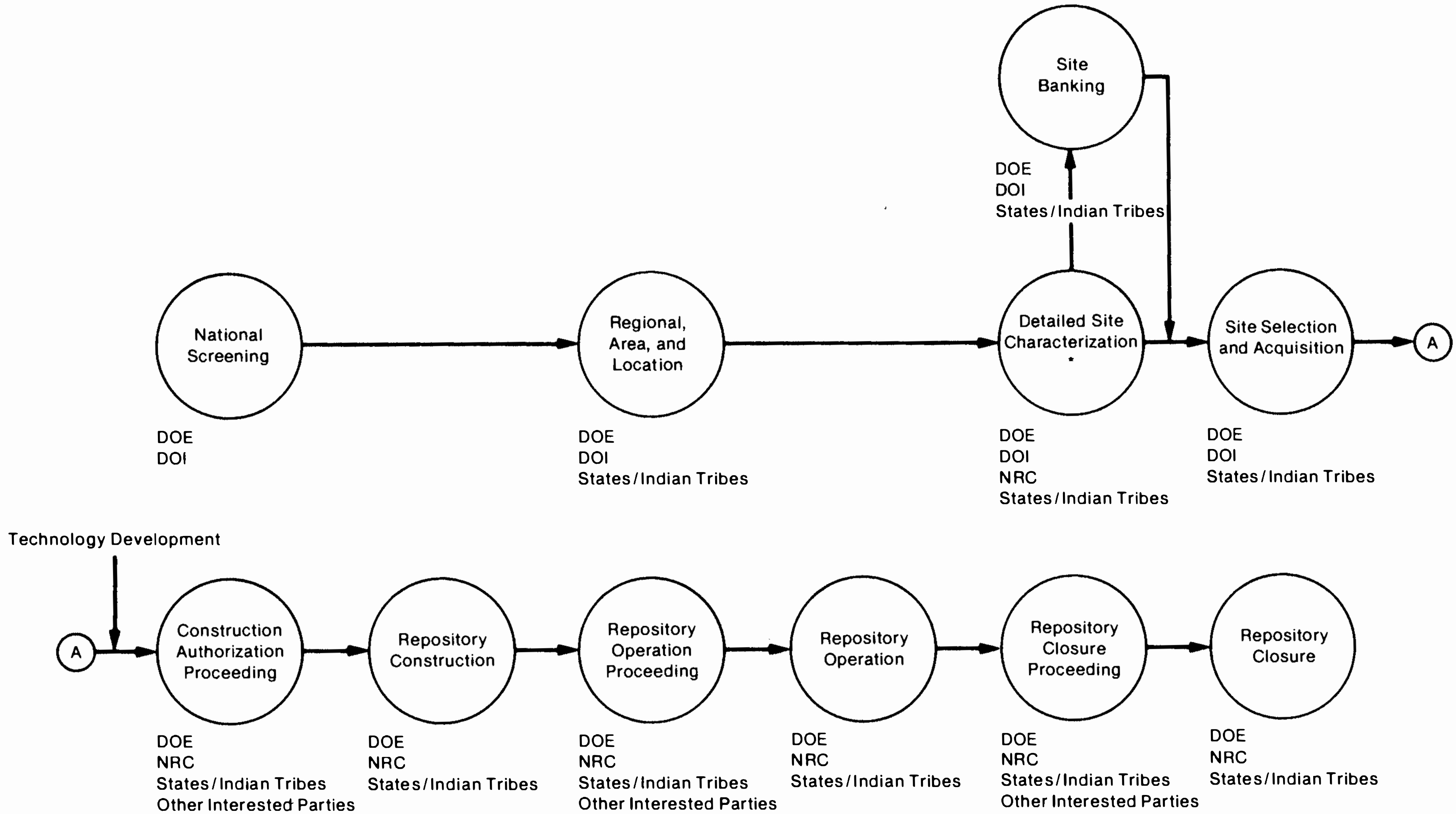
Institutional and Public Involvement in the Decision-Making Process

Permanently isolating radioactive waste from the environment is an issue of great public interest, which has been expressed by citizens' groups and representatives of State and local governments as well as the nuclear industry. Waste isolation spans the jurisdictions of a number of established institutions and extends into areas of general social concern.

The Federal Government is committed to the principle of State consultation, which provides that a host State will have a continuing role in Federal decision-making on the siting, design, and construction of a high-level waste repository. This "partnership" between the States and the Federal Government recognizes that the safe disposal of radioactive waste is a national, and not only a Federal responsibility. The decisions involved in achieving the long-term isolation of radioactive waste must be made openly, subject to public scrutiny, participation, and review. These decisions must also be acceptable to those members of society affected by their implementation and must take into consideration diverse viewpoints.

A conceptual overview of the steps in the repository development effort is shown in Figure B-1. In the early phases, the focus is on geologic screening, which involves characterization of surface and subsurface environments, leading to increasingly detailed studies of narrowed geographical and geologic areas until potential sites are identified. The information obtained during detailed characterization will assess a potential site's suitability and provide data required for the preparation of licensing documents.

Initial site protection measures will most likely be taken at the conclusion of the geographic screening phase when sites are selected for detailed site characterization. Because this characterization phase includes the sinking of exploratory shafts and in-situ testing in the proposed repository horizon, DOE will take steps to protect the land in order to protect its exploration investment. This protection is necessary to ensure that other actions at or near the site do not render the site unsuitable for use as a repository.



*Including Exploratory Shaft

Figure B-1

Steps in the Development of a Geologic Repository

Protection of a site does not require full ownership rights to the property, but does require sufficient ownership interest (e.g., short-term lease acquisition or easement) to maintain the integrity of the site and have full access for characterization activities.

The detailed evaluation of a site will determine whether the site is qualified for licensing by comparing its characteristics against established criteria (U.S. Department of Energy, 1981g). If a site is determined to be suitable, then additional land protection measures (e.g., long-term lease acquisition) will be taken to supplement those taken previously to preserve (or "bank") the site for possible later selection as a repository location. On the other hand, if detailed site characterization finds that a site is not suitable, any land protection measures taken previously on the site would be terminated and the property returned to other uses.

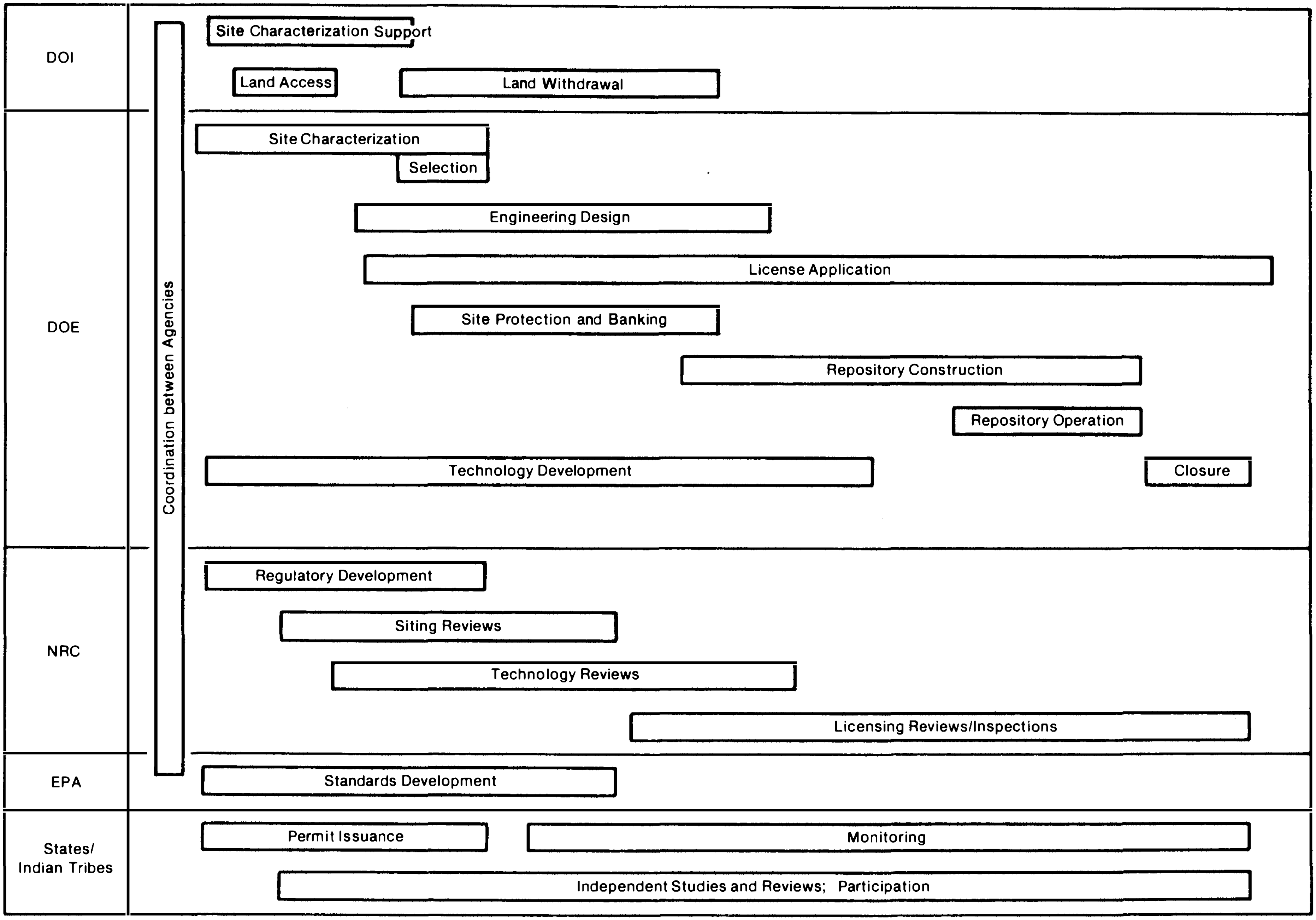
Action to obtain full ownership of the site would not be initiated until after site selection. An EIS will be prepared as input into the decision to select a site for development of a repository. When a minimum of three sites in two different geologic media have been characterized, one or more will be selected by DOE, and a construction authorization application will be submitted to NRC. Later in the process, licensing review, construction, and operation of the repository would take place.

The plan to develop the facilities to permanently dispose of radioactive wastes involves the coordinated and integrated efforts of several Federal agencies along with State and local governments. Figure B-2 indicates that DOE and NRC will be the major participants and that DOI and EPA will play significant supporting roles. It also indicates that numerous activities of different types will be underway in parallel. Coordination between the participants is shown occurring early in the process and will continue throughout the repository development effort.

Although many different activities will be underway in parallel, the effort in the early years focuses on finding suitable sites and developing the required technology. Many groups of people and organizations will be involved in the decision process. However, the decision process that will be followed must be established within the context of the roles and responsibilities of the organizations involved. The scope of the organizational interactions and the integrated plan are presented below.

Organization Agreements

Memoranda of Understanding (MOU's) and other agreements are used to clarify the roles of the Federal agencies in repository siting and technology development. A Procedural Agreement has been established between DOE and NRC and will be established between DOE and DOI. The DOE/NRC agreement establishes a formal mechanism to provide NRC detailed information concerning the status of DOE siting and technology development on a timely basis. Procedures are being developed to permit a relationship between DOE and NRC on potential issues without compromising NRC's ability to independently license and regulate future DOE HLW disposal. The DOE/DOI agreement will provide a definition of the role of BLM and DOE concerning provision of drilling permits, and access to and possible withdrawal of Federally controlled land from public access, if required. It will also formalize the role of USGS in supporting site identification activities.



Note: The Activities Are Not Drawn to Reflect the Actual Time Scales Involved.

Figure B-2

Relationship of Activities in Repository Development

Regulation Development

The Energy Reorganization Act of 1974 sets forth NRC licensing authority for receipt and storage of HLW generated from NRC-licensed activities and for the long-term storage of HLW generated by DOE activities, except those related to research and development. Therefore, while DOE will be responsible for the development of HLW disposal facilities, DOE will not construct the facilities or emplace radioactive waste in the facility until it receives a license from NRC. NRC must be assured through the licensing process that the public health and safety and the environment will be adequately protected.

Separate from this regulatory oversight by NRC, EPA is responsible for establishing generally applicable environmental standards for the management, storage and disposal of HLW and TRU wastes. While EPA issued standards for the nuclear fuel cycle in 1977 (40 CFR 190), these standards explicitly excluded operations involving waste management. A specific standard for waste management is now under development by EPA. This standard will provide the fundamental basis for NRC's licensing activities and will determine the overall performance standard for the repository.

DOE has developed broad objectives and criteria to guide its research and development programs pending the establishment of formal standards and regulations by EPA and NRC. DOE's program, while guided by DOE objectives and criteria, has been designed to accommodate developing regulations and standards by the regulatory authorities. Figure B-3 illustrates the relationship between DOE, EPA, and NRC, as the regulatory framework is developed.

The NRC is responsible for issuing regulations that implement the EPA standard. The basic regulations for geologic repositories are presented in 10 CFR 60. In the procedural portion of 10 CFR 60, the NRC established a series of steps that DOE must complete to obtain authorization to dispose of HLW and TRU. Included in this series of actions is a site characterization report on each prospective site, request for construction authorization, application for a license to possess and dispose of HLW, and various amendments to the license, including the final one to close and decommission the repository. DOE is also required to provide periodic progress reports on the several site characterization studies and on construction and operation of the repository. Table B-2 specifies the reports and documents to be exchanged.

On July 8, 1981, the sections of 10 CFR 60 covering technical requirements were published for comment as a proposed rule (U.S. Nuclear Regulatory Commission, 1981g). The proposed schedule for issuing other regulatory documents is presented in Table B-3.

In addition to the development of the regulatory framework and participation in the review in detail of siting activity, NRC will be given the opportunity to review the status of waste isolation technology. The DOE/NRC Agreement that establishes the formal interchange provides for periodic presentations and reviews of specific topics. DOE will make a special effort to document the issues and technical activities that have led to their resolution. Included in this formal interchange are a category of documents and reports

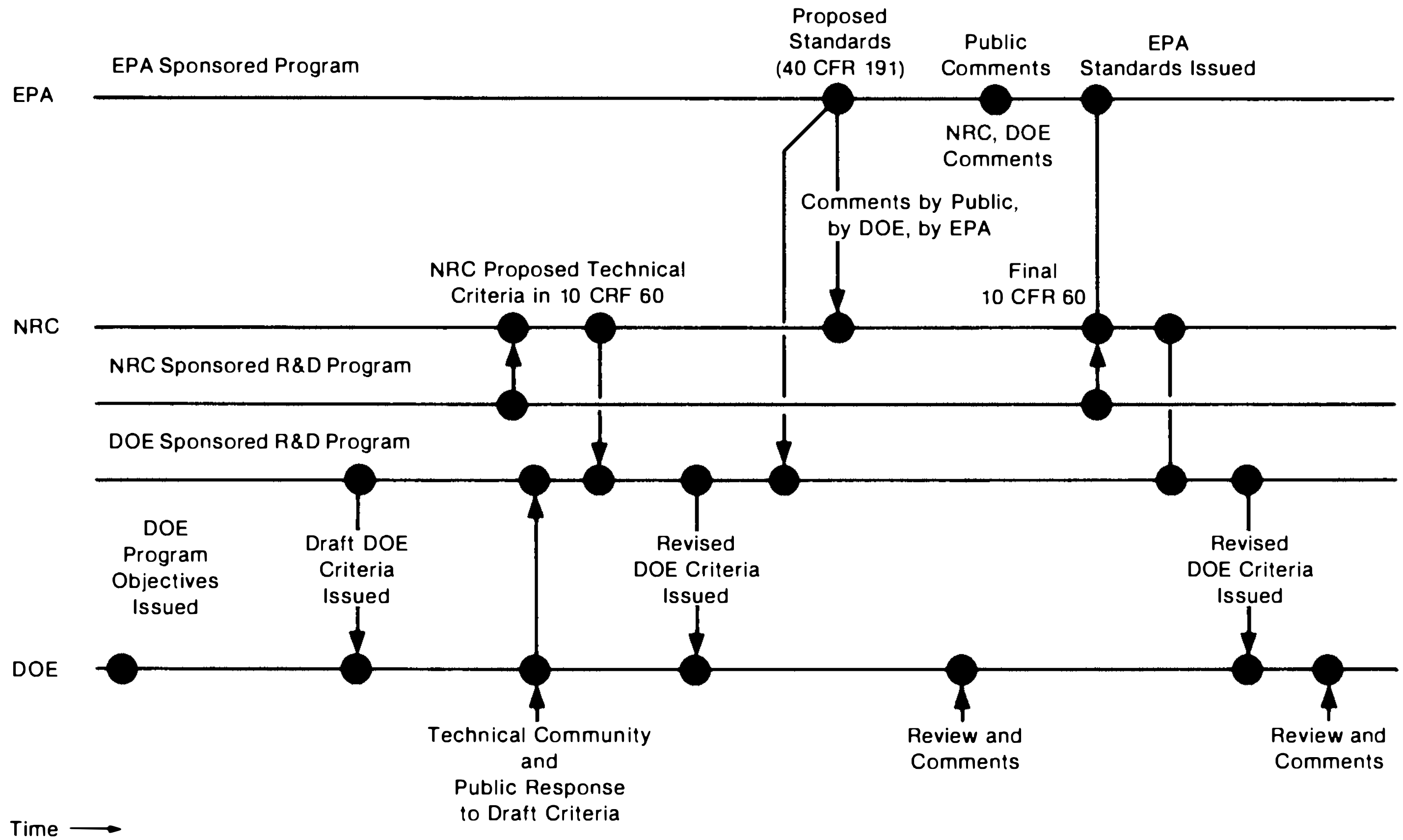


Figure B-3
Regulatory Framework Between DOE, EPA, and NRC

Table B-2

PROCEDURAL INTERACTIONS BETWEEN NRC AND DOE

DOCUMENT	WHEN FILED	CATEGORY OF NRC RESPONSE (REQUIRED DOE ACTION)
Draft EIS on Commercial Waste Management Program	April 1979	Review comments. (DOE must consider comments in preparation of Final EIS).
National Plan for Siting High Level Radioactive Waste Repositories	Fall 1981	Review comments. (DOE must consider comments).
Site Characterization Report and Environmental Document	When DOE proposes that a single location within a geologic region should be characterized in detail, including an exploratory shaft, and that this location should be protected.	Advisory response by director, NMSS. (DOE will incorporate NRC comments into final report. DOE must issue final environmental document before site can be protected or exploratory shaft can be sunk).
Updated (or Detailed) Site Characterization Report and Environmental Document	When DOE has completed its detailed site studies at one site, and has determined the site is suitable for a repository, and the candidate site should be protected accordingly.	Advisory comments
Site Recommendation Report and Draft EIS	When DOE proposes a specific preferred site for licensing and authorization for construction	Informal review of site to be submitted as preparation for receiving license application.
Application for Construction Authorization	When DOE Site Characterization Report and Final EIA is issued, and when the Environmental Report and Safety Analysis of the Repository are completed.	Formal licensing review, including public hearings. NRC could request additional technical information about site or additional design work.
Application for License to Receive and Emplace Waste	When detailed engineering design and procurement (Title I & II) and major construction are completed, and the Environmental Report and the Safety Analysis Report are updated	Further review of the license application, possibly including public hearings.
Amendment Application for Closure	When the repository has been substantially filled and its performance has been demonstrated to be satisfactory, and when the license application and Environmental Report are updated.	Formal proceedings including public hearings, to determine if long-term isolation of the emplaced waste is ensured.

*Depending on timing of suitability determination, this environmental document may be combined with the site recommendation EIS.

Table B-3

REGULATORY DOCUMENT PREPARATION SCHEDULE

DOCUMENT	ISSUE DATE
40 CFR 191 - Environmental Standards (Proposed)	FY 81
40 CFR 191 - Environmental Standards (Final)	FY 82
10 CFR 60 - Procedures* (Final)	FY 81
10 CFR 60 - Technical Requirements** (Proposed)	FY 81
10 CFR 60 - Technical Requirements (Final)	FY 82
Technical Requirement Rationale Document and Environmental Impact Assessment**	FY 81
Site Characterization Report Format and Content Guide (Draft)	FY 81
Site Characterization Report Standard Review Plan (Draft)	FY 82
Environmental Report Format and Content Guide	FY 83
Safety Analysis Report Format and Content Guide	FY 83
License Application Format and Content Guide	

*published 2/25/81
**published 7/8/81

to obtain formal NRC feedback on methods of handling and resolving technical questions that are known to be important for the authorization of construction and licensing of a repository for operation. Topics proposed to date for discussion include: (1) performance modeling relative to site selection; (2) brine migration; (3) volcanism as a factor in siting; (4) pre-application quality assurance; (5) seismicity as a factor in siting; and (6) human interference. In addition, a technical interchange between DOE and NRC concerning program activities will be conducted on a continuing basis. This mutual interchange will cover major areas--waste packages, repository development, site characterization, and performance assessment.

DOE Program for Permanent Isolation

DOE's program to establish geologic repositories has been designated by DOE as the National Waste Terminal Storage (NWTS) Program. The overall objective of the NWTS Program is to provide for the effective isolation of existing and future radioactive wastes from DOE and commercial activities so that they pose no significant threat to public health and safety.

To meet this overall objective, several general performance objectives have been formulated by the NWTS Program. These objectives are structured to allow adequate flexibility to meet specific regulatory requirements at the licensing phase of a repository. The objectives are not intended to negate the need for NRC and EPA regulations, but merely to provide interim guidance until comprehensive final regulations can be issued.

The following waste isolation system performance objectives (for any method of waste disposal) have been proposed in NWTS-33(1), Program Objectives, Functional Requirements and System Performance Criteria (U.S. Department of Energy, 1981e):

- o The mined geologic disposal system shall provide reasonable assurance that waste will be adequately isolated from the accessible environment for a period of at least 10,000 years with no prediction of significant decreases in isolation beyond that time. The potential risk to future generations shall be limited to the extent reasonably achievable.

- o The NWTS program shall be conducted in a manner that will promote institutional and societal participation and acceptance of the program plans and activities.

- o Technical conservation shall be applied throughout the NWTS program. The methods used to design, develop, and demonstrate the disposal system shall be sufficiently conservative to account for residual uncertainties of potential importance to system effectiveness and shall provide reasonable assurance that regulatory standards will be met.

- o The NWTS program shall provide multiple, regionally sited repositories insofar as technical considerations permit. Features of the repositories shall be standardized to the extent practicable to facilitate safe and economical development and operation.

- The system of NWTS repositories shall be capable of receiving and disposing of all commercial high-level and transuranic (TRU) wastes and defense high-level wastes in a safe manner, regardless of the amount of nuclear waste produced and of the specific fuel cycle or reactor that produced it.

- The safe disposal and isolation of radioactive wastes shall be achieved in a manner that provides effective utilization of resources.

- The mined geologic disposal system shall be developed based upon a level of technology that can be implemented within a reasonable period of time. It shall not depend upon scientific breakthroughs and shall be able to be assessed with current capabilities. Active maintenance or surveillance for unreasonable lengths of time into the future shall not be necessary to ensure adequate isolation.

In the implementation of the NWTS Program, the above waste isolation system performance objectives are reflected in formal performance criteria that are applied in the planning, execution, and evaluation of all program activities. These criteria are presented in the NWTS-33 series of documents (U.S. Department of Energy, 1981e, 1981g, 1981h, 1981i).

Although mined geological repositories will be the focal point of the comprehensive national radioactive waste management program, the Department of Energy will continue to support a limited program directed toward development of supplemental disposal options, such as the disposal of HLW by emplacement in sedimentary deposits beneath the bottom of the deep sea (thousands of meters below the ocean surface) in areas which have been geologically stable over millions of years. For more detailed information on alternatives for permanent disposal, see U.S. Department of Energy, 1980y.

NWTS Program Planning Structure

A description of all activities in the NWTS Program will be presented in the NWTS Program Plan, which describes in greater detail the individual sub-program plan documents. The relationships between these documents are shown in Figure B-4. These documents provide the statement of directions and the framework for coordinating the NWTS Program activities, and will be available in FY 82.

Program Activities

The following strategy has been established for the NWTS program in order to best accomplish the program objectives. The program will provide an early focus on actual alternative sites and emplacement of a few hundred packages of radioactive waste into an at-depth Test and Evaluation Facility (T&E) by 1990. Primary focus will be on three sites to allow an early determination that these sites meet generalized standards compatible with those under development by the EPA and NRC. These three sites are Hanford Site (basalt), Nevada Test Site (tuff), and a preferred salt site, to be determined. Work will subsequently proceed on the detailed site characterization, including exploratory shaft and at-depth testing to determine site suitability. The T&E, to be located at

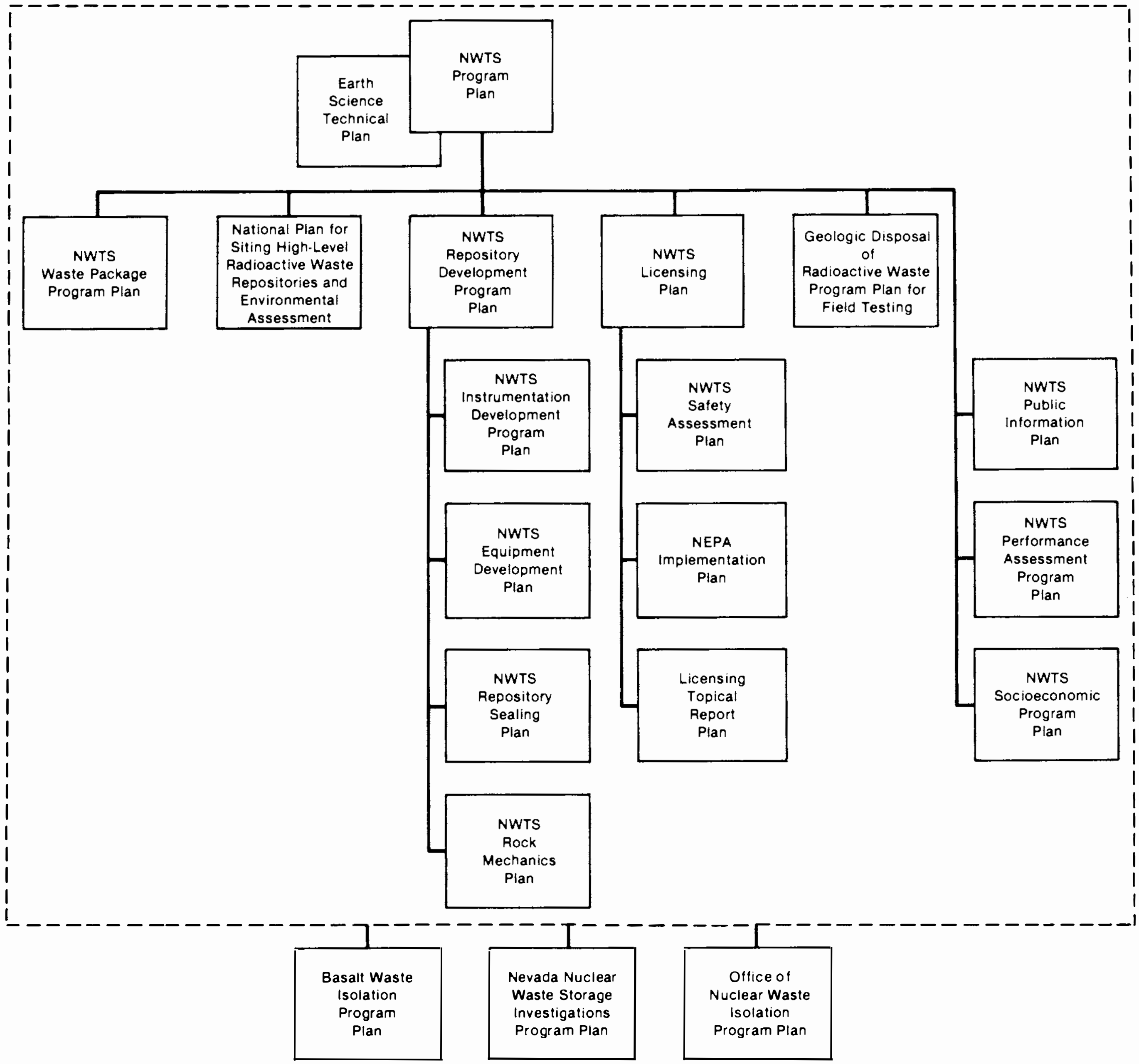


Figure B-4
Major Planning Documents of the NWTS Program

one of the three sites subsequent to exploratory shaft sinking, will allow the program to gain operational experience with waste handling, emplacement, and retrieval on a scale representative of a full-scale facility. The information gained from the T&E will be useful in design, and operation of full-scale repository. The T&E site, the other two sites at which exploratory shafts have been completed, and diverse geologies, such as granite, that are under long-term evaluation should provide multiple candidate sites for a regional repository system. The first repository location will be selected either after the first three sites have been deemed suitable (thus meeting the minimum requirements of 10 CFR 60), or after additional candidate sites in other media are available. The timing of this selection will be based on the availability of funding for detailed site characterization, as well as technical and institutional considerations. The NWTS program activities are being planned to support this strategy. These activities will be discussed below in terms of the mined geologic repository system.

As illustrated in Figure B-5, DOE subdivides the mined geologic repository system into three major subsystems: the waste package, including the waste-bearing canister and associated overpacks and barriers; the repository, including retarding backfills and seals; and the site, which consists of the host rock, the surrounding geologic formations, and the hydrogeologic environment. The man-made or engineered barriers incorporated in the waste package and repository subsystems will provide containment of the waste, delaying the initiation of and retarding the rate of radionuclide release to the host rock. The host rock and the natural geologic and hydrologic features of the repository site, as well as the remoteness of the repository (in terms of depth below the surface and distance from water supplies), will provide natural barriers for isolating radioactive waste from people and their environment. To ensure compatibility and to enhance the effectiveness of the barriers, these subsystems are analyzed together as a system in the selection of the host rock and repository site, as well as in the design of the waste package and repository structure. Each of the components of the mined geologic disposal system has been designated as a major task within the NWTS program and is discussed below.

Waste Package. The first of the major barriers to the release of radionuclides is the waste package, as shown in Figure B-5. Its ability to provide containment will be based on a system of multiple engineered barriers that include a leach-resistant waste form, a high-integrity canister, and buffers and radionuclide migration retardants. The functions and performance criteria will be described in the Waste Package Performance Criteria document (U.S. Department of Energy, 1981i). The program for R&D, design, fabrication, and testing, along with a detailed schedule, is presented in the Waste Package Program Plan (U.S. Department of Energy, 1981k).

Technical criteria proposed in the preliminary version of 10 CFR 60 require that the waste package contain the radionuclides for a period of at least 1000 years. The waste package program is directed toward developing the test methods for experimentally verifying the waste package system's performance, developing the models and calculational approach to predicting the long-term behavior of the package, and measuring the properties and performance characteristics of materials with which to construct the package. Figure B-6 is the schematic flow diagram for the development of a waste package.

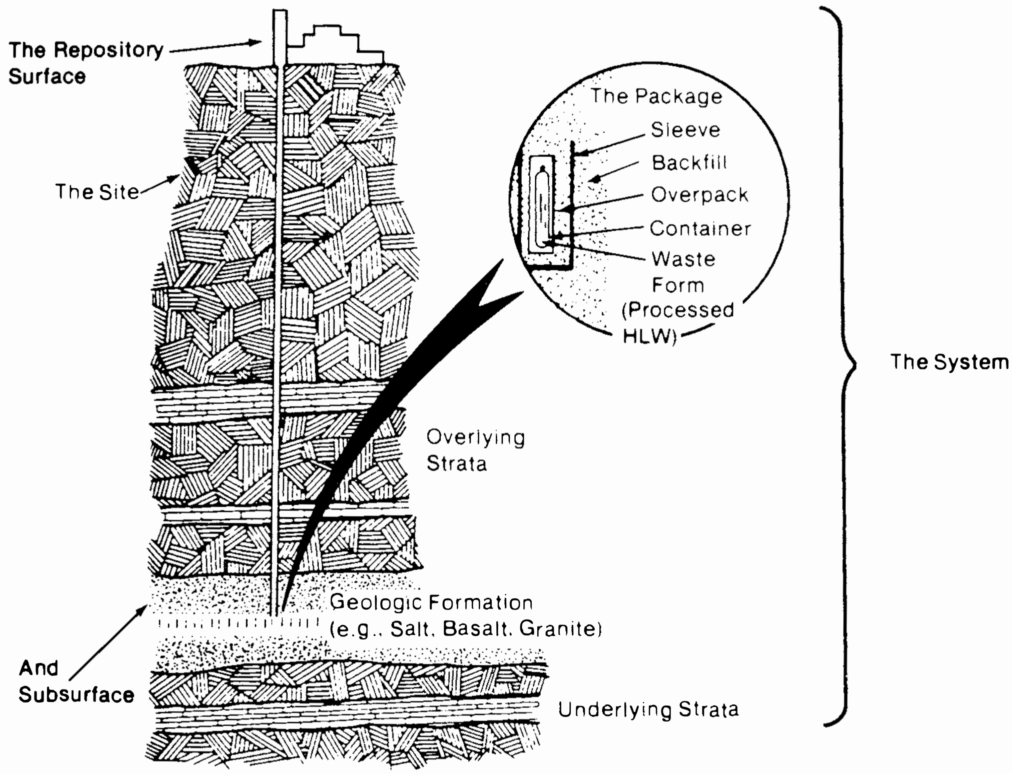


Figure B-5
Geologic Disposal System

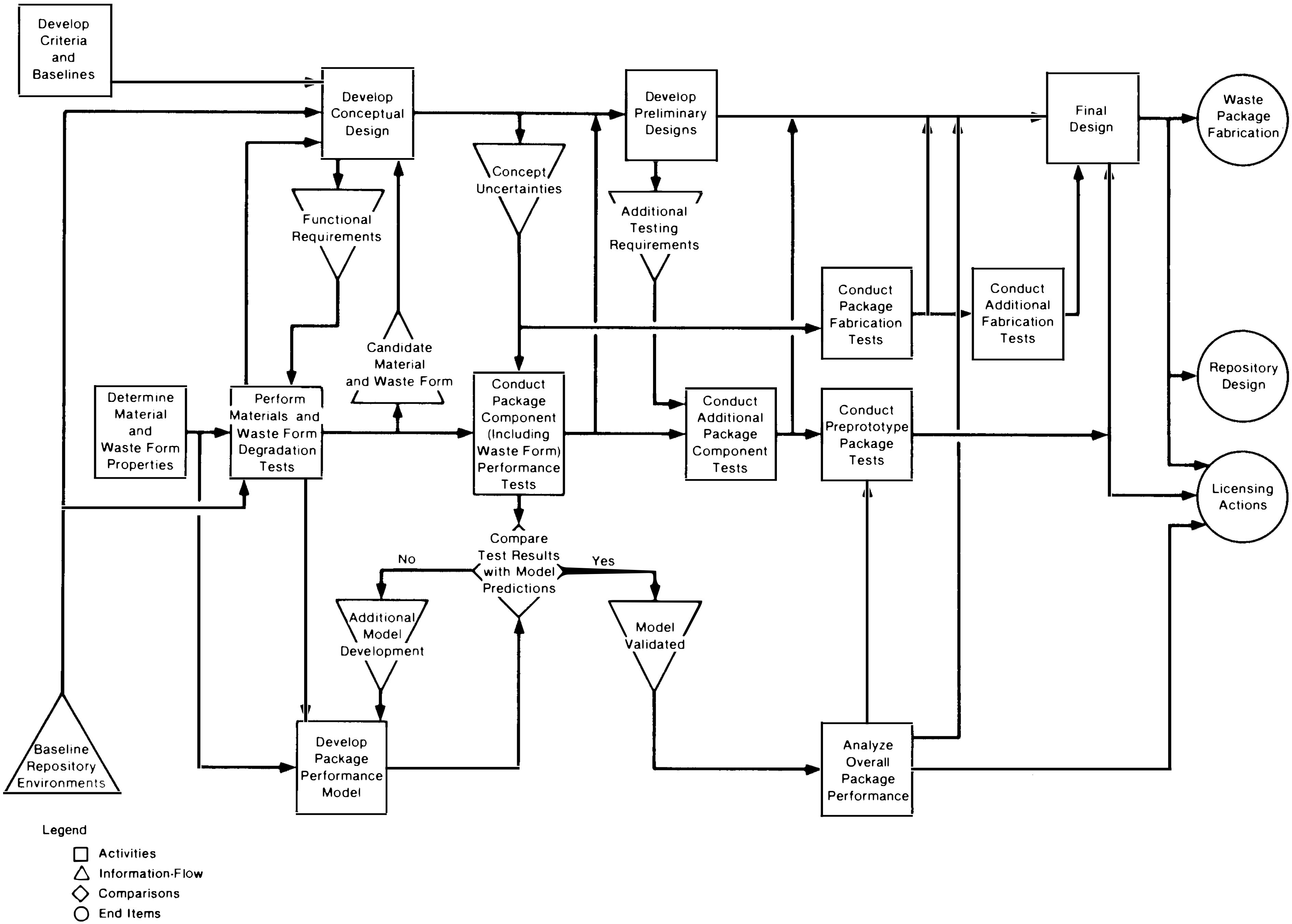


Figure B-6

Waste Package Program Work Flow

Extensive testing and development studies of various individual barrier components of the waste package under expected conditions of geologic isolation have been in progress for several years. While most of these studies are not complete, the data and results generated during the past few years do indicate that components of the waste package can delay and minimize release of radionuclides to the natural system by functioning as effective chemical and physical barriers.

Because of the many candidate materials suggested for each component of the waste package, barrier development programs have been initiated to address this area in a logical sequence, starting with simple materials screening, followed by interaction tests of increasing scale and complexity. Presently, most tests are being carried out in the laboratory, usually on single components, with tests focused on modeling the performance of the individual components. Most of the current laboratory tests are using simulated waste forms without the influence of a radiation field. Tests using radioactive materials will be run at a later date to ensure that the effect of radiation does not have a significant deleterious effect on component performance.

Experiments that simulate repository conditions and integrate the behavio of waste package components and the geological media are also in progress. Laboratory efforts directed toward more complex testing of subsystems involving more than one component are planned. Through such evaluations and accelerated tests, coupled models of the waste package component interactions will be developed. The results of such tests will support a decision on the materials to be considered in package conceptual design studies. This series of studies, investigating waste package component performance and qualification, will culminate in a large-scale system test specific to each repository host rock type, involving all components of the waste package. Such tests may be performed in the field to confirm the results of earlier detailed laboratory and large-scale tests. It is currently planned that prototype high-level waste packages will be emplaced in the Test and Evaluation Facility. Data on waste package handling in such a facility will provide input into the final design of the actual waste packages for repositories.

The NWTS program has developed a Waste Package Program Plan that provides the standards to be followed with respect to testing procedures and materials certification, and coordination of specific development activities among researchers and waste management entities. For review and integration, a Materials Steering Committee (MSC), a Materials Review Board (MRB), and a Materials Characterization Center (MCC) have been established. The MRB provides the overall coordination of activities. These organizations have been charged with supporting waste package design, development, and testing programs. The final objective is to produce suitable packages that meet established requirements.

Repository. The second major component of the waste isolation system is the repository structure, which includes the surface and subsurface facilities designed to receive waste. While the subsurface portion of the repository is basically a system of drifts within the natural host rock, this component contributes to overall system performance by limiting adverse impacts of excavation and emplacement activities on the site by emplacing backfill and seals in the underground openings at the time of decommissioning. The functions and performance criteria for the repository are described in the Repository Performance and Development Criteria document (U.S. Department of Energy, 1981h). The program for the development of repository technology will be covered in the Repository Development Program Plan. Details of the program will be further described and presented in two subtask plans: Rock Mechanics Plan, and Repository Sealing Plan.

NRC's proposed technical rule, 10 CFR 60, specifies that the release rate from the repository be less than 1 part in 100,000 per year of the amount present at 1000 years after the repository is sealed. The EPA proposed standard provides a limit on the quantity of specified radionuclides released from the repository over a 10,000-year period. Also, the proposed 10 CFR 60 technical criteria require that the repository shall be designed with the capability to retrieve all the emplaced waste for up to 50 years after emplacement room backfill. The repository development program, along with the waste package program, is directed toward developing the methods and technology to meet regulatory requirements as they evolve.

The repository structure must be designed to ensure that construction, emplacement of radioactive waste, and the effects of the waste will not compromise the natural integrity of the site. Also, the repository environment must be sufficiently defined to show that there are no interactions that will significantly compromise the performance of the waste package designs. The models for waste package and repository performance are integrated into what has been termed a near-field model. This model is then integrated with the model of the site, which has been termed a far-field model. These integrated far- and near-field models will be used to evaluate the effectiveness of the overall isolation system. Current activities are providing the basis for future design and performance assessments of repository structures. Rock mechanics research is being conducted for a broad set of geologic media to provide the basic understanding of the mechanical behavior of the media. Both laboratory and field tests are being conducted to provide the basic data on thermal, mechanical, and hydrological interactions, and combined effects in potential host media. Laboratory studies are underway to define the interactions between host rock, groundwater, and emplaced material which may influence radionuclide mobility and transport. Waste-induced influences, such as radiation and heat, on chemical reactions, are being investigated. Laboratory tests to obtain leaching and retardation coefficients for various waste form and host rock combinations are also being conducted. Improvements in understanding the transport mechanisms and predictive capabilities will result from these studies.

Field testing is being conducted to provide the required technology data base for assessing the validity of analytical models, comparing in-situ and laboratory behavior, and confirming by demonstrating the behavior of radioactive wastes emplaced in various geologies. In addition, to support facility development and licensing requirements for a repository, engineering design information must be obtained in the various candidate media. Presently, there are a number of field-testing activities underway or planned in the various media; Table B-4 is a summary of these activities. As part of the at-depth test program to be conducted at each potential site following exploratory shaft sinking, engineering confirmation tests will be conducted in the proposed repository horizon. The scope of these tests is currently under development.

Table B-4

REPOSITORY PROGRAM TEST FACILITIES

MEDIUM	FACILITY	LOCATION	SCOPE	PERIOD	COMMENTS
Salt Dome	Avery Island	Louisiana	• Thermomechanical • Brine migration	1978 - 1980 1980 - 1981	Three heater tests
Granite	Stripa (abandoned iron mine)	Sweden (U.S. partici-pation)	• Geohydrology • Thermomechanics • Rock mechanics • Fracturing/Frac-ture Hydrology	1978 - current	Heater tests, ventilation drift test
Granite	Climax	NTS	• Thermomechanics • Handling of spent • Fuel; Radiation effects • Radionuclide Mi-gration	1980 - 1985	Eleven canistered spent fuel assemblies, electric heaters, tracers and radioactive nuclides
Granite	Colorado School of Mines Experimental Mine	Colorado	• Effect of blast-ing on granite • Thermomechanics	1979 - 1984	Block tests
Basalt	Near Surface Test Facility (NSTF)	Hanford	• Thermomechanics • Rock mechanics	1980 - 1985	Heater and block tests
Tuff	G Tunnel	NTS	• Thermomechanics • Radionuclide Migration	1980 - 1985	Tracers and radioactive nuclides

Source: Adapted from U.S. Department of Energy. April 1980v. Statement of Position of the U.S. Department of Energy: Waste Confidence Rulemaking, U.S. Nuclear Regulatory Commission. DOE/NE-0007.

Studies are being conducted to identify performance criteria for repository structures, and to identify equipment and instrumentation requirements for repository construction, operation, decommissioning, and monitoring. Because of the recognized importance of sealing the repository, borehole and shaft-sealing laboratory and field tests are also being performed. The following paragraphs describe these activities in more detail. It is currently expected that the Test and Evaluation Facility will provide the capability to demonstrate some of these technologies as deemed necessary.

Engineering activities related to the repository include the development of specialized techniques and equipment, as well as design of the repository and related support facilities. An early continuing activity is the development of engineering design criteria to be used to guide the initial design of the facility, its equipment, and the testing to obtain operating data on prototype equipment. Equipment reliability and maintenance requirements will be addressed, as well as the functional requirements of size, weight, materials of construction, and performance. Following criteria development, processes and equipment can be specified and developed in the areas of waste packaging, handling, emplacing, mining, decommissioning (e.g., room backfilling), retrievability, security and safeguards, and occupational safety. Much of this work involves items unique to a repository, such as retrieval equipment and techniques. Mining processes will be adapted to ensure that containment and isolation integrity of the host rock are not compromised. Techniques and related instrumentation will be developed to ensure occupational safety of workers during the operational phase of the repository.

High-integrity repository sealing is desirable in order to ensure long-term waste isolation. Therefore, an extensive effort is underway to develop materials, design configurations, and emplacement techniques for repository sealing which are compatible with conditions that may be present at the sites selected for geologic repositories. Laboratory investigations of sealing material-rock interactions are in progress, as are literature searches and field investigations into geochemical conditions in candidate sites. These activities will lead to field testing and demonstrations of satisfactory seal designs. An initial borehole-seal field test has been completed in salt, and additional tests are being planned for basalt, salt, and tuff in the future.

Site. The final major component of the waste isolation system is the site. The site will be selected to include natural barriers that provide containment and isolation by: (1) maintaining the waste in its emplaced condition for a given period of time; (2) limiting radionuclide mobility through the geohydrologic environment to the biosphere; and (3) assisting in keeping man away from the waste (i.e., minimizing intrusion incentives such as a valuable resource). The site will contain a host rock suitable for construction of the repository and containment of the waste, as well as surrounding rock formations which can provide adequate isolation. General repository site performance criteria for the NWTS Program are contained in the Site Performance Criteria document (U.S. Department of Energy, 1981g). These final criteria are summarized in Table B-5. The program for screening characterization, and selection of sites is described in the NWTS National Plan for Siting High-Level Waste Repositories (U.S. Department of Energy, 1982).

An Earth Science Technical Plan (U.S. Department of Energy and U.S. Department

Table B-5

SITE PERFORMANCE CRITERIA

I. Site Geometry

- Minimum Depth
- Thickness
- Lateral Extent

II. Geohydrology

- Hydrological/Geochemical Regime/Path Length/Travel Time
- Aquifer Flow/Construction
- Dissolution of Rock
- Water Bodies/Climatic Cycles

III. Geochemistry

- Chemical Interactions
- Radionuclide Retardation

IV. Geology

- Stratigraphy
- Host Rock Characteristics
- Virgin Rock Strength

V. Tectonic Environment

- Seismicity
- Quaternary Faults
- Quaternary Igneous Activity
- Uplift or Subsidence Rates
- Tectonic Elements

VI. Human Intrusion

- Resources
- Exploration History
- Ownership and Control

VII. Surface Characteristics

- Hydrological System
- Topographic Features
- Meteorological Phenomena
- Industrial/Transportation/ Military Installations

VIII. Demography

- Transportation
- Urban Areas

IX. Environmental Protection

- Wilderness
- Rivers
- Wildlife
- National Parks
- Archaeology
- National Heritage
- Ambient Conditions

X. Socioeconomic Impacts

- Transportation Impacts
- Management of Impacts

Source: U.S. Department of Energy. February 1981g. NWTS Program Criteria for Mined Geologic Disposal of Nuclear Waste: Site Performance Criteria. DOE/NWTS-33(2), NWTS Program Office.

of the Interior, Geologic Survey, 1980dd), which identifies the basic scientific information necessary to evaluate the suitability of a site for location of a repository, has been jointly developed by DOE and USGS and is being implemented. Methods for predicting the ability of potential sites to fulfill their function in isolation of the waste have been developed and are being refined and verified.

Technical criteria in the proposed 10 CFR 60 contain specific siting requirements, including identification of potentially adverse site conditions and favorable site characteristics (10 CFR 60.122). The NWTS program is directed toward the identification, characterization, qualification, and selection of sites that will meet these regulatory requirements when they are issued.

Several media, including salt, basalt, granite, and tuff, have been identified as having features that could make them acceptable as host media for geologic repositories. Evaluation of these media is being carried out by relating them to the NWTS site performance criteria. These considerations are currently in various stages of the screening process. As stated earlier, emphasis in the near-term is on basalt, tuff, and salt, while other media are being considered over the long-term.

The siting process involves geological and environmental characterization studies to identify potential sites for mined geologic repositories and to obtain the technical data necessary to determine suitability of these sites. Steps in the site screening and characterization process are as follows:

1. National screening surveys.

2. Determination of regions for further study (up to several States in extent).

3. Recommendation of areas for more detailed investigation (up to a few thousand square miles).

4. Recommendation of specific locations for in-depth study (up to several tens of square miles).

5. Recommendation of preferred sites for detailed site characterization to confirm suitability.

Site searches are initiated by national screening surveys. Starting with the contiguous United States, the initial step in site exploration and characterization is to identify places that have some potential for waste isolation. These places may be regions (up to several hundred thousand square miles in area) or land areas having a particular suitability feature. National screening surveys have been structured in different ways, depending on the site suitability feature that is sought initially, as follows:

- A geologic approach, beginning with consideration of potentially suitable host rocks and identification of regions containing these formations. Early in the program, for example, rock salt was identified as a potentially suitable host medium; thus regions in the contiguous United States containing salt domes and bedded salt formations were delineated as starting points for site screening. Recently, DOE has screened the U.S. for regions containing crystalline and argillaceous rocks.

- An approach considering current land use. Examples of this approach are the studies being conducted at the Hanford Site and the Nevada Test Site, both of which are large tracts of land owned by the Federal Government and currently used for nuclear activities. These government reservations are classified as "areas" in the steps in the siting process. Investigations of both areas were initiated to determine whether geologic and hydrologic conditions, as well as other considerations, would allow use of these dedicated lands for waste repository sites.

- An approach, province screening, based on scrutiny of successively smaller units of land based on geohydrologic conditions, including multiple natural barriers to radionuclide migration. This approach provides further assurance that otherwise unexamined geologic formations having favorable repository properties will not be overlooked where they occur in a suitable geohydrologic environment. The USGS is initiating this approach in one of eleven provinces through a Province Working Group.

- An approach based on the consideration of all site suitability criteria also is being considered to screen the United States for sites. This systems screening approach, if implemented, should identify regions or smaller areas of potential use for repositories by simultaneously applying safety, environmental, and socioeconomic criteria for which there are useful data.

The host rock and land-use approaches may identify candidate sites from which the first site for a repository will be selected. Other approaches may identify alternative sites for later repositories.

Whether the starting point of the site selection process is selection of regions according to rock type, land use, hydrology, or some combination of these factors, the subsequent steps in the screening process are similar. The process established for proceeding through these subsequent steps is described in the National Plan for Siting High-Level Radioactive Waste Repositories (U.S. Department of Energy, 1982).

The status of activities related to characterization efforts as of September 1981 is:

- Final DOE site performance criteria that incorporate public comments were issued in April 1981.

- The Earth Science Technical Plan was issued jointly by DOE and the USGS in 1980. The research and development needs identified in the document are being implemented.

- Development of models for predicting the performance of geologic site waste isolation systems is continuing. Trial applications of preliminary models have been made.

Regions and areas containing salt, crystalline, basalt, and tuff rocks have been identified. Further studies on crystalline rocks in the Lake Superior region are pending negotiations with States on the proposed plans for characterization. Regional studies of crystalline rocks in the Appalachians have been started.

A national screening survey for other potential isolation systems has been planned but not yet implemented. A draft national survey report of studies to identify regions containing potentially suitable argillaceous rocks has been completed, but no siting activity in argillaceous rocks is planned.

Regional studies have been completed for the New York and Ohio portions of the Salina region. Recommendations for further studies are pending agreements between the States and DOE. Plans for regional studies in Michigan are being negotiated with that State.

Area characterization studies of the salt domes in the Gulf Coast region are nearing completion. DOE has recommended limited study of four of these domes. These studies will address key issues at each of these four locations to enable one site to be recommended. Once this choice is made, the recommended salt dome site may receive additional limited study to enable a comparison of it with one or more potential sites from the Paradox and Permian salt regions. One of these salt sites will then be characterized by an exploratory shaft and in-situ testing.

Area-level studies are currently being conducted in the Paradox region of Utah. Area studies are nearing completion in the Palo Duro and Dalhart areas of the Permian Basin in Texas.

Drilling and other field activities as part of location-level studies are in progress at potential locations on DOE's Nevada Test Site and Hanford Site in volcanic tuff and basalt environments, respectively.

Schedule

The reference schedule for permanent isolation in a geologic repository is shown in Figure B-7. The elements in the critical path leading to the first repository are summarized below:

- 1983 — Begin exploratory shafts at three potential sites--Hanford basalt, NTS tuff, and a salt site.
- 1985 — Reach proposed repository depth and begin in-situ investigations. Select one of first three sites for Test and Evaluation Facility site, and begin site-specific detailed design of the facility.
- 1986 — Initiate construction of the Test and Evaluation Facility.
- 1985 to 1988 — Continue underground testing for detailed characterization at the three sites with exploratory shafts. Continue characterization of additional potential sites including

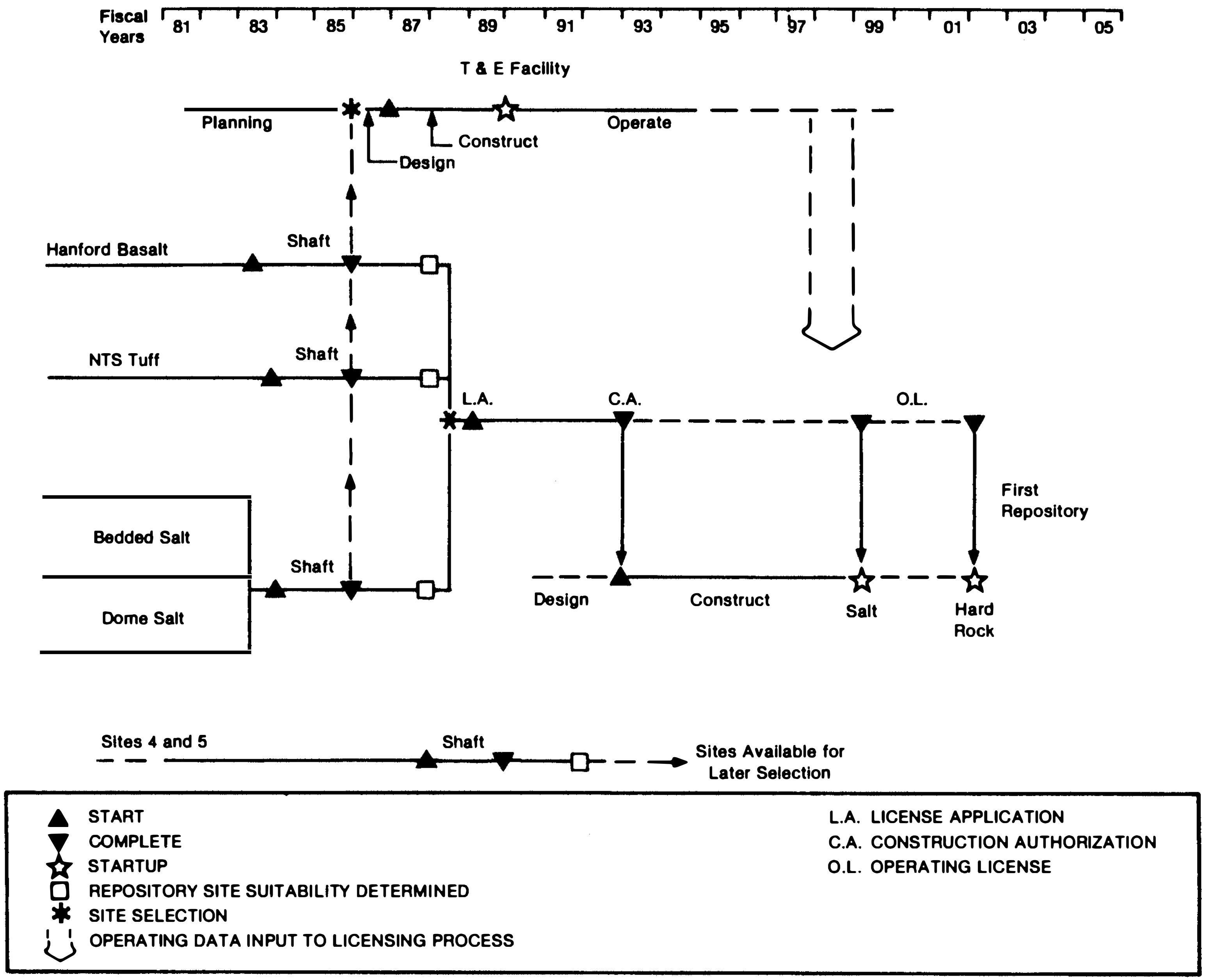


Figure B-7
Reference Schedule of Activities Leading to Geologic Repository Operation

exploratory shafts. Continue technology development to support the repository.

- o 1988 — Apply to the NRC for construction authorization at a site selected from among first three site alternatives.
- o 1989 — Complete construction of Test and Evaluation Facility and initiate emplacement of wastes.
- o 1992 — Issuance of the construction authorization by NRC.
- o 1998 to 2001 — Completion of construction and checkout for first repository.

Implementation of NEPA in the NWTS Program

In managing the National Waste Terminal Storage (NWTS) Program, DOE may undertake actions having potential environmental consequences, the effects and significance of which vary. Actions range from decisions on the overall strategy for waste disposal (involving a major resource commitment which ultimately may have a spectrum of potential environmental effects specific to that strategy) to the selection of specific sites for waste disposal facilities. Other actions include the conduct of research, which may have little environmental effect, but which may have important technological, cost, and time implications on long-term waste disposal.

DOE has developed a NEPA Implementation Plan which is integrated with the overall DOE planning and decision-making framework for the deep geologic disposal strategy. A NEPA Implementation Plan is found in the Statement of Position of the United States Department of Energy (DOE/NE-0007) filed In the Matter of Proposed Rulemaking on the Storage and Disposal of Nuclear Waste (Waste Confidence Rulemaking). Modifications to this plan are underway because of the changes in NRC's requirement for exploratory shaft construction and in situ testing at three alternative sites prior to DOE submitting a license application.

The program's NEPA Implementation Plan is based on the "tiered" approach, which is designed to eliminate repetitive discussions of the same issues and to focus on the actual issues ripe for decision at each level of environmental review. This approach allows coverage of general matters in broad EISs with subsequent narrower EISs or EAs incorporating by reference the general discussions and concentrating solely on the issues specific to the subsequent decision.

The first major decision process in the NWTS program was the selection of a program strategy for disposal of nuclear waste. The environmental effects of selecting a program strategy, including the selection of a preferred technical concept for waste disposal, are addressed in the Final EIS on Management of Commercially Generated Radioactive Waste, DOE/EIS/0045F (October 1980). Ten concepts, including mined geologic disposal, are analyzed in the EIS. The substantive issues raised through the public comment process were reviewed and addressed in the Final EIS. The Record of Decision selecting the mined geologic disposal program alternative was published on May 4, 1981 (46 Fed. Reg. 26677). The second major decision process is that involving the selection of sites for the disposal of nuclear waste. The major points in the site selection process are:

1. Adoption of a National Plan for Siting High-Level Radioactive Waste Repositories and performance of screening surveys.

2. Detailed site studies (including exploratory shaft).

3. Acquiring an interest in land, including action to protect potential sites from other uses.

4. Selection of a candidate site for the first, or a subsequent, repository.

The selection of a site for the T&E Facility is not part of, but is related to, the repository siting process. Because such a facility may cause impacts at a site under study for a repository, it is included in the NEPA implementation planning.

While the appropriate NEPA document is being prepared for the various decision points, program activities that have been analyzed in previous NEPA documents may continue. In addition, new site characterization activities may begin, if it is clear, on the basis of DOE's review, that they do not (1) have an adverse environmental impact or (2) limit the choice of reasonable alternatives. These activities could include additional environmental studies, routine geophysical studies, and borehole drilling.

REFERENCES

U.S. Department of Energy and U.S. Department of the Interior, Geological Survey. 1980dd. Earth Science Technical Plan for Disposal of Radioactive Waste in a Mined Repository. DOE/TIC-11033.

U.S. Department of Energy. 1980y. Final Environmental Impact Statement: Management of Commercially Generated Radioactive Waste. DOE/EIS-0046F.

U.S. Department of Energy. April 1981e. NWTS Program Criteria for Mined Geologic Disposal of Nuclear Waste: Program Objectives, Functional Requirements, and System Performance Criteria. DOE/NWTS-33(1), Public Draft. NWTS Program Office, Columbus, OH.

U.S. Department of Energy. February 1981g. NWTS Program Criteria for Mined Geologic Disposal of Nuclear Waste: Site Performance Criteria. DOE/NWTS-33(2). NWTS Program Office.

U.S. Department of Energy. 1981h. NWTS Program Criteria for Mined Geologic Disposal of Nuclear Waste: Repository Performance and Development Criteria. DOE/NWTS-33(3), Draft. NWTS Program Office.

U.S. Department of Energy. 1981i. NWTS Program Criteria for Mined Geologic Disposal of Nuclear Waste: Waste Package Performance Criteria. DOE/NWTS-33(4), Draft. NWTS Program Office.

U.S. Department of Energy. 1981k. NWTS Waste Package Programs Plan Volume II: Program Logic Networks. DOE/NWTS-96, Draft. NWTS Program Office.

U.S. Department of Energy. 1982. National Plan for Siting High-Level Radioactive Waste Repositories and Environmental Assessment. DOE/NWTS-4, and DOE/EA-151, February 1982, Washington, DC.

U.S. Nuclear Regulatory Commission. 1981g. "10 CFR Parts 60 - Disposal of High-Level Radioactive Wastes in Geologic Repositories: Technical Criteria, Proposed Rule." Federal Register 46 FR 130:35280-35296.

Appendix C
EXCERPTS FROM CRBR SAFETY STUDY,
CRBRP-1, MARCH 1977

EXECUTIVE SUMMARY

SECTION 1. INTRODUCTION AND RESULTS

The objective of the CRBRP risk assessment is to provide a realistic evaluation of the risk to the public from the Clinch River Breeder Reactor Plant, to place that risk in perspective relative to other societal risks, and to provide a basis for assessing the comparability of the risk from the CRBRP with risks associated with previously licensed reactors. The assessment formally and systematically evaluated the CRBRP risk and showed that

- o the risk associated with postulated accidents of the CRBRP is negligible when compared with nonnuclear risks to which the local population is already exposed,
- o CRBRP risks are comparable to those from light-water reactors (LWRs) of the current generation as characterized in the Reactor Safety Study (RSS),[1]
- o the results of this study and those presented in the RSS reveal that the societal risk from currently defined nuclear power systems (both LWRs and the CRBRP) is extremely small.

To present a proper perspective on CRBRP accident risk, it is compared with those risks arising from other sources. Because calculations have predicted that all early* fatalities caused by highly improbable CRBRP accidents would occur within 10 miles of the site, nonnuclear risks have been evaluated for the population (approximately 42,000) living within that region. Some of the nonnuclear risks occur as a direct result of man-caused activities, whereas others arise from naturally occurring phenomena. Figures C-1 and C-2 provide a comparison between several of the nonnuclear societal risks and the risk from CRBRP accidents; they show that the CRBRP risk is much lower than other societal risks. For example, explosions are more than 10,000 times more likely and tornados approximately 1000 times more likely to cause a given number of fatalities than is the CRBRP.

Risk can also be expressed in terms of individual risk of death per year. Table C-1 compares individual risks from both natural and man-caused sources with individual risk from the CRBRP. This table shows that a person living within 10 miles of the CRBRP site is 100 thousand times more likely to be fatally injured by lightning and 1 million times more likely to drown than to be fatally injured by a CRBRP accident.

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[1] Reactor Safety Study, Main Report, United States Nuclear Regulatory Commission, WASH-1400, (NUREG-75/014) (October 1975).

*Early fatalities are defined as those occurring within one year of a core-disruptive accident; they would be due largely to acute radiation exposure from noble gases.

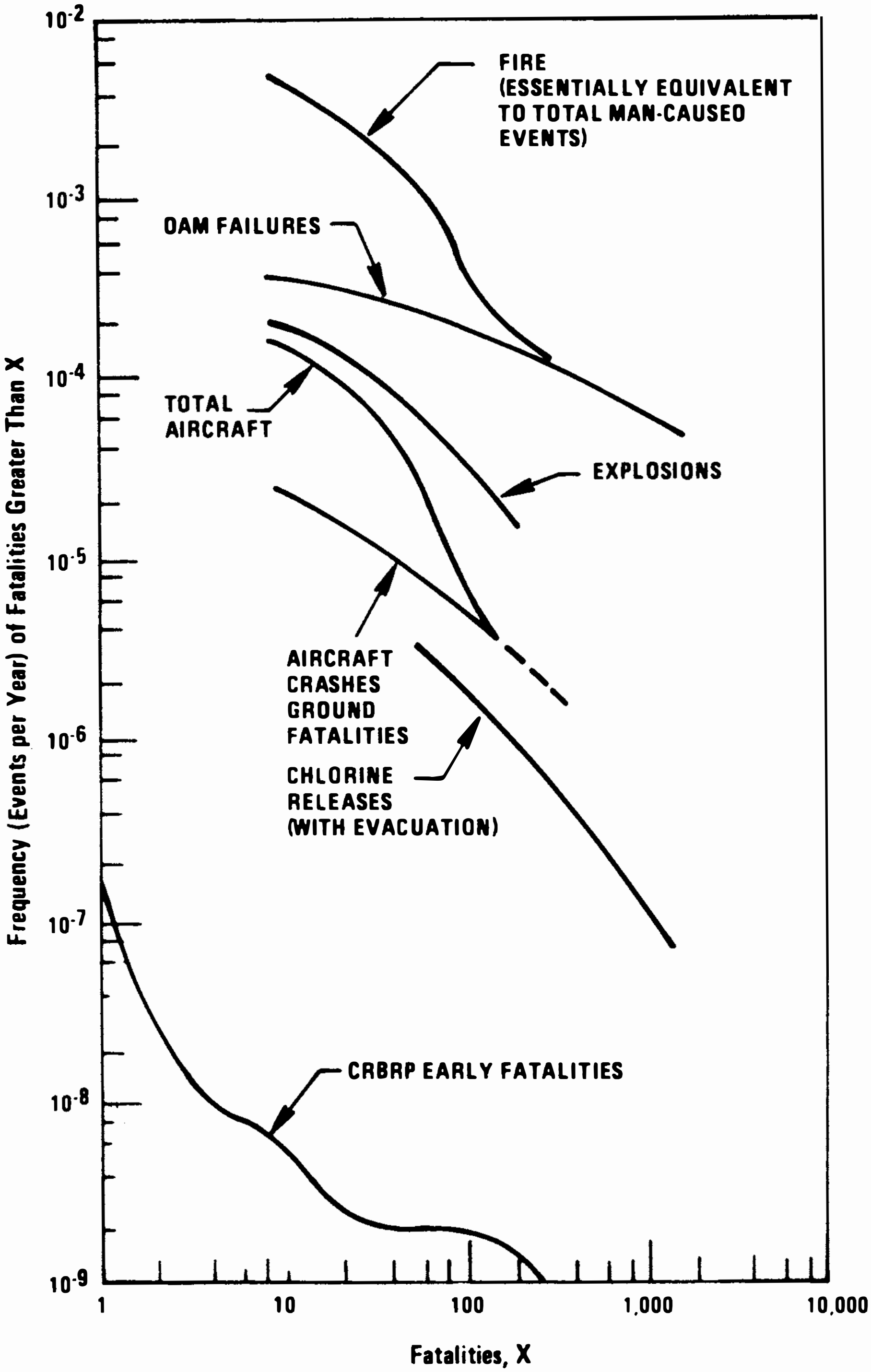

Figure C-1

Frequency of Fatalities Due to Man-Caused Events
Occurring within 10 Miles of the CRBRP Site

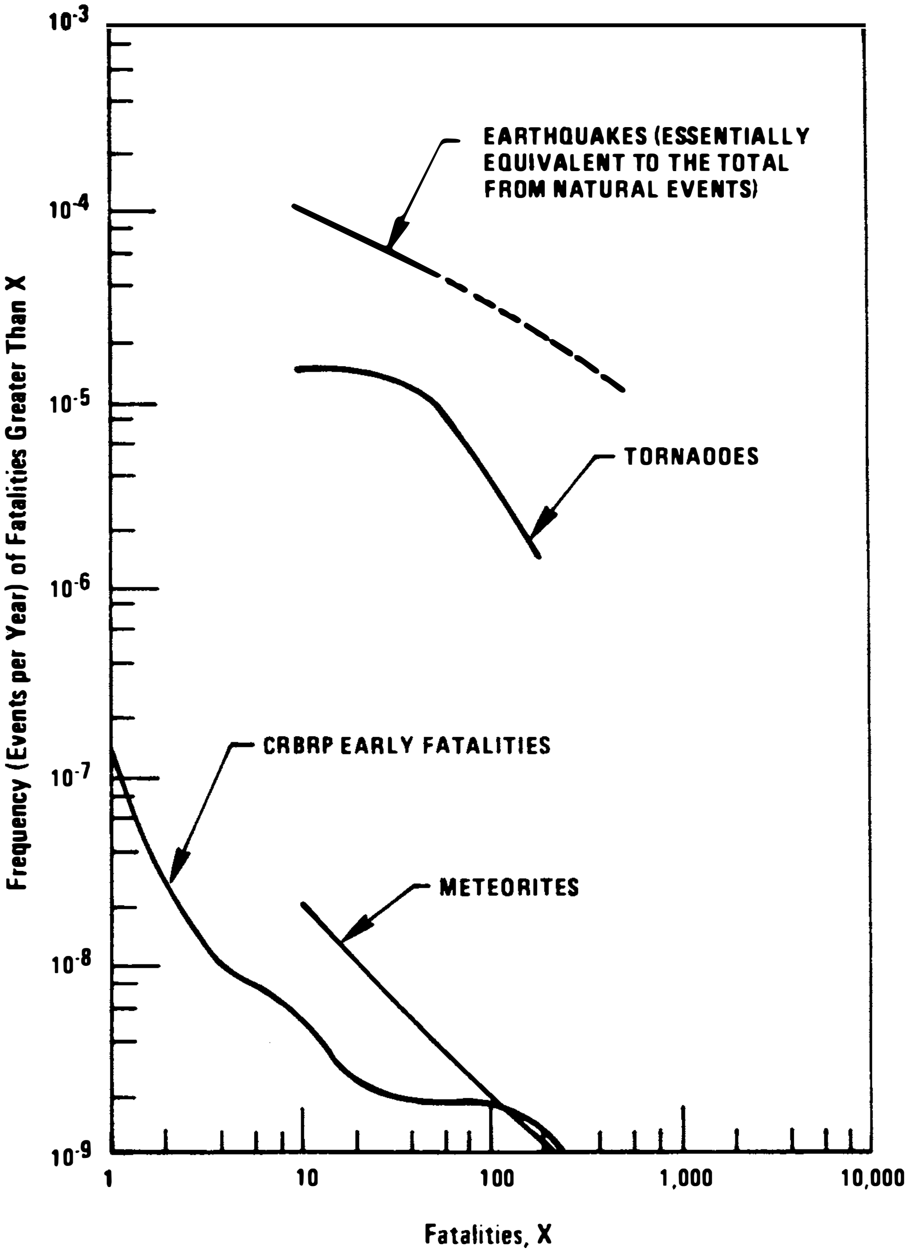

Figure C-2

Frequency of Fatalities Due to Natural Events Occurring within 10 Miles of the CRBRP Site

Table C-1
Individual Risk of Fatality by Various Causes.[a]

Source of Fatality	Death per Resident per Year: Probability	Chance
Motor vehicles	3.7×10^{-4}	1 in 2,700
Falls	8.1×10^{-5}	1 in 12,000
Fires and burns	3.1×10^{-5}	1 in 32,000
Drowning	2.6×10^{-5}	1 in 38,000
Poison	2.5×10^{-5}	1 in 40,000
Firearms	1.3×10^{-5}	1 in 77,000
Water transport[b]	7.6×10^{-6}	1 in 132,000
Air transport[b]	5.2×10^{-6}	1 in 192,000
Railroad transport[b]	3.3×10^{-6}	1 in 303,000
Farm accidents[c]	1.7×10^{-6}	1 in 5,900
Electricity usage	5.2×10^{-6}	1 in 192,000
Lightning	3.2×10^{-6}	1 in 313,000
Tornadoes	3.0×10^{-7}	1 in 3.3 million
All accidents	7.2×10^{-4}	1 in 1,400
Suicide	1.2×10^{-4}	1 in 8,300
Homicide	1.4×10^{-4}	1 in 7,100
Cancer	1.8×10^{-3}	1 in 550
LWRs[d]	4.3×10^{-11}	1 in 20 billion
CRBRP accidents		
Early[e]	2.9×10^{-11}	1 in 30 billion
Latent[f]	4.5×10^{-12}	1 in 200 billion

[a]These probabilities have been derived from data for the population within 50 miles of the CRBRP site for the year 1973 (approximately 700,000). Year-to-year variations are expected to be small, as are local population variations within this region.

[b]Excludes persons on duty.

[c]Per farm residents only.

[d]Based on RSS estimate of early fatalities for one reactor and all affected population within 25 miles.

[e]The estimated probability of early fatalities per resident per year based on the assessment presented in this report for the population within 10 miles of the CRBRP site (approximately 42,000).

[f]The estimated probability of latent fatality per resident per year based on the assessment presented in this report for the population within 10 miles of the CRBRP site.

The CRBRP risk arises from a number of highly improbable accidents that have the potential for release of radioactivity from the reactor core into the environment. Although all those accidents are very low probability events, some are more likely to occur than others. The potential for release of any radioactivity exists only for accidents of very low probability. For example, the most likely such accident is estimated to have a probability of occurrence of about 1 in 50,000 per year of CRBRP operation. The radioactivity release associated with that event would be quite small and would cause an insignificant effect on public health. On the other hand, an extremely improbable accident that could affect a large number of people is estimated to have a probability of occurrence of 1 in 200 million per year of CRBRP operation.

As coexisting facets of the nuclear power industry, the LWRs and the CRBRP make a very small contribution to the overall risk to society. Figures C-3 and C-4 show the distributions of early and latent* fatalities for the CRBRP and a typical LWR. When considered in the context of the technological and natural contributions to risk presented in Figures C-1 and C-2, the comparisons in Figures C-3 and C-4 indicate that neither the CRBRP nor a typical LWR makes a significant contribution to overall risk.

*Latent fatalities are defined as those occurring during the 30-year period from 10 to 40 years after a core-disruptive accident.

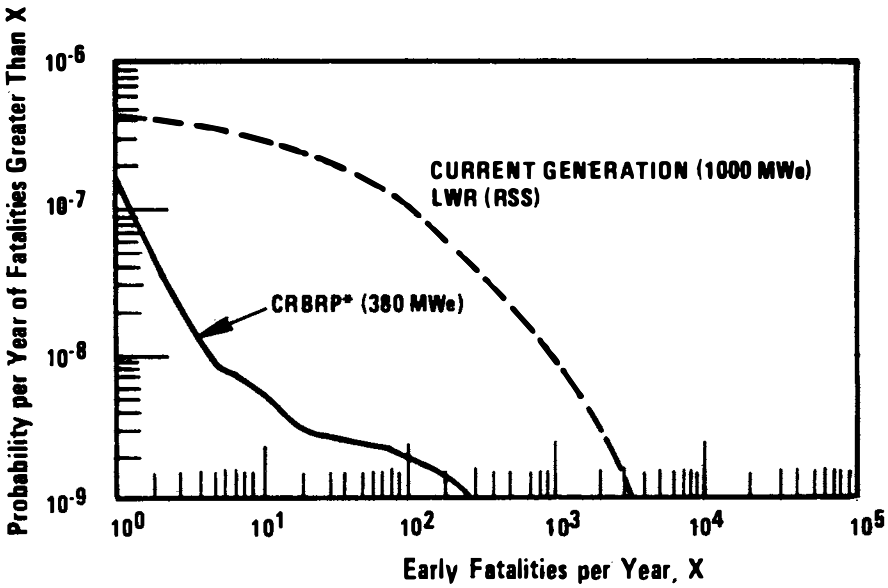

Figure C-3

Comparison of Cumulative Probability Distribution per Reactor Year for Early Fatalities Due to LWR Accidents with Early Fatalities Due to CRBRP Accidents.

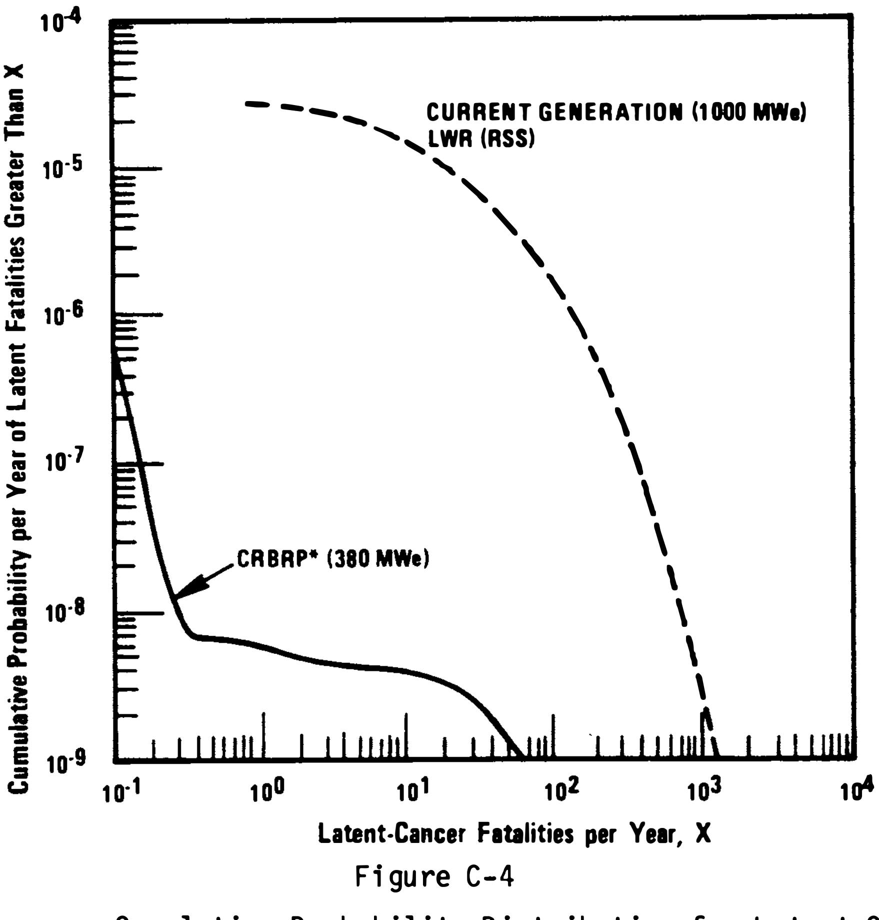

Figure C-4

Cumulative Probability Distribution for Latent-Cancer Fatality Incidence per Year: CRBRP vs. LWR.

2.3 The CRBRP Risk Assessment

2.3.1 What is the CRBRP risk assessment, and why was it carried out?

The CRBRP risk assessment is a formal and systematic study of the risk from highly improbable accidents in the CRBRP. It has been performed to place that risk in perspective with other societal risks and to provide a common basis for comparison between the CRBRP risk and the risks associated with previously licensed and operating nuclear power plants.

2.3.2 How is risk defined?

Risk has been defined as the probability, per year of reactor operation, that residents surrounding the CRBRP site will experience consequences arising from potential accidents in the CRBRP. The concept of risk involves both the likelihood that some events will occur and the consequences of the occurrence of such events. The following consequences were considered in the CRBRP risk assessment:

- early death,
- respiratory impairment,
- development of thyroid nodules,
- fatal latent cancer.

2.3.3 Was this study specifically performed for the CRBRP, or can the results be applied more generally?

The study was performed specifically for the 380-MWe CRBRP. It is site-specific in that actual weather and population data for the area surrounding the Clinch River site were used to assess the potential consequences of highly improbable accidents. Since the study was conducted only for the CRBRP at its particular site, specific results cannot be directly applied to other breeders. The general results can be used, however, for comparative purposes to gauge the risk from an LMFBR in relation to other societal risks.

2.3.4 Since the CRBRP design has not yet been finalized, is the risk assessment meaningful?

Yes, because the design is sufficiently developed to allow a meaningful risk assessment. All systems that are significant to plant safety have been described in the Preliminary Safety Analysis Report. Additional design documents and supporting information were also available. When design details were not available, conservative evaluations were made on the basis of reliability consistent with the performance of existing nuclear plants. Moreover, studies indicated that minor changes in design details or assumptions will not significantly affect the results of this assessment. The risk assessment should be viewed as a continuing effort that can be revised as more details of the design become available, as more is learned about LMFBRs, and as experience is gained in building and operating the CRBRP.

Because the study has been carried out with the CRBRP still in the design stage, two distinct benefits can be realized: The possibility exists for significant feedback into the design, which can further reduce reactor accident risks; and the risk assessment will be useful to help focus on important areas for further LMFBR safety research.

2.3.5 How does this study compare with the Rasmussen study on present light-water reactors (WASH-1400)?

The CRBRP risk assessment was patterned after WASH-1400.[1] Although there are important differences between it and WASH-1400, many of the methods and much of the information developed for WASH-1400 are applicable to the CRBRP study. To introduce risk assessment experience gained in the WASH-1400 study, key participants in that study were employed as consultants and reviewers for the CRBRP study. Some important differences between the CRBRP risk assessment and WASH-1400 are summarized in Table C-2.

Table C-2

Comparison of CRBRP Risk Assessment and WASH-1400.

	CRBRP Risk Assessment	WASH-1400
Number of reactors	1	100
Type of reactor	Liquid-metal fast breeder reactor (LMFBR)	Light-water reactor* (LWR)
Reactor power rating	380 megawatts electric (MWe)	1000 MWe
Location of reactors	On the Clinch River at Oak Ridge, Tennessee	At six composite sites representative of LWR sites throughout the United States
Status of reactors	In the final design stage; construction not yet started	More than 60 commercial LWRs are operating in the United States, 7 of which have a power rating of 1000 MWe or greater
Duration of the study	10 months	3 years

*Includes both pressurized-water reactors and boiling-water reactors.

Table C-2 indicates that care must be exercised in drawing conclusions from comparative results of the two studies. It also indicates that the CRBRP risk assessment results must be regarded as more preliminary than the WASH-1400 results, since the CRBRP is still in the design stage but a large number of LWRs are operational.

2.3.6 Who performed the study and how long did it take?

The CRBRP risk assessment was commissioned and directed by the CRBRP Project Office. Westinghouse, as lead reactor manufacturer, was responsible for coordination of the work. Approximately 45 engineers and scientists representing nine organizations were employed as participants and consultants. To take advantage of existing experience, as many persons as possible who had played key roles in the WASH-1400 study were employed in this work. In addition to the participants Westinghouse, General Electric, Atomics International, and Burns and Roe, the following organizations played key roles:

- Science Applications, Inc.,
- EG&G Idaho, Inc. (formerly Aerojet Nuclear Corporation),
- Hanford Engineering Development Laboratory,
- Argonne National Laboratory,
- consultants.

2.3.7 How do we know that all possible accident-initiating events and resulting core accident sequences have been identified?

One of the key tasks involved in this risk assessment was to identify those accident sequences that contribute significantly to public risk from operation of the CRBRP. It is neither reasonable nor necessary to attempt to identify and evaluate all possible accident sequences. Rather, the important question is whether or not the important accident initiators have been identified and evaluated with sufficient completeness to assure that any potential errors or omissions will not significantly alter the results. Factors supporting the conclusion that this condition has been met and that the important accident sequences have been identified and correctly assessed include the following:

- There is an extensive body of information, covering the past 20 years, on the identification and analysis of potential reactor accidents and the response of various reactor safety systems to such events. This information includes safety analyses for both LWRs and LMFBRs. The people who made this risk assessment believe that the subject has been sufficiently researched, analyzed, tested, and documented (supported by 260 reactor years of LWR operating experience) to provide reasonable assurance that all important mechanisms and causal categories that could result in a risk-producing situation have been identified.

- The source of radioactivity within the CRBRP can be specifically located and completely defined.

- o Radioactivity can be released from the core only if specific causal events occur, namely, the reactor power being greater than the capacity to remove heat or the amount of heat removed being insignificant for the amount of heat generated.

- o The occurrence potential of the two events listed above were identified and evaluated by a systematic approach. Proven methods and experienced personnel were used to make an orderly and exhaustive search and a realistic evaluation of potential accident sequences.

Also, studies indicate that the results of the risk assessment are relatively insensitive to significant changes in the basic input data and assumptions.

For the reasons cited the assessors believe that the significant contributors to the CRBRP risk have been identified.

2.3.8 How likely is a core-disruptive accident?

This risk assessment indicates that an accident involving gradual melting of the reactor core has a probability of 1 in about 50,000 per year of reactor operation. Such an event would have an insignificant effect on the health of residents in the area surrounding the CRBRP site.

The most severe accident analyzed was one in which a significant fraction of the radioactive core material is assumed to be released to the environment as a direct result of the accident; it was estimated to have a probability of occurrence of approximately 1 in 200 million per year of reactor operation. This type of highly improbable accident could have a significant effect on the health of the population in the vicinity of the CRBRP site.

Both accidents are called core-disruptive accidents (CDAs). As used in this study, CDA means a loss of coolable configuration of the reactor core. It covers a spectrum of highly improbable accidents ranging from those involving partial fuel melting to those in which a bubble of fuel vapor, assumed to form in the core during the accident as a result of a rapid temperature transient, expands rapidly. The rapid expansion causes mechanical damage to the reactor vessel head and possibly to the Reactor Containment Building. Assuming conditions that are necessary for a CDA, the most likely result is a fuel meltdown accident with little or no fuel vapor formation.

2.3.9 What health consequences might a core-disruptive accident produce?

If a highly improbable core-disruptive accident were to occur, serious health effects could result only if the radioactive material contained within the core were released first from the reactor vessel and then from the Reactor Containment Building to the environment. Should that sequence of events occur, a number of possible health effects could result, including:

- o early death,
- o respiratory impairment,
- o development of thyroid nodules,
- o fatal latent cancer.

2.3.10 What are the most likely consequences of a core-disruptive accident?

Should a core-disruptive accident occur, it is most likely that there would be no significant consequences to the health of the general public. Most of the radioactive material released from the core in low-probability accidents would be contained within the Reactor Containment Building. Such accidents could cause the loss of the core and might require the owner to abandon the plant; the consequences to the general public, however, would not be discernible since no significant fission product activity or plutonium would be released from the Reactor Containment Building.

The expected results of the consequences following the most likely of the highly improbable core-disruptive accidents in the CRBRP were calculated to be

- o zero early fatalities,*
- o zero lung illnesses,
- o approximately one thyroid nodule case,
- o less than one latent-cancer fatality.*

2.3.11 How many early fatalities would be expected as a result of a core-disruptive accident in the CRBRP?

If the most likely of the highly improbable core-disruptive accidents were to occur, the average number of early fatalities was determined to be zero. The probability of such an accident was determined to be about 1 in 50,000 per year of reactor operation. Because of the mitigating effect of the Reactor Containment Building and its associated cooling and cleanup systems, the release of radioactive material to the environment in the event of a core-disruptive accident would be small relative to the amount of radioactivity in the core.

The maximum number of early fatalities as determined in this study was about 2000. The probability of the accident leading to this number of fatalities is 1 in 200 million per year of reactor operation. The maximum number of fatalities could result from this highly improbable accident only if weather conditions were quite unfavorable, and the chance of unfavorable weather conditions is less than 1 in 100. Therefore, the probability of the most severe consequences is less than 1 in 20 billion per year of reactor operation.

*Early fatalities are defined as those occurring within one year of a core-disruptive accident; they would be due largely to acute radiation exposure from noble gases. Latent fatalities are those occurring during the 30-year period from 10 to 40 years after a core-disruptive accident.

2.3.12 What is the expected magnitude of latent, or long-term, health effects?

If the most likely of the highly improbable core-disruptive accidents were to occur, the average number of latent fatalities was determined to be less than 1. The probability of such an accident was determined to be about 1 in 50,000 per year of reactor operation. The maximum number of latent fatalities as evaluated in this study was determined to be about 200 per year. The probability of this accident, as in the case of the early fatalities, was determined to be less than 1 in 10 billion per year of reactor operation.

Appendix D

PLUTONIUM TOXICITY

The WASH-1535 Appendix on plutonium toxicity (II.G) was a lengthy document, including 151 references. Much of the information in that Appendix is still relevant. In the interests of brevity, this information is not repeated, nor is it exhaustively updated in this supplement. Attention is restricted primarily to those areas where developments since WASH-1535 have necessitated significant changes in the evaluation of transuranic health effects. The general plan of Appendix II.G of WASH-1535 has been followed and replacement tables are provided in all cases in which significant numerical changes are required.

Source Term

No changes have been considered necessary in the source term.

Atmospheric Dispersal

No changes have been made in the models for atmospheric dispersal, deposition, or resuspension of the airborne source term. Estimates of the quantity inhaled have not been changed.

Transport Via Food Chains

The general approach to transport via food chains remains the same as that outlined in WASH-1535. The discussions in Appendix II.G concerning the relative insignificance of aquatic pathways and animal pathways remains relevant, and the assumption that all food-chain transport occurs by way of a conservatively modelled soil-plant-man pathway has been retained. This pathway has been an area of very active research interest over the past 10 years and a significant change in model parameters has seemed justified.

Two major areas of uncertainty were identified in WASH-1535. These concerned the assumption of undiminished availability -- that the transuranics remain uniformly distributed through the top 20 cm of the soil, available for root-uptake or resuspension, for the life of the radionuclide -- and the assumption that the concentration of transuranics in or on plant-derived foods, on a wet-weight basis, would be equal to 10% of their concentration in soil. For the present evaluation we have retained the first of these assumptions, but reduced the plant/soil concentration factor to 1%, for reasons discussed in the following paragraphs.

The assumption of undiminished availability is conservative. Some fraction of the released transuranics, over the thousands of years covered by this model, will certainly become unavailable for root uptake by plants or for wind resuspension. This is a critical assumption. If as little as 0.1% per year of the soil deposited plutonium became unavailable for root uptake, the calculated ingestion dose from plutonium would be reduced by a factor of 35. Precisely because of this sensitivity of the model to the value chosen, one is reluctant to introduce such a factor for diminished availability, when there is no clear basis for choosing a value of 0.1% per year rather than a factor of 1.0% or 0.01%. It was therefore decided to retain the assumption of undiminished availability while stressing the conservatism of such a choice.

In the area of transuranic uptake by plants, the problem is more amenable to experimental study. The difficulty lies not with the absence of data, but with the plethora of data, which suggest plant/soil ratios ranging from 1 to 10^{-6}. Much new data is available in this area, which has not narrowed the range of values, but has gone far to explain the reasons for such a range of values. These data cannot be considered in detail here, but have been recently reviewed.[1, 2, 3, 4] Plant/soil ratios greater the 10^{-2} seem to be associated with either chelated transuranics, with external contamination of the plant, or with non-edible portions of the plant. On balance, a plant/soil ratio of 10^{-2} would seem to be a conservative assumption. Such a conclusion is supported by observations of fallout plutonium uptake, as cited in WASH-1535, and is supported by more recent experiments in which fallout plutonium and americium uptake was measured in corn, potatoes, and peas, with resulting plant/soil ratios for both radionuclides ranging from 3.5×10^{-3} downward.[4]

It must be acknowledged that agricultural practices involving the application of chelating agents could lead to plant/soil ratios larger than 10^{-2}. Such practices, however, would be limited to a small fraction of the total U.S. agricultural area, and the high ratios would be observed only in foods that would make up a small fraction of the total diet. It seems very unlikely that total food intake would exhibit a higher ratio than 10^{-2}. It can also be argued that any agricultural practice that might promote high uptake of transuranics would also have the effect of rapidly depleting the concentration of these elements in the soil, both by plant uptake and by leaching from the root zone.

As a consequence of the changed value for the plant/soil ratio, estimates of transuranic ingestion by man have been decreased by a factor of 10. These changes are reflected in the revised Table II.G-8 (numbered to correspond with the table in WASH-1535 that it replaces). Total transuranics ingested now correspond to 4.4×10^{-7} Ci per 1000 MWe-year, or about 0.1% of the total transuranics released.

Other changes in Table II.G are occasioned by increases in the gastrointestinal absorption fraction (to be discussed later), which approximately counterbalance the effect of the changed plant/soil ratio.

Metabolism and Dosimetry in Man

The metabolic model employed to describe the distribution and retention of transuranic elements in man in WASH-1535 has been retained in its general outline, but specific changes in metabolic parameters have been made to conform with current ICRP recommendations and to reflect more recent developments in the area of gastrointestinal absorption. Parameter values employed in the present evaluation are shown in revised Table II.G-9.

Minor changes appear in Table II.G-9 for the fraction of transuranics transferred from blood to gonads. These changes correspond to ICRP recommendations.[5] The major parameter change is that defining the absorption of transuranics from the gastrointestinal tract. WASH-1535 employed a value of 10^{-3} for americium and curium, but a much smaller fraction of 3×10^{-5} for plutonium. The plutonium value of 3×10^{-5} corresponded to the then recommended ICRP value.[6] In 1979, ICRP revised its recommendations to 10^{-4} for more soluble forms of plutonium and 5×10^{-4} for americium and curium.[5] For the present evaluation the more conservative value of 10^{-3} has been chosen for all transuranics, because of recent evidence that absorption may be substantially increased at very low mass concentrations, such as would be present as a result of LMFBR releases.[7] Although absorption fractions somewhat higher then 10^{-3} have been measured for some compound forms in some animal species, 10^{-3} is considered a conservative value for the probable average form of plutonium ingested. This conclusion is supported by measurements of fallout plutonium in Northern and Southern Finns, who differ greatly in their ingestion of plutonium, but show no significant differences in their plutonium deposition.[8] This would indicate that deposition of fallout plutonium in man occurs primarily via inhalation, which would not have been the case if the gastrointestinal absorption fraction were as high as 10^{-3}.

Significant changes have also been made in the procedures for calculation of radiation dose to organs and tissues, in compliance with revised recommendations of the ICRP.[9] Where in WASH-1535 an average dose was calculated for bone, separate doses are now calculated for the more critical volumes of bone surfaces and for red marrow. Separate doses are not calculated for pulmonary lymph nodes, but their transuranic content is considered as part of that in the lung; this maximizes dose to lung, which, experimentally, has been shown to be much more prone to cancer induction than are the lymph nodes.

Dose estimates for these organs and tissues are described in revised Tables II.G-10 to II.G-14. Dose calculations were modified from those published by the ICRP, the principle modifications being those dictated by a higher gastrointestinal absorption fraction, and by a smaller particle size than employed by ICRP. The ICRP tables provide values for the number of nuclear transformations that will occur in each tissue, including contributions from radioactive daughters, over a period of 50 years following inhalation or ingestion.[10] The 50-year period was chosen as a conservative interval of dose accumulation for occupationally exposed persons. It is less conservative for a member of the general public, but will still overestimate actual exposure.

From the numbers of radioactive disintegrations occurring in the various organs and tissues, the ICRP calculates the absorbed radiation dose within each organ or tissue of interest. Multiplying this committed dose by a quality factor Q results in the Committed Dose Equivalent, which the ICRP calculates in terms of sieverts per becquerel intake. For present purposes these have been converted to units of rem per 10^{-9} Ci intake, and these values for each source term radionuclide and for each organ of potential concern are listed in Tables II.G-10 to II.G-14. The quality factor (Q) employed in calculations of dose equivalent from alpha radiation had a value of 20, which relates to the high linear energy transfer (LET), and consequent greater biological effectiveness, of alpha radiation. This is larger (more conservative) by a factor of two than the value employed in WASH-1535. A more detailed account of the dose calculation procedures and the background for these procedures may be obtained from ICRP Publication 30.[5, 10]

As noted in WASH-1535, the models employed are based on the exposure of adults and no special account has been taken of the fetus, infant, or child. Arguments presented in WASH-1535 justifying this omission are still pertinent.

Health Effects

This Section (Appendix II.G) in WASH-1535 discussed at some length four principal sources of information having potential bearing on the estimation of health effects from transuranic elements in man. These are considered under separate headings below.

Human Exposures to Transuranic Elements: Additional data obtained over the past 10 years on transuranics in man, resulting from exposure of the general population to weapons test fallout, and accidental exposure of workers in nuclear industries, has not changed the conclusion that no statistically valid inferences can be drawn from this data, relative to any correlation of transuranic exposure with observed health effects.[4,19]

Human Exposures to Other Types of Natural Radiation: A very extensive review and discussion of this topic appeared in NCRP Report No. 45[11] and in Annex B of the 1977 UNSCEAR Report.[12] This more up-to-date information is summarized in replacement Table II.G-20, which also includes a comparison with estimated organ dose equivalents per 1000 MWe-year of LMFBR operation.

Plutonium Toxicity in Animals: Data continue to accrue from a number of large- and small-animal studies being conducted in DOE laboratories and in laboratories abroad. A complete and current reanalysis of all this data has not been made, but there is no indication of major unanticipated trends that would alter the conclusions of WASH-1535 in this area.

Effects of Other Types of Radiation in Man: The general discussion of WASH-1535 in this area remains relevant. However, several new and authoritative estimates of human cancer risks and human genetic risks from radiation exposure must be noted.

The cancer and genetic risk estimates of WASH-1535 were based primarily on risk factors provided by the National Academy of Sciences Committee on the Biological Effects of Ionizing Radiation (BEIR I).[13] A successor Committee (BEIR III) published in 1980 revised estimates of these risk factors.[14] In 1977 the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reported its estimates of cancer and genetic risks from radiation.[12] The ICRP has also published its estimates, which are based primarily on the UNSCEAR values.[9] These various risk factors are summarized in Table D-1, together with the risk factors employed in the present evaluation.

WASH-1535 calculated an average radiation dose to bone and calculated from this an estimated incidence of bone cancer. In the present evaluation, in accord with present ICRP practice, a dose to bone surfaces and a dose to red marrow has been estimated. Bone cancers are thought to arise from cells located on bone surfaces, while irradiation of the red marrow may cause leukemia. BEIR III (p. 202) provides a risk estimate for leukemia (averaged for males and females) of 23 per 10^6 rem.[14] This value, based on a linear quadratic dose response model, best fits the available human data and is in close agreement with UNSCEAR and ICRP estimates. Although leukemia has seldom been observed to result from transuranic exposure in experimental animals, and was not considered in WASH-1535, it has been included in the present estimates of possible cancer effects from LMFBR releases.

The BEIR III risk factor for bone cancer (p. 417) was derived from human experience with radium-224, an alpha-emitter which deposits on bone surfaces in a manner similar to transuranics.[14] The BEIR III risk factor for liver cancer (p. 379) was derived from human experience with the radioactive contrast medium, Thorotrast, which contains the alpha emitting thorium-232. BEIR III gives no single value for a cumulative risk factor for lung cancer, but the data considered in BEIR III are the same as those which led to the risk factors recommended by ICRP and UNSCEAR.

BEIR III estimates of the genetic consequences of radiation exposure do not differ greatly from the earlier BEIR I estimates, and are still expressed with a substantial range of uncertainty.[14] ICRP and UNSCEAR have chosen single best estimate values.[9,12] All of these estimates distinguish between those effects to be expected in the first offspring generation (or the first two generations), and those to be expected over all future generations. These genetic risk estimates are based on high dose-rate data, from experimental animals, and include a factor of three reduction for estimated effects at low rates. It is stressed in BEIR III (p. 128) that such a reduction is probably not appropriate for high-LET exposure (such as that from transuranic alpha emitters); therefore the genetic risk factors listed in Table D-1 are all three-fold larger than the factors recommended by the various organizations.[14]

Single conservatively chosen risk factors (Table D-1) have been chosen for use in this document. This was done to avoid the confusion inherent in the use of ranges, where such ranges have no clearly definable implications. The discussion in WASH-1535 with regard to uncertainties involved in the derivation and application of these risk factors remains valid. A very recent re-evaluation of Japanese atomic-bomb-survivor data would seem to indicate that all of these estimates of genetic effects may be too high by at least a factor of two.[15]

Problems of Averaging Dose

This final Section of WASH-1535, Appendix II.G, was concerned with the so-called "hot particle hypothesis" of Tamplin and Cochran[16], which was a controversial issue at the time. The discussion remains valid. Since issuance of WASH-1535, this question has been addressed by several specially appointed groups, government agencies, and international bodies, including the National Academy of Sciences -- National Research Council[17], the National Council on Radiation Protection and Measurements[18], the Nuclear Regulatory Commission[19], the Medical
Research Council of the United Kingdom[20], the National Radiological Protection 11
Board of the U.K.[21,22], the German Ministry of the Interior[23], and the International Commission on Radiological Protection[24]. Some of these groups allow the possibility that, under special circumstances not yet experimentally or clinically defined, aggregates of radioactivity that remain localized in specific regions may represent a greater cancer risk than the same quantity of radioactivity uniformly dispersed. However, none of these groups has accepted the quantitative implications of the Tamplin-Cochran Hot Particle Hypothesis, and none has recommended abandoning the practice of basing risk estimates on average organ dose.

Transuranic Health Effects Program Plan

The primary health effects issue raised at the time ERDA-1535 was published was that related to plutonium toxicity, specifically the "hot particle" hypothesis. This hypothesis questioned whether or not the health risks as presented in WASH-1535 might have been underestimated because of the possibility that carcinogenic risk to the respiratory tissues from small, discrete, highly radioactive alpha-emitting particles ("hot particles") deposited in the lung might be very much greater than that obtained using more commonly accepted methodology (i.e., averaging the radiation over the mass of the lung).

This issue was fully presented and discussed in WASH-1535. Since that time additional authoritative national and international organizations, identified in the preceding paragraphs, have addressed the issue. This is discussed on page D-9 and in Section IV.(4) of the Supplement.

While studies pertaining to the "hot particle" issue continue, and will not be concluded for a number of years, at present there is no indication of any basis for reconsideration of the position contained in ERDA-1535: that, of the evidence available and of the preponderance of scientific opinion, it would not be prudent to make decisions based upon such a poorly supported hypothesis.

Other components of the transuranic health effects program continue to provide data and information to the scientific community via numerous scientific journals and publications. These data have been incorporated into metabolic models and risk estimates published since ERDA-1535 by the National Academy of Sciences - National Research Council Committee on the Biological Effects of Ionizing Radiation, the United Nations Scientific Committee on the Effects of Atomic Radiation, and the International Commission on Radiological Protection. These more recent findings have been incorporated into the present document and are fully identified and discussed.

The several transuranic health effects studies identified in ERDA-1535 are continuing and are expected to provide information in the time period identified therein. During the interim, however, data is being accumulated continually and made available to the scientific and radiation protection committees for use in modeling development and risk analysis.

Table II.G-8 (Replacement)

FOOD CHAIN MOBILIZATION OF TRANSURANIC ELEMENTS FROM SOIL TO MAN FOR 1000 MWe-YEAR OF LMFBR RELEASES

1	2	3	4	5	6
	Transuranic Input to Soil		Transuranics in Plant-Derived Food Ingested by Man		Transuranics Absorbed by Man from Food Ingested[d] (Ci)
Radionuclide	Total (Ci)	Initial Conc.[a] (Ci/g)	Total[b] (Ci)	Initial Conc.[c] (Ci/g)	
Pu-238	$.18 \times 10^{-3}$	4.5×10^{-23}	$.05 \times 10^{-7}$	4.5×10^{-25}	$.05 \times 10^{-10}$
Pu-239	$.04 \times 10^{-3}$	1.0×10^{-23}	$3. \times 10^{-7}$	1.0×10^{-25}	$3. \times 10^{-10}$
Pu-240	$.05 \times 10^{-3}$	1.2×10^{-23}	$1. \times 10^{-7}$	1.2×10^{-25}	$1. \times 10^{-10}$
Am-241	$.17 \times 10^{-3}$[e]	4.2×10^{-23}	$.3 \times 10^{-7}$	4.2×10^{-25}	$.3 \times 10^{-10}$
Cm-242	$.07 \times 10^{-3}$	1.8×10^{-23}	$.0001 \times 10^{-7}$	1.8×10^{-25}	$.0001 \times 10^{-10}$
Cm-244	$.01 \times 10^{-3}$	$.2 \times 10^{-23}$	$.0006 \times 10^{-7}$	$.2 \times 10^{-25}$	$.0006 \times 10^{-10}$
Total	$.52 \times 10^{-3}$[e]	13×10^{-23}	4.4×10^{-7}	13×10^{-25}	4.4×10^{-10}

[a] Assumes uniform distribution in top 20 cm of U.S. soil of density 2.0, or 4×10^{18} g of soil. Because of the delayed input of most of the Am-241, the concentration based on total input slightly overestimates initial concentration.

[b] Calculated using Equation (1) as described in text.

[c] Values from Column 3 multiplied by plant/soil concentration factor of 0.01.

[d] Values from Column 4 multiplied by a gastrointestinal absorption fraction of 10^{-3}.

[e] This number is larger than the original source term because of an added 0.16 mCi of Am-241 which results from the complete decay of the -emitting Pu-241.

Table II.G-9 (Replacement)

VALUES EMPLOYED FOR PARAMETERS DESCRIBING THE METABOLISM OF TRANSURANIC ELEMENTS IN MAN

1	2		3	4	5
Source Region		Pathway**	Further Qualifi-cations***	Regional Fraction†	Biological Half-Life (days)
Total Inhaled	(1)	exhaled		0.42	
	(2)	to nasopharynx region of lung		0.08	
	(3)	to tracheobronchial region of the lung		0.08	
	(4)	to pulmonary region of lung		0.42	
Total Ingested	(5)	to gastrointestinal tract		1.0	
Lung					
Nasopharynx Region	(6)	to gastrointestinal tract	Class W	0.9	0.4
			Class Y	0.99	0.4
	(7)	to blood	Class W	0.1	0.01
			Class Y	0.01	0.01
Tracheobronchial Region*	(8)	to gastrointestinal tract	Class W	0.5	0.2
			Class Y	0.99	0.2
	(9)	to blood	Class W	0.5	0.01
			Class Y	0.01	0.01
Pulmonary Region*	(10)	to gastrointestinal tract	Class W	0.4	1
				0.4	50
			Class Y	0.4	1
				0.4	500
	(11)	to blood	Class W	0.15	50
			Class Y	0.05	500

Table II.G-9 (Continued)

1	2	3	4	5
Source Region	Pathway**	Further Qualifi-cations***	Regional Fraction†	Biological Half-Life (days)
	(12) to lymph nodes	Class W	0.05	50
		Class Y	0.15	500
Pulmonary Lymph Nodes*	(13) to blood	Class W	1.0	50
		Class Y	0.9	1000
			0.1	∞
Gastrointestinal Tract	(14) to blood		0.001	
Blood	(15) to bone		0.45	
	(16) to liver		0.45	
	(17) to gonads	male	0.00035	
		female	0.00011	
Bone Surface* (120 g)	(18) excreted		1.0	36500
Red Marrow* (1500 g)	--		--	--
Liver* (1800 g)	(19) excreted		1.0	14600
Gonads* (testes, 35 g, ovaries, 11 g)	(20) no loss		1.0	

* Organs for which dose commitments were calculated. Organ mass employed in calculations is shown in parentheses. Tracheobronchial region, and pulmonary lymph nodes were considered as one composite organ (lungs) of mass 1000 g for dosimetric purposes. Dose to red marrow derived from deposit on bone surfaces.

** Number in parentheses refers to labeled pathway in Fig. II.G-2.

***This column indicates where values apply to a Class W or Class Y compound (see text), or to a specific element or organ.

† The fraction of the radionuclide in the source region (column 1) that is following the pathway indicated in Column 2, with the half-time indicated in Column 5.

Table II.G-10 (Replacement)

LUNG DOSE EQUIVALENT COMMITMENT ESTIMATED FOR 1000 MWe-YEAR OF LMFBR TRANSURANIC ELEMENT RELEASES

1	2	3	4
Radio-nuclide	Quantity Inhaled* (10^{-9} Ci)	Dose-Equivalent per 10^{-9} Ci Inhaled** (rem)	Total Equivalent*** (man-rem)
Pu-238	1.2	2.0 (Class Y)	2.4
Pu-239	2.0	2.0 (Class Y)	4.0
Pu-240	0.9	2.0 (Class Y)	1.8
Pu-241	42	0.02 (Class Y)	0.84
Am-241	0.2	†	†
Cm-242	0.4	0.09	0.04
Cm-244	0.05	†	†
Total			9.1

* From Table II.G-5.
** Modified from ICRP Publication 30 (Supplement to Part 1).[10]
***Product of Columns 2 and 3.
† No value listed by ICRP because of the insignificant contribution of lung exposure to total risk.

Table II.G-11 (Replacement - Partial)

RED MARROW DOSE EQUIVALENT COMMITMENT ESTIMATED FOR 1000 MWe-YEAR OF LMFBR TRANSURANIC ELEMENT RELEASES

1	2	3	4	5	6	7	8
			Dose Equivalent per 10^{-9} Ci***		Total Dose Equivalent		
Radio-nuclide	Quantity Inhaled* (10^{-9} Ci)	Quantity Ingested** (10^{-9} Ci)	Inhaled (rem)	Ingested (rem)	Inhaled† (man-rem)	Ingested†† (man-rem)	Total (man-rem)
Pu-238	1.2	5	.73 (Class W)	.006	.88	.03	.91
Pu-239	2.0	300	.81 (Class W)	.006	1.62	1.8	3.42
Pu-240	.9	100	.81 (Class W)	.006	.73	.6	1.33
Pu-241	42	†††	.02 (Class W)	†††	.84	†††	.84
Am-241	.2	30	.81	.006	.16	.18	.34
Cm-242	.4	.01	.015	.00014	.006	.00	.01
Cm-244	.05	.06	.41	.004	.02	.00	.02
Total					4.3	2.6	6.9

* From Table II.G-5.
** From Table II.G-8.
***Modified from ICRP Publication 30 (Supplement to Part 1).[10]
† Product of Column 2 and Column 4.
†† Product of Column 3 and Column 5.
†††Significant exposure via ingestion is from alpha-emitting daughter, which is included in ^{241}Am total.

Table II.G-11 (Replacement - Partial)

BONE SURFACE DOSE EQUIVALENT COMMITMENT ESTIMATED FOR 1000 MWe-YEAR OF LMFBR TRANSURANIC ELEMENT RELEASES

1	2	3	4	5	6	7	8
			Dose Equivalent per 10^{-9} Ci***		Total Dose Equivalent		
Radio-nuclide	Quantity Inhaled* (10^{-9} Ci)	Quantity Ingested** (10^{-9} Ci)	Inhaled (rem)	Ingested (rem)	Inhaled† (man-rem)	Ingested†† (man-rem)	Total (man-rem)
Pu-238	1.2	5	9.0 (Class W)	.067	10.8	.34	11.1
Pu-239	2.0	300	10.2 (Class W)	.078	20.4	23.4	43.8
Pu-240	.9	100	10.2 (Class W)	.078	9.2	7.8	17.0
Pu-241	42	†††	.21 (Class W)	†††	8.8	†††	8.8
Am-241	.2	30	10.2	.082	2.0	2.5	4.5
Cm-242	.4	.01	.19	.0017	.08	.00	.1
Cm-244	.05	.06	5.3	.04	.27	.00	.3
Total					51.6	34.0	85.6

* From Table II.G-5.
** From Table II.G-8.
***Modified from ICRP Publication 30 (Supplement to Part 1).[10]
† Product of Column 2 and Column 4.
†† Product of Column 3 and Column 5.
†††Significant exposure via ingestion is from alpha-emitting daughter, which is included in ^{241}Am total.

Table II.G-12 (Replacement)

LIVER DOSE EQUIVALENT COMMITMENT ESTIMATED FOR 1000 MWe-YEAR OF LMFBR TRANSURANIC ELEMENT RELEASES

1	2	3	4	5	6	7	8
			Dose Equivalent per 10^{-9} Ci***		Total Dose Equivalent		
Radio-nuclide	Quantity Inhaled* (10^{-9} Ci)	Quantity Ingested** (10^{-9} Ci)	Inhaled (rem)	Ingested (rem)	Inhaled† (man-rem)	Ingested†† (man-rem)	Total (man-rem)
Pu-238	1.2	5	2.0 (Class W)	.015	2.4	.08	2.5
Pu-239	2.0	300	2.2 (Class W)	.016	4.4	4.80	9.2
Pu-240	.9	100	2.2 (Class W)	.016	2.0	1.6	3.6
Pu-241	42	†††	.04 (Class W)	†††	1.7	†††	1.7
Am-241	.2	30	2.2	.017	.4	.51	.9
Cm-242	.4	.01	.050	.0004	.02	.00	.02
Cm-244	.05	.06	1.2	.01	.06	.00	.06
Total					11.0	7.0	18.0

* From Table II.G-5.
** From Table II.G-8.
***Modified from ICRP Publication 30 (Supplement to Part 1).[10]
† Product of Column 2 and Column 4.
†† Product of Column 3 and Column 5.
†††Significant exposure via ingestion is from alpha-emitting daughter, which is included in ^{241}Am total.

Table II.G-13 (Replacement)

DELETE

(Dose to lymph nodes included in lung dose, in accord with current ICRP practice).

Table II.G-14 (Replacement)

GONAD DOSE EQUIVALENT COMMITMENT ESTIMATED FOR 1000 MWe-YEAR OF LMFBR TRANSURANIC ELEMENT RELEASES

1	2	3	4	5	6	7	8
			Dose Equivalent per 10^{-9} Ci***		Total Dose Equivalent		
Radio-nuclide	Quantity Inhaled* (10^{-9} Ci)	Quantity Ingested** (10^{-9} Ci)	Inhaled (rem)	Ingested (rem)	Inhaled† (man-rem)	Ingested†† (man-rem)	Total (man-rem)
Pu-238	1.2	5	.11 (Class W)	.00085	.13	.004	.13
Pu-239	2.0	300	.13 (Class W)	.00096	.26	.29	.55
Pu-240	.9	100	.13 (Class W)	.00096	.12	.10	.22
Pu-241	42	†††	.0028 (Class W)	†††	.18	†††	.18
Am-241	.2	30	.13	.001	.03	.03	.06
Cm-242	.4	.01	††††	††††	.00	††††	††††
Cm-244	.05	.06	.065	.0005	.00	.00	.00
Total					.72	.42	1.14

* From Table II.G-5.
** From Table II.G-8.
*** Modified from ICRP Publication 30 (Supplement to Part 1).[10]
† Product of Column 2 and Column 4.
†† Product of Column 3 and Column 5.
††† Significant exposure via ingestion is from alpha-emitting daughter, which is included in ^{241}Am total.
††††No value listed by ICRP because of the insignificant contribution of gonad exposure to total risk.

Table II.G-20 (Replacement)

DOSE EQUIVALENT TO U.S. POPULATION FROM NATURAL RADIATION SOURCES COMPARED WITH ESTIMATED DOSE EQUIVALENT FROM 1000 MWe-YEAR OF LMFBR TRANSURANIC ELEMENT RELEASES

(units of organ-rem)

Organ	From All Natural Radiation Sources[a] (1 Generation)	From Naturally Occurring Alpha-Emitters[a] (1 Generation)	From 1000 MWe-Year of LMFBR Operation[b] (All Generations)
Bone Surfaces	3.2×10^9	2.0×10^9	86
Red Marrow	1.8×10^9	$.54 \times 10^9$	7
Lung	11.0×10^9	9.0×10^9	9
Gonads	1.3×10^9	$.26 \times 10^9$	1

[a]Data from 1977 UNSCEAR Report, p. 81.[12] A quality factor of 20 was used for alpha-emitters in converting rad doses to rem dose equivalents. Period of dose accumulation was taken as 70 years for 2×10^8 persons.

[b]Data from Tables II.G-10 to II.G-14 (Replacement).

Table D-1

SUMMARIZED RISK ESTIMATES FOR EXPOSURE TO TRANSURANICS EXPRESSED AS EXCESS CANCER DEATHS OR MAJOR GENETIC DEFECTS per 10^6 organ-rem

	Source of Risk Estimates			
Organ	BEIR III[14]	ICRP[9]	UNSCEAR[12]	Chosen for Use in This Document
Lung		20	25-50	35
Bone Surface	1.4	5	2-5	5
Red Marrow	23	20	15-25	25
Liver	15			15
Gonads (for number of generations indicated	15-225 (1) 180-3300 (all)	300 (2) 600 (all)	189 (1) 555 (all)	1,000 (all)

References

1. R. L. Watters, D. N. Edgington, T. E. Hakonson, W. C. Hanson, M. H. Smith, F. W. Whicker, and R. E. Wildung, "Synthesis of the Research Literature," in Transuranic Elements in the Environment (W. C. Hanson, ed.), U.S. D.O.E. Doc. DOE/TIE-22800, pp. 1-44, 1980.

2. D. C. Adriano, A. Wallace, and E. M. Romney, "Uptake of Transuranic Nuclides from Soil by Plants Grown under Controlled Environmental Conditions," in Transuranic Elements in the Environment (W. C. Hanson, ed.), U.S. D.O.E. Doc. DOE/TIE-22800, pp. 336-360, 1980.

3. D.C. Adriano, J. C. Corey, and R. C. Dahlman, "Plutonium Content of Field Crops in the Southeastern United States," in Transuranic Elements in the Environment (W. C. Hanson, ed.), U.S. D.O.E. Doc. DOE/TIE-22800, pp. 381-402, 1980.

4. B. G. Bennett, "Environmental Aspects of Americium," U.S. D.O.E. Doc. EML-348, 1978.

5. International Commission on Radiological Protection, Limits for Intake of Radionuclides by Workers, ICRP Publication 30, Part 1, Pergamon Press, Oxford, 1979.

6. International Commission on Radiological Protection, Report of Committee II on Permissible Dose for Internal Radiation, ICRP Publication 2, Pergamon Press, Oxford, 1959.

7. M. F. Sullivan, "Absorption of Actinide Elements from the Gastrointestinal Tract of Rats, Guinea Pigs, and Dogs," Health Phys., 38, 159-171, 1980.

8. J. K. Miettinen, H. Mussalo, M. Hakanen, T. Jaakkola, M. Keinonen, and P. Tahtinen, "Distribution of plutonium and americium in human and animal tissues after chronic exposures," Book of Papers, 5th International Congress of the International Radiation Protection Association, Vol. III, pp. 265-268, 1980.

9. International Commission on Radiological Protection, Recommendations of the International Commission on Radiological Protection, ICRP Publication 26, Pergamon Press, Oxford, 1977.

10. International Commission on Radiological Protection, Limits for Intake of Radionuclides by Workers, Supplement to Part 1, Pergamon Press, Oxford, 1979.

11. National Council on Radiation Protection and Measurements, Natural Background Radiation in the United States, NCRP Report No. 45, Washington, D.C., 1975.

12. U.N. Scientific Committee on the Effects of Atomic Radiation, Sources and Effects of Ionizing Radiation, United Nations, N.Y., 1977.

13. U.S. National Academy of Sciences - National Research Council, The Effect on Populations of Exposure to Low Levels of Ionizing Radiation, Report of the Advisory Committee on the Biological Effects of Ionizing Radiations, Washington, D.C., 1972.

14. U.S. National Academy of Sciences - National Research Council, The Effect on Populations of Exposure to Low Levels of Ionizing Radiation: 1980, National Academy Press, Washington, D.C., 1980.

15. W. J. Schull, M. Otake, and J. V. Neel, "Genetic Effects of the Atomic Bombs: A Reappraisal," Science 213: 1220-1227, 1981.

16. A. R. Tamplin and T. B. Cochran, Radiation Standards for Hot Particles, Natural Resources Defense Council, Washington, DC, 1974.

17. National Academy of Sciences - National Research Council, Health Effects of Alpha-Emitting Particles in the Respiratory Tract, Washington, D.C., 1976.

18. National Council on Radiation Protection and Measurements, Alpha-Emitting Particles in the Lung, NCRP Report No. 46, Washington, D.C., 1975.

19. U.S. Nuclear Regulatory Commission, "Natural Resources Defense Council - Denial of Petition for Rule Making," Federal Register, 41 (71), 15371-15379, 1976.

20. Medical Research Council, The Toxicity of Plutonium, Her Majesty's Stationery Office, London, 1975.

21. G. W. Dolphin, "Hot Particles," Radiol. Prot. Bull., 1974(8), 8-10, 1974.

22. G. W. Dolphin, "The Hot Particle Problem," Radiol. Prot. Bull. 1975(12), 38-39, 1975.

23. German Ministry of the Interior (Bonn), "On the Toxicity of Inhaled Hot Particles with Special Reference to Plutonium," Radiat. Environ. Biophys. 15, 3-11, 1978.

24. International Commission on Radiological Protection, Publication No. 31, Biological Effects of Inhaled Radionuclides, Pergamon Press, Oxford, 1980.

YEAR: FY 76

APPENDIX E
SAFETY PROGRAM ACCOMPLISHMENTS, FY 1976-1981

ACCOMPLISHMENT	SIGNIFICANCE	REFERENCE
Completed series of TREAT tests simulating loss-of-flow accidents, transient overpower accidents, and phenomenological experiments.	Developed data base to support code developments to assess LMFBR energetics potential.	ANL/RAS 76-2, 76-7, 76-8, 76-9, 76-11, 76-32, 76-36.
Completed models of fuel pin behavior under accident conditions.	Provided basic information for accident analysis codes.	ANL/RAS 76-19, 76-20.
Completed preliminary evaluation of air-cleaning systems to be used in LMFBRs.	Developed initial approach for air-cleaning systems to be used in FFTF and CRBRP.	HEDL-TME 76-41.
Completed steady-state hydraulic tests on full length (FFTF) 19-pin bundle.	Verified COBRA and SABRE code methods.	ORNL-TM 6106 & 6553.
Completed FFTF control rod environmental lifetest.	Prototype FFTF control rod was successfully tested to demonstrate satisfactory performance under the range of operational conditions.	WARD-SC7-8.
Conducted SLSF experiment P2.	Experiment was the first to simulate an LOF with a large bundle (19 pins) and full-length, preconditioned pins; monotonic fuel dispersal (no recriticality due to slumping) was demonstrated.	ANL/RAS 78-23.

YEAR: FY 77

ACCOMPLISHMENT	SIGNIFICANCE	REFERENCE
Completed SLSF experiment P3A.	Thirty-seven-full-length pin bundle provided spectrum of fuel disruption modes during nominal power LOF for use in pin failure modeling activities.	ANL/RAS 77-19, 77-48, 78-53.
Completed postaccident heat removal experiments and analyses for particulate beds and molten core debris pools.	Provided data base for analysis of core-debris behavior following postulated accidents.	ANL/RAS 77-2.
Completed 12 intermediate-scale sodium-concrete reaction tests.	Demonstrated the basic nature of the consequences of accidental contact between hot sodium and structural concrete.	HEDL-TME 77-99.
Completed out-of-pile experiments on a six-channel nonheat-generating blockage.	No propagation occurred; verified that the presence of a blockage in a fuel subassembly has little effect on boiling patterns.	ORNL-TM-6792 & 7162.
Completed development of SOMIX-I sodium spray fire code.	Advanced state of the art in predicting consequences of sodium fires in inerted cells by utilizing a two-dimensional model based on first principles for gas convection and energy transport.	AI-ESG Report N707T1130045.

YEAR: FY 78

ACCOMPLISHMENT	SIGNIFICANCE	REFERENCE
Completed comparison of containment systems for large sodium-cooled breeder reactors.	Showed that a containment-confinement configuration is a superior approach for large LMFBRs as well as for CRBRP.	HEDL-TME 78-35.
Completed analysis of potential emergency air-cleaning systems.	Developed basic approach for air-cleaning systems to be used in FFTF and CRBRP.	HEDL-TME 78-32.
Completed improved methods for structural analysis of reactor systems.	Improved confidence of prediction of structural effects of hypothetical accidents.	ANL/RAS 78-5, 78-6, 78-9, 78-10, 78-11, 78-12.
Developed transient sodium boiling model for inclusion in SABRE-28 code. Completed 19-pin bundle verification test.	Improved available methods for analysis of sodium boiling in reactor accident sequences.	ORNL-TM-7617, 7701, 8041.
Completed assessment of FBR candidate shutdown heat removal systems (SHRS).	Provided trade-off reliability studies for a spectrum of SHRS configurations to allow design selections to be made for a large plant.	WARD-SR-3045-6 & -7.

YEAR: FY 79

ACCOMPLISHMENT	SIGNIFICANCE	REFERENCE
Completed TREAT experiments simulating loss-of-flow accidents in LMFBRs using oxide fuel and carbide fuel.	Improved data base for verification of accident analysis methods.	ANL/RAS 79-3, 79-6.
Completed an analytical method to predict water evolution from heated concrete and two large demonstration tests.	Provided a basis for confident prediction of water release from concrete under post-HCDA conditions.	HEDL-TME 78-87.
Completed steady-state thermal-hydraulic tests on full-length (CRBRP) 61-pin bundle.	Verified SABRE and COBRA code methods of analysis and provided important design data to LMFBR design groups.	ORNL-TM-7315 & 7229.
Demonstrated rapid agglomeration and fallout of high-density aerosols.	Reduced predicted source terms and consequences of accidents.	AI-ESG Report N707TR130030.
Models for analyzing the transition phase (the gross core disruption phase of the unprotected loss-of-flow accident, which is currently called the meltout phase) were developed including the FUMO-T code.	The model helped to support the conclusion that a severe recriticality during the transition phase was unlikely for the FFTF reactor.	HEDL-TME 78-63, 78-59, 78-64.
The CACECO containment analysis code was documented and verified against known analytical solutions.	The code was used to study the cost and technical merit of various containment options for large LMFBRs; validation provided a tested method to evaluate containment systems for LMFBRs.	HEDL-TME 79-22, 79-2, & HEDL-TC 1590.

YEAR: FY 79 (Contd.)

ACCOMPLISHMENT	SIGNIFICANCE	REFERENCE
Complete Phase I of CRBRP PCRS accelerated lifetest.	Testing of prototype CRBRP PCRS simulated CRBRP control rod duty cycle both at normal operating conditions and under conditions of gross misalignment.	CRBRP-ARD-0255.
Completed initial out-of-pile cladding tests.	Unirradiated and irradiated fuel pin cladding testing capabilities were developed to address TUCOP failure criteria, TOP fuel-cladding mechanical loading, and cladding rip propagation characteristics; data base allowed improvement in cladding failures criteria.	HEDL-TME 81-28.

YEAR: FY 80

ACCOMPLISHMENT	SIGNIFICANCE	REFERENCE
Developed two region, two-dimensional boiling code THORAX.	Enabled rapid analysis of sodium boiling test results.	ORNL-TM-7814 & 8042.
Conducted SLSF experiment W2.	Provided unique data on behavior of near-fresh preconditioned full-length fuel pins under slow ramp-rate TOP conditions.	Ltr. report, D. R. Ferguson to R. Bauer, September 30, 1980 (DRF:226).
Completed test of FFTF air-cleaning scrubber concepts.	Provided verification of performance for FFTF air cleaner.	HEDL-TME 80-47.
Completed assessment of TOP-HCDA for FFTF ACN-1 carbide assembly.	Provided safety basis for irradiation of carbide assembly within the oxide FFTF core.	HEDL TC-1739.
Completed initial evaluation of homogeneous vs heterogeneous core behavior for CDS.	Provided input to CDS design selections on licensing considerations in the core design process.	Ltr. report, R. Avery to R. Bauer, March 3, 1980.
Completed UPI UO_2/Na test.	Addressed the potential for an energetic pressure driven recompaction in a rod bundle geometry.	ANL/TMC 81-2, April 1981, p. 136.
Conducted TREAT experiments F3 and F4.	Provided first direct optical observation of fuel pin disruption during in-pile testing for use in model validation studies.	ANL/TMC 81-8, February 1981, p. 114.

YEAR: FY 80 (Contd.)

ACCOMPLISHMENT	SIGNIFICANCE	REFERENCE
Completed evaluation of design options for CDA core-debris accommodation.	Provided input to CDS design activity on licensing considerations and design trade-offs.	GE XL-898-00569/P2778.
Completed assessment of HCDA loads to containment.	Provided assessment of containment system response to HCDA initiated loads for a range of containment internal configurations to allow selection of design options.	WARD-SR-9400-18.
Completed CRBRP PCR maintenance tooling test.	Test demonstrated cooling access and use in a full-size mockup of the CRBRP reactor head area.	WARD-D-0264.

YEAR: FY 81

ACCOMPLISHMENT	SIGNIFICANCE	REFERENCE
Perform boiling test on full-length 61-pin bundle.	Showed two-dimensional boiling patterns which correlated with SABRE-2P and THORAX codes. Enabled extrapolation to full-size fuel bundle.	ORNL-TM-7541 & 7922.
Completed initial version of SAS4A.	SAS4A will be the principal analysis tool for core-disruptive accidents. Significantly improved models and solution methods in comparison with SAS3D capabilities.	Ltr. report, R. Avery to R. Bauer, March 10, 1981 (RA:2104).
Completed initial version of TRANSIT-HYDRO.	Provided first available mechanistic multichannel treatment for assessing whole-core implications of the transition phase.	Ltr. report, R. Avery to R. Bauer, March 31, 1981 (RA:2115).
Irradiate SLSF experiment P4.	First large-bundle (37-pin) steady-state blockage irradiation experiment to bound consequences of local faults.	Ltr. report, D. Ferguson to R. Bauer, September 8, 1981 (DRF:397).
Completed 3D piping analysis code SHAPS.	Provided capability to assess piping system response to postulated accident loads and thermal transients through treatment of fluid-structure interactions and transient thermal loads.	ANL/TMC 81-2, April 1981, p. 70.

YEAR: FY 81 (Contd.)

ACCOMPLISHMENT	SIGNIFICANCE	REFERENCE
Completed UPI simulant fluid experiments.	Experiments allowed assessment of the potential for energetic contact between molten UC core material and section in the above-core structure region, and hence the potential for energetic recriticality in a carbide-fueled core.	ANL/RAS 81-25.
Completed TREAT experiments C01 and L01.	First two experiments of the joint USDOE/UKAEA PFR/TREAT program completed, which will provide a systematic study of fuel behavior under TOP and LOF conditions using full-length preirradiated fuel.	HEDL TC-1915.
Completed large-scale submerged-gravel-scrubber performance tests.	A series of four large-scale tests of capacity and removal efficiency of the submerged-gravel-scrubber completed; system will provide highly reliable, passive and efficient filtering of aerosols.	HEDL-TME 81-30.
Completed LBR risk assessment model.	Supports CDS risk studies, including design trade-offs and siting changes.	GEFR-00573.

YEAR: FY 81 (Contd.)

ACCOMPLISHMENT	SIGNIFICANCE	REFERENCE
Perform boiling test on full-length 61-pin bundle.	Showed two-dimensional boiling patterns which correlated with SABRE-2P and THORAX codes. Enabled extrapolation to full size fuel bundle.	ORNL-TM 7541 & 7922.

Appendix F

ENERGY AND THE ECONOMY

Historical data from the American economy over the last thirty years show a steady increase in the consumption of energy (Fig.1)[1]

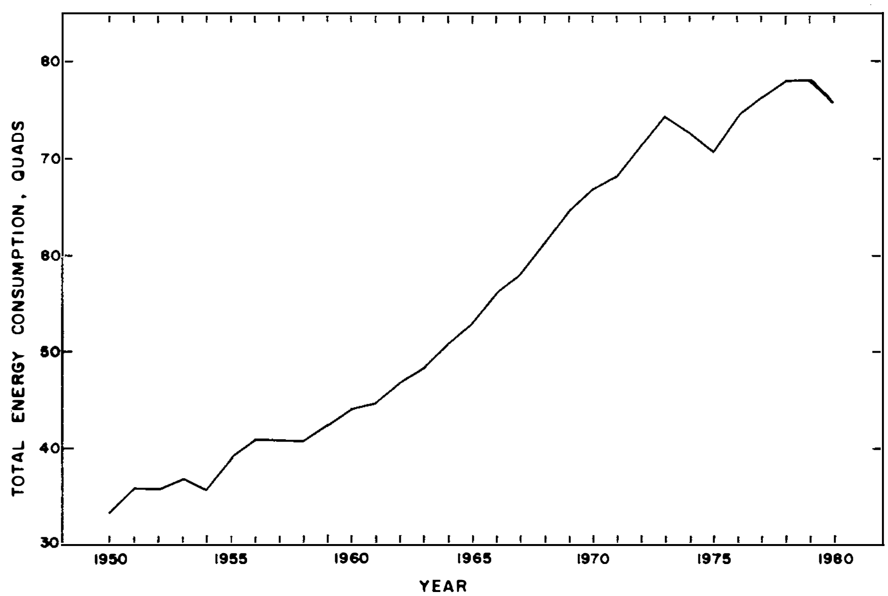

Fig. 1. Total Energy Consumption as a Function of Time (Ref. 1)

An exception to this steady increase occurred after the 1973 oil embargo when the OPEC oil supply was restricted. After 1975 energy consumption increased again, although in the last few years a slowing of the rate of increase has occurred; in fact a small decrease in consumption occurred in 1980.

The changes in energy consumption have historically been accompanied by similar changes in the gross national product (GNP). The correlation between energy consumption changes and GNP changes is illustrated in Fig. 2.[1,2,3] As Fig. 2 shows, the percent change in GNP fell along with energy consumption after 1973 and both recovered together in 1975 and both have fallen together since 1976.

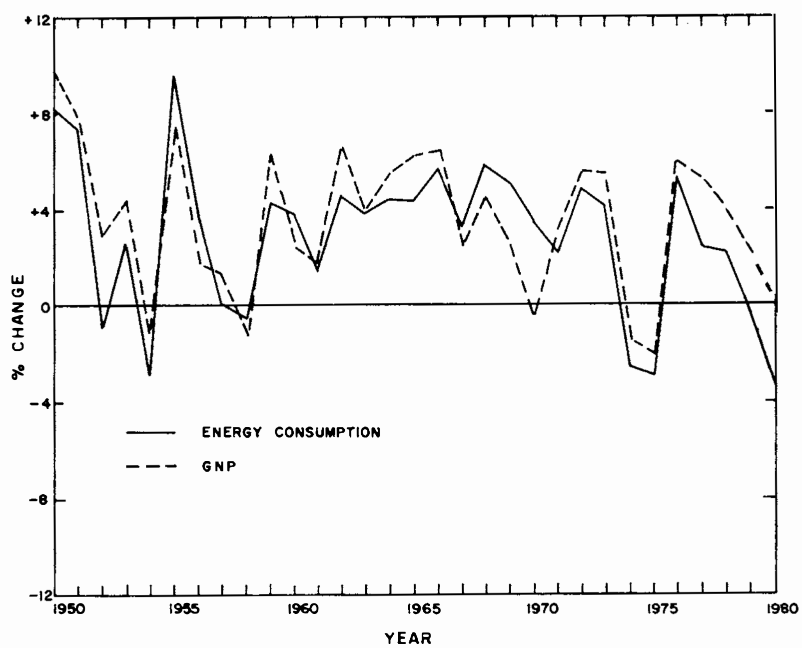

Fig. 2. Change in Total Energy Consumption and in GNP as a Function of Time. (Refs. 1,2,3)

This correlation of energy consumption and GNP implies that the energy efficiency of the American economy, defined as the value of goods and services produced per unit energy consumed, can change only slowly. This is confirmed by the historical data shown in Fig. 3.[1,2,3] In 1950 one quad of energy produced 24.1 billion dollars of GNP (constant 1978 dollars). In 1960 a quad produced 25.2 billion dollars of GNP while the 1970 value was 24.5 billion dollars. The period of relatively cheap energy in the 1960s was followed by a slow decline in energy efficiency, while the sharp rises in energy costs during the 1970s were followed by efficiency increases, so that a quad in 1979 produced 27.7 billion

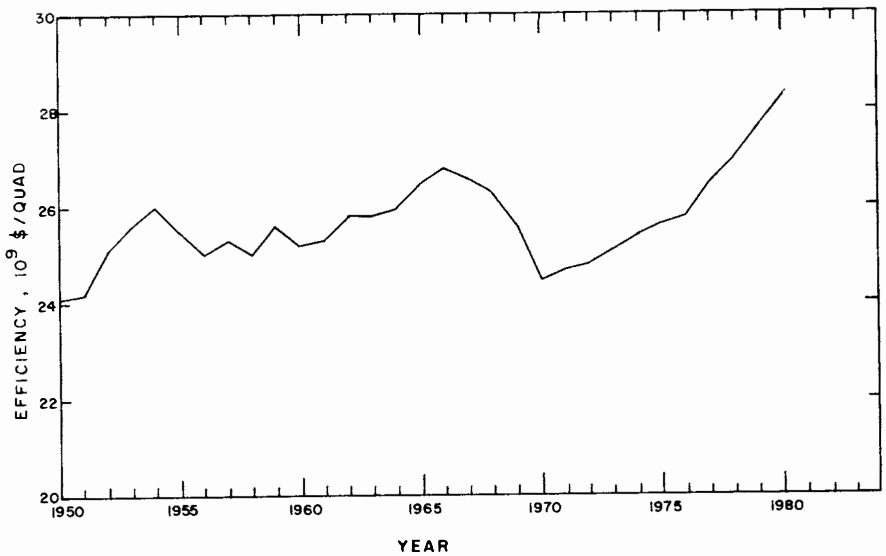

Fig. 3. Energy Efficiency as a Function of Time. (Refs. 1,2,3)

dollars of GNP. Between 1970 and 1980 the increase in energy efficiency averaged about 1.6% per year and was somewhat higher during 1977-1980. It is clear from these data that the economy does respond to cost incentives; however it is also clear that energy efficiency improvements are slow to be realized.

With respect to electrical energy, one trend has been remarkably constant, the increase in the market share of electricity as illustrated in Fig. 4.[4] This increase was continuous between 1950 and 1980. Between 1970 and 1980 electricity sales (billion kWh) increased 50% while total energy consumption increased only 14%. Thus, in addition to the energy growth displayed in Fig. 1, electrical energy has grown even more appreciably as it has been utilized to meet an increasing share of U.S. energy demand.

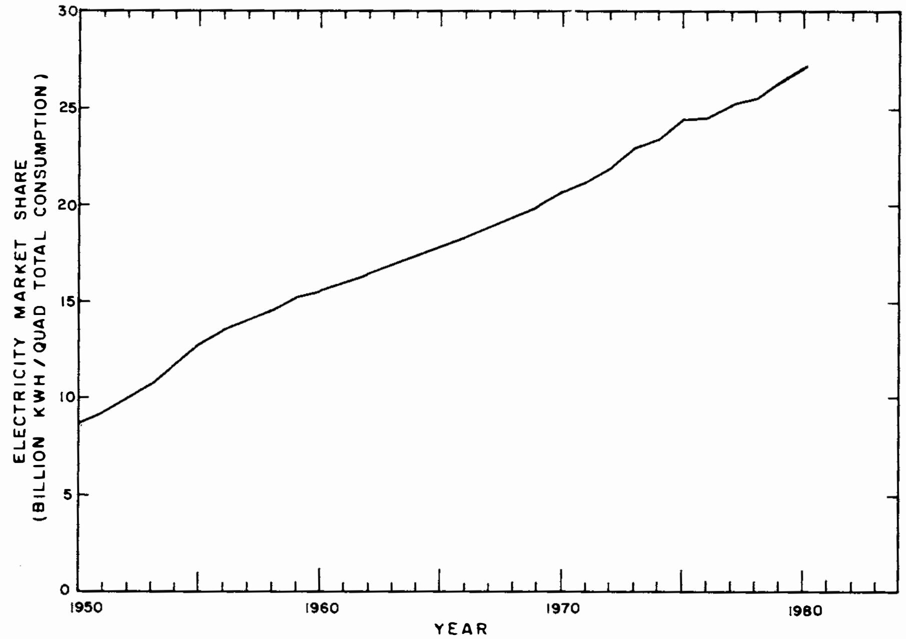

Fig. 4. Electricity Market Share as a Function of Time. (Ref. 4)

Planning for adequate future energy supplies requires that some projection into the future be made about energy demand and the economy, and by its nature such a prediction is uncertain, particularly on a time scale of 30 years or more. To demonstrate the uncertainty in future total energy demand, consider results of the National Research Council's CONAES study.[5] Predicted total energy demand in 2010 varied by almost a factor of three (58-160 quads; the 1975 base level was 71 quads), depending on the future scenario selected. In the CONAES study scenarios, demand forecasts were largely driven by the assumed values for three variables. These variables were:

1. future energy price,
2. the long-term response of the economy to energy price changes, and
3. future GNP growth.

In the CONAES study the GNP growth was fixed at 2% per year while the 2010 energy prices (constant dollars) varied from a factor of two to a factor of four higher than in 1975. Maintaining the historical 3.4% annual GNP growth would increase the CONAES 2010 demand projection range by about 70%, to 99-270 quads.

Based on the historical evidence there is a highly probable need for energy growth. The future growth rate will probably be less than the historical one, but some growth appears required for an expanding economy and a growing population. It seems unlikely that energy growth can be brought to zero without major economic changes--it would require a reversal of historical trends. In the CONAES study, zero energy growth was found to require large increases in real energy price. Though some may argue that such a reversal will occur, or can be made to occur, it would be imprudent to base national energy policy on such selective assumptions.

Some variables of the energy demand projection equation may be less uncertain than future total demand. Technological efficiency improvements may be expected to continue in response to high and probably rising energy costs.

The continuous increases in the fraction of total energy supplied by electricity are expected to continue, although selective assumptions can be used which run counter to the historical evidence. Nevertheless, electricity is and will probably continue to be a highly preferred and flexible energy form. Thus growth rates in electrical energy may be expected to continue to be higher than those for total energy demand. Put another way, the need for electrical energy growth is even more probable than the need for total energy growth.

Over 70% of the total U.S. energy demand is now supplied by oil and natural gas,[1] resources that are being rapidly depleted. At current (1980) rates of consumption (domestic plus imports), proven domestic reserves plus estimated total resources of oil[6] would be depleted in 17 years; those of natural gas[6] in 42 years. Even accounting for uncertainty in these numbers, the conclusion is that the U.S. faces a massive energy substitution problem. Other forms of energy must replace oil and natural gas fairly soon. Electricity can play an important part in this substitution process.

The need for electricity growth is therefore based on two elements:

1. a highly probable need to support a growing economy and population, and
2. a certain need to assist in eventual weaning of the U.S. from oil and natural gas use.

The only certain alternatives for electricity production on the scale required are coal and nuclear energy. Other alternatives are either too small in potential (e.g. geothermal or expanded hydroelectric facilities) or too far off with uncertain development schedules (e.g., solar electricity or fusion). In 1980, coal generated about 51% of all electricity in the U.S.; Light Water Reactor (LWR) nuclear plants about 11%;[7] and for the first time annual produc-
9 tion of electricity by nuclear power exceeded electricity production using oil. Coal and LWR plants now compete for essentially all new, large electrical capacity additions.

Until the last few years this competition between coal and nuclear units was relatively close. The electricity production in 1978 was 764 billion kWh higher than that generated in 1969. Of this total, the increased generation by coal was 270 billion kWh while the increased generation by nuclear plants was 262 billion kilowatt hours.[8] Recently, however, the balance has tipped in favor of coal-fired plants as utilities have had to deal with substantial uncertainties in the nuclear regulatory climate, current high rates of interest and inflation, and the present demand-growth projections that are below historical levels. Although these problems also affect coal-fired plants to some degree, the net impact has not been as severe. Because the factors which determine the competition between coal and nuclear power change with time, the competitive balance could shift again toward nuclear power as conditions change.

One of the principal factors that affects this balance is the cost of burning coal which will likely increase as demand on the resource increases. In addition to increased demand for coal for electricity generation in the U.S., coal exports have increased and there likely will be coal requirements for fluid fuel production as other fossil fuels are depleted. Environmental concerns such as the effect on land and water resources of massive mining and transportation requirements, CO_2 buildup, and acid rain may eventually make the use of coal more expensive or may limit its use for electricity production.

Future events that impact the availability and cost of both nuclear power and coal will determine their market shares. It appears that neither coal nor nuclear energy alone can supply all the electricity that will probably be needed in 2010. From the current U.S. electrical production of 2400 billion kWh, a 3% annual growth* (about half the historical electrical growth rate) would result in a 5800 billion kWh demand in 2010. With what is likely an

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*EIA Mid-range projections:

1985-90	3.4%	
1990-95	3.3%	9
1978-2000	2.7%	
2000-2010	2.0%	

optimistic assumption of 20% electrical supply from renewable resources (about twice the current value), and essentially no electricity production from oil and natural gas, the remainder is 4700 billion kWh to be supplied by coal and nuclear energy. Without nuclear energy, the annual coal requirement for electricity alone would be 2.2 billion tons, or over three times the total amount of coal mined and used in 1980. Conversely, without coal, roughly 800 new nuclear plants would have to be constructed between now and 2010. Neither seems to be a feasible path, and it appears that the only way to accommodate economic and population growth is extensive use of both coal and nuclear power in electricity production.

REFERENCES FOR APPENDIX F

1. Annual Report to Congress: 1980, Volume Two, DOE/EIA-0173(80)/2, p. 7, (1979).

2. U.S. Bureau of the Census, "Statistical Abstract of the United States: 1980," (101st edition) Washington, D.C., 1980.

3. U.S. Department of Commerce, "Historical Statistics of the U.S.: Colonial Times to 1970," Washington, D.C., 1976.

4. op. cit., DOE/EIA-0173(80)/2, p. 7, p. 161.

5. National Research Council, National Academy of Science, "Energy in Transition 1985-2010, Final Report of the Committee on Nuclear and Alternative Energy Systems," P. 9, W.H. Freeman and Company, San Francisco, 1979.

6. op. cit. DOE/EIA-0173(80)2, p. 7, p. 31, p. 41.

7. Ibid., p. 151.

8. Ibid., p. 155, p. 162, p. 157.

Appendix G

CRBR SITE SELECTION

The CRBRP project site location is the result of a series of programmatic decisions by the Department's predecessor agencies, the AEC and ERDA, which can now be examined in light of present circumstances. In 1969, Congress authorized the commencement of the Project Definition Phase of the LMFBR program as part of the fourth round of the Atomic Energy Commission's cooperative power reactor demonstration program.[1] Pursuant to this authorization, three different conceptual design proposals for large-scale demonstration liquid metal fast breeder reactors were developed and submitted to the AEC by three separate reactor manufacturer/utility teams. These efforts resulted in establishing a firm understanding and definition of the technical and economic characteristics which would be desirable in connection with the first demonstration plant. Upon completion of the Project Definition Phase, in 1970 Congress authorized the AEC to negotiate a definitive cooperative AEC/utility arrangement for the design, construction and operation of the nation's first large-scale demonstration LMFBR.[2] As a result of the Project Definition Phase experience, it was estabished that the technical, financial, and managerial burdens associated with a demonstration plant project would be beyond the resources and capabilities of a single reactor manufacturer and utility team. In recognition of this experience, the AEC appointed a senior utility advisory committee to develop the appropriate technical, managerial and financial criteria and other ground rules for a cooperative AEC/utility LMFBR demonstration plant project, and to engage the resources of the entire utility industry in support of the project.[3]

Through the mechanism of the utility advisory committee, specific proposals for definitive cooperative arrangements were sought from utility industry teams representing the major regions of the United States. In response, three proposals were received. Although the three proposals varied as to specificity of terms and conditions, only three clearly identifiable and reasonably firm proposals were received. These were proposals from: 1) TVA and Commonwealth Edison, 2) the New England Electric System, and 3) the Empire State Atomic Development Association (ESADA).[4]

In addition, proposals from utility groups from other major regions were actively sought during the course of the advisory committee proceedings. These efforts included attempts to obtain firm proposals from utility groups in Northwestern and Southeastern regions of the United States.

In the Northwest, efforts were made to obtain proposals for a demonstration project at what are now the Hanford Engineering Development Laboratory and Idaho National Engineering Laboratory sites through the Joint Power Planning Council, a group of 104 public agencies, private utilities, and the Bonneville Power Administration. The Power Planning Council advised the utility advisory committee that if a proposal were made, the Hanford site represented the best available location in the region, and that the Idaho site was not feasible since no utility operator could be found in the area, and the transmission facilities and backup power resources were insufficient to absorb an interruptible power source of the size (350 MWe) contemplated for the demonstration plant.[5] Independent of these considerations, the Northwest utilities determined that they had neither the financial nor managerial resources to undertake a leadership role in a project of the dimensions sought for the demonstration plant. A subsequent review by the Northwest utilities in 1976 indicated that this conclusion had not changed, and that the substantial commitments to nuclear plant construction in the region precluded taking on any additional obligations.[6]

In the Southeast, a group of five major utilities -- Carolina Power & Light Company, Virginia Electric and Power Company, the Southern Company, South Carolina Electric & Gas Company, and the Duke Power Company -- considered the feasibility of developing a proposal for locating the demonstration project at the Savannah River site. After careful consideration, this group, and in particular its anticipated lead utility (the Duke Power Company), concluded that, in light of their existing nuclear program commitments, they had neither the financial nor management capacity available to undertake a proposal.[7] Upon review of the three proposals by the utility advisory committee, a series of recommendations emerged. This, in turn, led to further AEC internal deliberations and culminated in the selection of the joint Commonwealth Edison/TVA proposal as the basis for further negotiation of definitive project arrangements and ultimate review by the Joint Committee on Atomic Energy. The basis for the selection included a balance of all relevant environmental, safety, and programmatic considerations. All three proposals included sites which presented no major insurmountable environmental or safety obstacles. Moreover, upon comparison, none stood out as offering an identifiable advantage or disadvantage.[8] The major distinctions among the proposals were reflected in their respective abilities to meet certain programmatic criteria, and thus it was possible to evaluate the proposals in terms of their relative merit as alternatives for meeting programmatic objectives. In this regard, the major factors were:

a) The TVA/Commonwealth Edison proposal was viewed as presenting the most firm and definitive proposal among the alternatives. It offered the most siting flexibility, and established a reasonable definition of respective government/utility responsibilities. Moreover, it reflected the most substantial commitment of resources and managerial capability.

b) The ESADA proposal did not include financial participation by the lead utilities. Moreover, the commitment of resources was potentially insufficient.

c) The New England proposal was expressly preconditioned upon substantial changes in statutory authority regarding licensing, including elimination of operating license hearings, limitations upon intervention, and provision of exclusive authority in the AEC to issue permits otherwise issued by federal or state agencies. In addition, the New England proposal was less than firm and limited any form of government participation. Congressional approval was subject to substantial uncertainty.

When viewed against the programmatic objective of operation of the demonstration plant as part of the power generation facilities of a utility system, and against the prospects for ultimate congressional approval of the TVA/CE proposal as a basis for negotiation and a definitive arrangement, it is clear that the TVA/CE proposal was the preferred alternative among those reasonably available.[9] Moreover, the fact that this proposal was approved by the Congress after extensive review and consideration lends support to this conclusion. The necessary implication of this conclusion is that the only reasonable and indeed, possible, alternative locations for the demonstration plant project fall within the parameters of the TVA/Commonwealth Edison proposal. Since that proposal only included sites within the TVA region, and TVA's operations are necessarily confined to that region, the range of reasonable alternative locations can be no broader than locations in the TVA region.

The initial selection of the Clinch River site as the preferred site within the TVA region resulted from an evaluation of a number of multiple potential sites.[10] The evaluation was based on a comparison of site features and environmental factors such as: hydrology, climatology, seismology, ecology, population, and land use of the potential sites, and included consideration of the additional factors of: 1) immediate availability of the sites for use by the demonstration plant, and 2) no competing use of the sites for commercial generation of electricity in the near future. These factors provided a framework for screening and for evaluation of comparative environmental impacts. Some 20 sites were evaluated in the screening process. From these studies, it was concluded that there were no sites with an apparent overall environmental advantage over the Clinch River site. Further, there were no known physical, engineering or environmental reasons that would preclude consideration of the demonstration plant at the Clinch River site.

Subsequently, ERDA and NRC reviewed the site selection process within and outside the TVA region. Within the TVA region, the original analysis was again reviewed in light of information from continuing TVA studies. This review concluded that for the sites originally evaluated, four sites could be eliminated due to certain unfavorable factors and that the remaining available sites continued to offer no overall environmental advantage relative to the Clinch River site.[11] Independently, the NRC drew the conclusion that previous and current construction permit application reviews by the NRC staff of alternative plant sites in the TVA region have not identified any sites which would offer substantial advantages relative to the Clinch River site.[12]

At the request of the NRC, ERDA also evaluated alternative sites not within the TVA region to determine if a substantially better alternative existed. All ERDA landholdings were screened, and 29 sites were identified which could accommodate the plant from the standpoint of land area. Further analysis of environmental and technical characteristics of the sites yielded three possible candidate areas - Hanford, Savannah River, and Idaho. These three areas were further evaluated to determine the environmental factors associated with each. From these evaluations, both ERDA and NRC concluded that there were no substantial differences between these three sites with respect to environmental impacts from construction or plant operation.

There were three additional findings. First, cooperative utility agreements could not be reached for the three candidate sites, thereby negating a primary project objective.[13] Second, the major significant difference between the Clinch River site and the three candidate sites is that these candidate alternative sites have a reduced population density relative to Clinch River. Additional analyses performed by ERDA[14] indicated that the magnitude of the environmental impacts that would be affected by differences in population density were so small that there is no practical difference in environmental impact between Clinch River and the three alternative sites.

Third, the timing of the LMFBR program could not be met if an alternative site were adopted. On the basis of these factors, both ERDA and the NRC concluded that there were no substantially preferred alternative sites.

Reevaluation of the situation today leads to the following conclusions:

1. The conclusions with respect to the lack of environmental advantage of the three candidate alternative sites are unchanged;

2. The fundamental project objective of utility participation remains, and the three candidate alternative sites cannot meet that objective; and

3. The timing of the LMFBR program and CRBRP project (as detailed in Section III) calls for the CRBRP to be completed as expeditiously as possible. In light of this, none of the three alternative sites are viable alternatives for the Clinch River project, in that each alternative would entail an additional delay.

Given this programmatic consideration, it would follow that, if the demonstration plant site is determined by NRC to be adequate based on environmental and radiological health and safety considerations, then relocation to a site other than Clinch River would not provide a superior alternative for meeting programmatic objectives. In fact, it would involve substantial delay and additional cost. NRC's 1977 Final Environmental Statement and Site Suitability Report found the site to be acceptable on both programmatic and environmental grounds.[15] Considering the present LMFBR program objectives, the Clinch River site remains the best alternative for meeting program and project objectives.

REFERENCES FOR APPENDIX G

1. P.L. No. 91-44, 83 Stat. 46 (1969).

2. P.L. No. 91-273, 84 Stat. 299 (1970).

3. LMFBR Demonstration Plant Program, Proceedings of the Senior Utility Steering Committee and Senior Utility Technical Advsiory Panel for the Period April 1971 through January 1972, March, 1972, WASH-1201 (hereinafter referred to as "WASH-1201").

4. WASH-1201 pp. 398-507.

5. Letter from Richard C. Nyland, Chairman, Joint Power Planning Council Committee on LMFBR to Mr. Peter Van Nort, General Manager, Project Management Corporation, December 28, 1976.

7. Letter from B. B. Parker, Executive Vice President, Duke Power Company, to Presidents of Carolina Power & Light Co., Virginia Electric Power and Light Company, the Southern Company, and South Carolina Electric & Gas Co., June 1, 1978.

8. WASH-1201, pp. 398-507.

9. WASH-1201, pp. 508-528.

10. Clinch River Breeder Reactor Plant Environmental Report, Volume 1, Section 9.2.1-9.2.3, February 1977.

11. Clinch River Breeder Reactor Plant Environmental Report, Appendix A.

12. NUREG 0139, Environmental Statement Related to the Construction and Operation of Clinch River Breeder Reactor Plant, 9.2.4, February 1977.

13. Clinch River Breeder Reactor Plant Environmental Report, Appendix D.

14. Clinch River Breeder Reactor Plant Environmental Report, Appendix E.

15. Final Environmental Statement Related to the Construction and Operation of the Clinch River Breeder Reactor Plant, Docket No. 50-537, February 1977, NUREG-0139; Site Suitability Report by the Office of Nuclear Reactor Regulation, USNRC, in the Matter of the Clinch River Breeder Reactor Plant, Docket No. 50-537, March 4, 1977.

Appendix H

HEALTH EFFECT RISK ESTIMATES

This appendix presents a compilation of health effects estimates for low linear energy transfer (LET) radiation (i.e., gamma and x-radiation and electrons). Estimates for high LET radiation (alpha particles) are given in Section VI.A(4) and Appendix D.

Two tables are given, one for somatic effects (cancers) and one for genetic effects. The material is taken from two recent DOE Environmental Impact Statements[1,2]. Detailed references supporting these tables may be found in those documents.

REFERENCES FOR APPENDIX H

1. DOE/EIS-0046F, "Final Environmental Impact Statement, Management of Commercially Generated Radioactive Waste," Volume 2, Appendix E, October 1980.

2. DOE/EIS-0082D, "Draft Environmental Impact Statement, "Defense Waste Processing Facility, Savannah River Plant, Aiken, S.C.," Appendix J, September 1981.

Table H-1
COMPARISON OF VARIOUS ESTIMATES OF CANCER DEATHS PER MILLION MAN-REM

	BEIR I Report (NAS-NRC 1972)					Reactor Safety Study (NRC 1975)				BEIR III Report (1980)	
	Absolute Risk Model		Relative Risk Model								
Type of Cancer	30-Year Plateau	Life Plateau	30-Year Plateau	Life Plateau	EPA	Upper Bound[b]	Central Estimate[c]	UNSCEAR Report (1977)	ICRP-26	Probable Risk[d]	Maximum Risk[e]
Leukemia	-26-[a]	-	-37-[a]	-	54	28	5.6	15-25	20	20[f]	45[f]
Non-leukemic	60	74	122	417	-	106	42	-	-	-	-
Lung	16	19	-	-	60	22	4.4	25-50	20	28	100
Bone	2.4	3.0	-	-	16	7	1.4	2-5	5	-	-
Thyroid	-	-	-	-	-	13	2.6	5-15	5	6.9	25
Total Cancers	86	100	159	454	200	134	48	100	100	120	400

(a) 10-year risk plateau following in utero exposure, otherwise 25 years.
(b) Lower bound is zero for all cancers.
(c) Calculated on the assumption that no individual dose will exceed 10 rem.
(d) Linear-quadratic average of absolute and relative models.
(e) Linear, relative model only.
(f) Leukemia and bone cancers combined.

Table H-2
ESTIMATES OF GENETIC EFFECTS OF RADIATION OVER ALL GENERATIONS*

Type of Effect	BEIR I Report (1972)	UNSCEAR Report (1977)	EPA (1973)	Newcombe (1975)	BEIR III Report (1980)
Autosomal Dominant Disorders	50-500	100		10	-
Chromosomal Disorders		40			-
Multifactorial Disorders	10-1000	45			-
Total	60-1500	185	300	10	60-1100

*per 10^6 man-rem.

XI. GLOSSARY/ACRONYMS

ACRS	Advisory Committee on Reactor Safeguards
AEC	Atomic Energy Commission
AMAD	Activity Median Aerodynamic Diameter
ASM	Aggragated Systems Model
BNFP	Barnwell Nuclear Fuel Plant
CBR	Commercial Breeder Reactor
CCTV	Closed Circuit Television
CRBRP	Clinch River Breeder Reactor Plant
CREDO	Centralized Reliability Data Organization
CY	Calendar Year
DOE	Department of Energy
D-T	Deuterium-Tritium
EA	Environmental Assessment
ERDA	Energy Research and Development Administration
ETR	Engineering Test Reactor
FEIS	Final Environmental Impact Statement
FESEM	Forcible Entry Safeguards Effectiveness Model
FFM	Fuel Failure Mockup
FFTF	Fast Flux Test Facility
FMEF	Fuels and Materials Examination Facility
FONSI	Finding of No Significant Impact
FSAR	Final Safety Analysis Report
GWe	Gigawatts Electric
HCDA	Hypothetical Core Disruptive Accident
HLW	High Level Wastes
IAEA	International Atomic Energy Agency

ICRP	International Commission on Radiological Protection
IRG	Interagency Review Group
ISEM	Insider Safeguards Effectiveness Model
kW	Kilowatt
LANL	Los Alamos National Laboratory
LDP	Large Development Plant
LET	Linear Energy Transfer
LMFBR	Liquid Metal Fast Breeder Reactor
LWR	Light Water Reactor
MWe	Megawatts Electric
MWt	Megawatts Thermal
NAS	National Academy of Sciences
NRC	Nuclear Regulatory Commission
NURE	National Uranium Resource Evaluation
OPERA	Out-of-Pile Expulsion and Reentry Apparatus
OTEC	Ocean Thermal Energy Conversion
PBF	Power Burst Facility
PFES	Proposed Final Environmental Statement
PSAR	Preliminary Safety Analysis Report
R&D	Research and Development
RRD	Reactor Research and Development
RSS	Reactor Shutdown System
SACRD	Safety Analysis Computerized Reactor Data
SAFE	Safeguards Automated Facility Evaluation
SAREF	Safety Research Experiment Facility
SHRS	Shutdown Heat Removal System
SLSF	Sodium Loop Safety Facility
SNAP	Safeguards Network Analysis Procedure

SNM	Special Nuclear Material
ST	Short Ton (2000 lbs)
SVAP	Safeguard Vulnerability Analysis Program
THORS	Thermal Hydraulic Out-of-Reactor Safety facility
TREAT	Transient Reactor Test facility
TRU	Transuranic
USGS	U.S. Geological Survey
WECS	Wind Energy Conversion Systems

Forward costs are the yet-to-be-incurred costs of producing U_3O_8 from a given resource and include the direct costs of developing and operating a mine and building and operating a uranium mill. They are used to indicate the economic availability of a uranium resource. A forward cost category includes all resources at or below the stated forward cost. Forward costs are not to be confused with price, which includes past costs, exploration costs, cost of money, marketing costs, rate of return, profit, some taxes, etc. A rough rule of thumb is that the U_3O_8 price is up to two times forward cost.

Special nuclear material means (1) plutonium, uranium 233, uranium enriched in the isotope 233 or in the isotope 235 or (2) any nuclear material artificially enriched.

XII. COMMENT LETTERS RECEIVED

Number	Individual/Organization
1	State of Alaska*
2	Frank von Hippel (Princeton University)
3	State of Oklahoma (Clearinghouse)*
4	Roy Dycus (Shirley's Enterprises)
5	Atomics International Division, Rockwell International
6	U.S. Department of Commerce (National Oceanic and Atmospheric Administration)
7	National Science Foundation
8	Northeast Utilities
9	U.S. Nuclear Regulatory Commission
10	U.S. Environmental Protection Agency
11	Natural Resources Defense Council, Inc.
12	State of Missouri (Clearinghouse)*
13	State of Arizona (Clearinghouse)*
14	State of Tennessee (Clearinghouse)*
15	State of Nevada (Clearinghouse)*
16	East Tennessee Development District (Regional Clearinghouse)*
17	State of Maryland (Clearinghouse)*
18	Burns and Roe, Inc.
19	Commonwealth of Virginia (Council on the Environment)
20	State of North Carolina (Clearinghouse)*
21	State of California
22	State of South Dakota (Clearinghouse)*
23	State of Ohio (Clearinghouse)*
24	Commonwealth of Pennsylvania*
25	State of North Dakota (Clearinghouse)*
26	State of Oregon*
27	State of Delaware (Clearinghouse)*
28	State of Idaho (Clearinghouse)*

*No Comments

Comment letters received on the Draft Supplemental EIS (referred to as the Supplement) are reproduced on the following pages in the order given in the above table. General and specific comments and DOE responses to them are given starting on page xix. Comments are identified by comment letter numbers (e.g., Letter #7, National Science Foundation) and page(s) of comment letter.

STATE OF ALASKA

OFFICE OF THE GOVERNOR
DIVISION OF POLICY DEVELOPMENT AND PLANNING
GOVERNMENTAL COORDINATION UNIT

JAY S. HAMMOND, Governor

POUCH AW (MS - 0165)
JUNEAU, ALASKA 99811
PHONE: (907) 465-3562

January 7, 1982

Mr. William A. Vaughan
Assistant Secretary
Environmental Protection,
Safety, and Emergency Preparedness
U.S. Department of Energy
Washington, D.C. 20585

Dear Mr. Vaughan:

On behalf of Governor Hammond, thank you for your December 18, 1981 letter and opportunity to review the Draft Supplemental Environmental Impact Statement on the Liquid Metal Fast Breeder Program (ERDA-1535). The State of Alaska has no comment on this proposal at this time, but we would like to be kept informed of future developments in this program.

Sincerely,

David W. Haas

David W. Haas
Acting State Federal Coordinator

Princeton University SCHOOL OF ENGINEERING/APPLIED SCIENCE
CENTER FOR ENERGY AND ENVIRONMENTAL STUDIES
THE ENGINEERING QUADRANGLE
PRINCETON, NEW JERSEY 08544

January 14, 1982

Mr. Wallace R. Kornack, NE-6GTN
Office of Nuclear Reactor Programs
Office of the Assistant Secretary
for Nuclear Energy
U.S. Department of Energy
Washington, D.C. 20545

Dear Mr. Kornack,

This letter is in response to DOE's request for comments on the Draft Supplementary Environmental Impact Statement on the Liquid Metal Fast Breeder Reactor Program (DOE/EIS-0085-D).

I will not comment on the technical details of this draft supplement at this time because it is missing an essential part which is required to make it meaningful — namely, a cost/benefit analysis of the proposed LMFBR Program.

As I will show below, the DOE has recently completed all the elements of such an analysis, and has concluded both that the U.S. has plenty of low cost uranium to support light water reactors for many decades and that the LMFBR will not be economically competitive with light water reactors for as far in the future as DOE has made projections (40 years). This is quite a different conclusion than that which was arrived at in the original EIS on the LMFBR Program where the AEC and ERDA argued that a uranium shortage was imminent in the U.S. and that the LMFBR would be economically competitive in the 1990's.

The DOE's failure to reveal in the Draft Supplementary EIS the collapse of the basic rationale of the LMFBR demonstration program is, therefore, in effect if not by intention a coverup. For this reason I request that this Draft Supplementary EIS be withdrawn and be replaced by one which contains the updated cost/benefit analysis. Below I will discuss in more detail the essential ingredients of this cost/benefit analysis and why it is critical to the reconsideration of the LMFBR Program at this time. I will also comment on the reasons given by the DOE for not including such a cost/benefit analysis in this Draft Supplement.

The Cost/Benefit Analysis and its Importance to a Reconsideration of the LMFBR Program

As the Draft Supplementary EIS states (p. 3):

> Cost/Benefit Analyses of the LMFBR program were included in WASH-1535 and ERDA-1535.

WASH-1535 and ERDA-1535 are the AEC'a proposed and ERDA's final LMFBR Program Environment Statement, respectively. These analyses were published in 1974 and 1975 and provided the basic rationale for the decisions made in that time period to proceed with an LMFBR program aimed at commercialization in the 1990's. The basic argument presented in WASH-1535 was quite straightforward and can be summarized as follows:

- In 1974 WASH-1535 projected U.S. nuclear capacity at 1200 Gw(e) in the year 2000 and 3300 Gw(e) in the year 2020;[1]
- It also estimated that the U.S. resources of low cost uranium could support only about 1000 Gw(e) of LWR capacity;
- The AEC also believed at the time that the breeder would be economically competitive with LWRs fueled by even low cost uranium;[2]
- As a result the AEC concluded that it was necessary and cost-effective to commercialize LMFBRs as soon as possible.

By 1981, however, the picture had completely changed:

- It had become quite clear that the historical decline of real electricity prices had ended and that in fact real prices could be expected to increase for at least a decade.
- As a result it was clear that the period during which U.S. electricity demand doubled every decade had also passed and that in the future U.S. electricity demand would, like the demand for the products of most other mature industries, grow little or no more rapidly than the economy as a whole. Accordingly, by 1981 the DOE's midrange projection for U.S. nuclear capacity had fallen to 175 Gw(e) for the year 2000 and to 290 Gw(e) for the year 2020[3] -- capacities which were respectively one seventh and one eleventh of those which had been projected by the AEC only seven years earlier;
- With these new projections the DOE found that, instead of predicting that the U.S. will be exhausting its uranium resources by about the year 2000, it was now estimating that even by 2020 U.S. LWRs will have consumed only about one quarter of the nation's resource of low cost U_3O_8 (less than $100 per pound forward cost).[4,5]

- During this past seven years the DOE has also concluded that, even a large breeder system fully enjoying all the available economies of scale in the production of reactors and in fuel cycle facilities, will not be able to compete economically with LWRs operating on a once-through fuel cycle until the cost of U_3O_8 rises to extremely high levels. In 1979, in its report on the Nonproliferation Alternative Systems Assessment Program, the DOE estimated that the LMFBR would become competitive with a once-through LWR system with 15 percent improved uranium efficiency only when the cost of U_3O_8 rises to somewhere in the range of $115-205 per pound.[6] Including nonretrofittable cost-effective improvements in the uranium efficiency to new LWRs and advanced isotope separation technology for enrichment tails stripping would raise this crossover range to $150-250 per pound of U_3O_8.[7] These numbers are 2-3 times DOE's 1981 estimate of the price of U_3O_8 in 2020: $78 per pound.[8]

- As a result of this changed situation, a revised cost analysis presented in the Supplementary EIS based on the most recent DOE analyses would show that LMFBRs will not be economic until far beyond the DOE's furthest horizon - 2020.

Of course, the nation could decide to proceed with the program anyway. The purpose of an Environmental Impact Statement, however, is to lay out tradeoffs involved so that they can be subjected to public and peer review.

<u>DOE's Reasons for not Including a Cost/Benefit Analysis in the Draft Supplementary EIS</u>

On p. 3 of the Draft Supplementary EIS it is stated that

> ... no such further [since ERDA-1535] cost/benefit analyses have been performed and none, therefore, are included in this supplement...

As my discussion above demonstrates, however, the DOE has performed all the essential parts of an updated cost/benefit analysis.

The EIS then continued on pages 3 and 4 to give three additional reasons why an updated cost/benefit analysis has not been included in the Draft Supplementary EIS:

1) Cost/benefit analyses are not required in an EIS (see CEQ regulations, 40 CFR 1502.23)...

In the light of the description above of the conclusions which can be drawn from the analyses which the DOE has made, this legalistic statement gives the impression that the DOE finds the results of its updated cost/benefit analyses unwelcome and does not wish to bring them to public attention.

2) Cost/benefit information for alternative long-term technologies (fusion and solar electric) has not been developed to a degree that would make cost/benefit analyses of these alternatives meaningful.

This may be true, but it is also irrelevant. If, as it appears from current DOE analyses, the LMFBR cannot even compete for many decades with other fission technologies such as the LWR, why should the nation move ahead now with a demonstration-commercialization program? This question can be answered without any information about the long-term prospects of nonfission technologies.

3) Parameters (e.g., discount rate(s), LMFBR introduction date(s), future nuclear capacity, future cost of coal) used in complex cost/benefit analyses of the LMFBR are so uncertain at present that the value of such analyses would be questionable. It is the goal of the breeder research and development to reduce such uncertainties.

First of all, the principal focus of the LMFBR Program described in the Draft Supplementary EIS is to demonstrate the hardware of LMFBR power plants. This program has very little resemblance to a research program on: the uncertainties in the discount rates used to determine the value of such a program, in the future of U.S. nuclear capacity, or even uncertainties in the future cost of coal!

Secondly, the uncertainties in the parameters which are critical to a cost/benefit analysis of the breeder -- future U.S. nuclear capacity growth, the magnitude of U.S. uranium resources, and the capital and fuel cycle cost differentials between LMFBRs and LWRs -- have been significantly reduced since the AEC-ERDA cost/benefit analysis was published. Indeed, it appears from the DOE's own analyses that they have been reduced enough so that the values of the key parameters used by the AEC and ERDA in their justification of the LMFBR demonstration program are now way outside the remaining uncertainty bonds and that, as a result, it is pointless to go ahead with an LMFBR demonstration program at this time.

On page 43 the Draft Supplementary EIS states that:

> the prudent course is to gear the development program toward possible commercialization of LMFBRs fairly early in the next century.

Yet, at the same time, the DOE has refused to present in this document its own analyses which support by a very wide margin a conclusion that the LMFBR will <u>not</u> be needed early in the next century.

In the past the AEC, ERDA and DOE all accepted the basic assumption which led to the requirements of Environmental Impact Statements: the public has right to expect the government to present the rationale for its proposed programs for public and peer review. This was done in WASH-1535, and ERDA-1535. A number of independent policy analysts took a great deal of trouble to critique these analyses[9] and, as I have demonstrated above, the DOE ultimately changed its own projections drastically. Yet now the DOE, like the tailors in Hans Christian Andersen's fairytale, demands that the public admire the invisible new clothes which it has produced in this Draft Supplementary EIS and accept the bland recommendation that to proceed with the LMFBR demonstration program would be "prudent."

The requirements that govermmental agencies prepare Environmental Impact Statements on their major programs was a big step forward toward providing citizens with access to the information and analyses which they require if their rights as citizens are to be meaningful in an increasingly complex society. In this context, acceptance of this Draft Supplementary EIS would be a step backwards. I therefore request, both in the interests of good public policy in this case and in the interests of good government more generally, that the DOE withdraw this Draft Supplementary EIS and publish a new draft which includes the results of DOE's updated cost/benefit analysis.

Sincerely yours,

Frank von Hippel

FvH/zk

References and Footnotes

1) US AEC, Proposed Final Environmental Statement, Liquid Metal Fast Breeder Reactor Program (WASH-1535, December 1974), p. 11.2 - 11.3.

2) ref. 1. pp. 11.2-4, 11.2-10, and 11.2-30.

3) US DOE, EIA, Annual Report to Congress, 1980: Vol. 3 Forecasts, [DOE/EIA-0173 (80)/3], p. 158.

4) Compare Ref. 3, p. 177 (converting primary energy released into pounds of U_3O_8 at the rate of 170 million Btus per pound) with ref. 5.

5) US DOE, An Assessment Report on Uranium in the United States of America [GJO-111(8), 1980], p. 1.

6) US DOE, Nuclear Proliferation and Civilian Nuclear Power: Report of the NonProliferation Alternative Systems Assessment Program (Draft DOE/NE-0001, 1979), Fig. 11.

7) Using the curve shown in ref. 6, fig. 6 for the economics of a 30 percent improved LWR and the estimate in ref. 6 (p. 9)that advanced isotope separation systems could strip enrichment tails from 0.2 to 0.05 percent U^{235} at a cost equivalent to $43 per pound U_3O_8

8) ref. 3, p. 177.

9) See e.g., the report to ERDA by the following members of ERDA's LMFBR Review Stearing Committee; Thomas B. Cochran, Russell E. Train, Frank von Hippel and Robert H. Williams, Proliferation Resistant Nuclear Power Technologies: Preferred Alternatives to the Plutonium Breeder (April 6, 1977) and the subsequent publication by Harold A. Feiveson, Frank von Hippel and Robert H. Williams, "Fission Power: An Evolutionary Strategy," Science, January 29, 1979, p. 330.

OKLAHOMA DEPARTMENT OF ECONOMIC AND COMMUNITY AFFAIRS
FEDERAL ASSISTANCE MANAGEMENT DIVISION
State Grant-In-Aid Clearinghouse
4545 N. LINCOLN, SUITE285 OKLAHOMA CITY, OKLAHOMA 73105 (405) 528-8200

January 20, 1982

Mr. Wallace R. Kornack, NE-6 GTN
Office of Nuclear Reactor Programs
Office of the Assistant Secretary for Nuclear Energy
U. S. Department of Energy
Washington, D.C. 20545

RE: Draft Supplemental Environmental Impact Statement to the final EIS on the Liquid Metal Fast Breeder Program

Dear Mr. Kornack:

This letter acknowledges receipt of the draft supplemental Environmental Impact Statement to the final EIS on the Liquid Metal Fast Breeder Program.

This office does not have any record reflecting the review of the Liquid Metal Fast Breeder Program prepared by the U. S. Energy Research and Development Administration in December 1975.

Therefore, due to the short time frame before comments on the supplemental Environmental Impact Statement are requested, the Oklahoma State Clearinghouse submits no comment on the supplemental statement.

Sincerely,

Don N. Strain
Director

DNS:lrm

STATE CLEARINGHOUSE
30 EAST BROAD STREET • 39TH FLOOR • COLUMBUS, OHIO 43215 • 614 / 466-7461

January 21, 1982

Mr. Wallace R. Kornack
Office of Nuclear Reactor Programs
Office of Ass't Secretary for Nuclear Energy
U. S. Department of Energy
NE-6, Room H-404
Germantown, Maryland 20545

RE: Review of Environmental Impact Statement/Assessment Report
Title: Draft Supplement Environmental Impact Statement on the Liquid Metal Fast Breeder Reactor Program.
SAI Number: 36-471-0016

Dear Applicant:

Your Environmental Impact Statement/Assessment was received on the above date. The review process will now begin at the state level. You may expect notification that the review has been completed no later than 40 days following the receipt date of a draft Environment Impact Statement/Assessment and 32 days for a final Environmental Impact Statement/Assessment.

A State Application Identifier Number (SAI) has been assigned to your Environmental Report. Please refer to this number in all future contacts with the State Clearinghouse.

Sincerely,

Rose Metzger Roesch
A-95 Coordinator

Shirley's Enterprises
"Producing To Fight Pollution"
Route 2 Box 271
Blue Ridge, Georgia 30513

January 25,1982

Mr. Wallace R. Kornack, NE-6 GTN
Office of Nuclear Reactor Programs
Office of the Assistant Secretary for Nuclear Energy
U.S. Department of Energy
Washington,D.C. 20545

Dear Sir; -

I thought we killed this make-work project for the Nuclear Community in 1975. I was wrong.

I also see you choose not to use Mr. Reagan's rigid rule of only funding programs that met a so-called cost/effective criteria.....MMMmmmmm. If Solar wants a program , it must pass this test---but,if Mr. Reagan's super-rich friends wants to loan money to fund Nuclear,it is exempt..It will never get off the ground,the economy is in shambles,because,no Nation of two hundred and twenty five million peoples can maintain a debt of one trillion dollars. And if it is built,you have to borrow money to do it.

The DOE spent six hundred million dollars on hardware for this project,but did not spend any for test of the damage done to human cells by low level nuclear radiation,by such eminent Molenuclear Biologist as Mr Walter Gilbert and his colleagues---for to do so, would so prejudice your case for Nuclear power,(Of any kind.) it would make the Nuclear (let's borrow money to do it.) advocates look like clowns. This project would cost ten billion dollars,and give us nothing but more debt and dangers. It will be just one more A-1 Priority target.

I sure hope the Money-bags who loaned the money to build the now operating Nukes,have welded the safties on the Sam-5's now installed and targeted on all operating Nuclear Power plants in the South East. The new improved Sam-5's maintained and kept in constant readyness by Soviet crews in the silos in Cuba,have a range of twelve hundred miles. Your Clinch river site is just right.

The Nuclear Community of America have strategically placed LWR's across our country until a Soviet strike,(Or a threat of a strike) will render us slaves to Communism. Don't give me that crap,"If a Nuclear war comes,it dosen't matter...." It matters---when you have Plutonium up to your knees,it helps if it never reaches you eyeballs.

And if a warhead hits Hanford Washington,and seventy two Nukes, that's precisely where it will be,as our weather moves from West to East we've had it.

I hear kinky little wheels clicking in your head"The Soviets have LWR's,they can be hit." True---but,get out your little ole World map and you will see,they placed theirs in such a location, that Geographically the Radioactive fallout hits Alaska,Cannada, Japan,and China.....Not the Soviet peoples....Who needs enemies when we have the Nuclear Community.

In each case where stastitics have been collected and correlated, Enzyme Disfunction Diaseases,(Heart,Fetal deaths,Strokes,and Cancer.) have accelerated the death toll in the populations who live near and adjacent to Nuclear Installations. Rocky Flats, Hanford,Washington,The Savannah River Atomic Energy Reservation at Barnwell,S.C. (Finial Impact Statement 1975) and Dr.Sternglass's correlations. Low level Nuclear Radiation kills folks, and as more excapes into our Environment,more bodies will fall.

By the year 2000 the U.S.A. will have enough Nuclear Wastes to build a four lane hiway from the West coast to the East coast,one foot deep. At what point,does the Nuclear Community say...Yes... we have plenty. Plenty of Plutonium,Nuclear wastes,megatonnage of bombs...You won't. There is enough Nuclear Arms today to kill four and one half billion people,fourty times over...and still the Congress and Senate says more,more,more.

We the people have one chance. If the Super-rich who loans funds to build Nuclear power plants becomes frightened and thinks they might loose their power over the control,a Nuclear accident will happen,somewhere,and the Politicans of this planet will rush to enact legisation to ban Nuclear Power Plants to protect their constituents,thus,becoming heros. The peoples taxes will be collected and pay the Super-rich their funds,(With interest of course.) and every one will be happy ever after.

Sincerely,

Roy Dycus

Roy Dycus

Atomics International Division
Energy Systems Group
8900 De Soto Avenue
Canoga Park, California 91304

Telephone: (213) 341-1000
TWX: 910-494-1237
ESG CN PK
Telex: 181017
ESG CNPK A

Rockwell International

January 29, 1982

In reply refer to 82ESG-1162

Mr. Wallace R. Kornack, NE-6 GTN
Office of Nuclear Reactor Programs
Office of the Assistant Secretary
for Nuclear Energy
U.S. Department of Energy
Washington, D.C. 20545

Dear Mr. Kornack:

Subject: Review of LMFBR Program Draft Environmental Impact Statement

We appreciate having the opportunity to review and comment on the Draft Environmental Impact Statement for the Liquid Metal Fast Breeder Reactor Program, DOE/EIS-0085-D dated December 1981. In general, we feel the document is well written, quite comprehensive and appropriately balanced. We would however like to suggest a few additions:

1. Under Section IV, A, 2, c, (1) Fuel Reprocessing, we would suggest that some acknowledgement be made of the fact that LMFBR fuel reprocessing is well along toward being a demonstrated technology. Britain and France have already successfully reprocessed substantial quantities of spent LMFBR fuel from DFR, PFR, Rapsodie and Phenix at their respective reprocessing facilities at Dounreay, Scotland and at Marcoule and LaHague in France. (Ref. BNES Conference on Fast Reactor Fuel Cycles, London, November 9-12, 1981)

2. Under Section VI, A, 4 Health Effects, some recognition should be given to the much lower dose rates received by LMFBR workers than by conventional LWR plant workers. For instance, the total exposure received by all workers in the first eight years of Phenix operation (~60 person-rem) is less than that received in one month by all workers in a typical U.S. LWR in 1980 (~65.9 person-rem). (Ref. 21. Section III and Inside Energy September 18, 1981)

Rockwell International

3. We would appreciate your adding the Atomics International Division of Rockwell International to your list of Industrial Organizations on page ix. We also would be pleased to assist you in preparing any further updates of the EIS.

Thank you again for giving us the opportunity to review and comment on this draft.

Very truly yours,

J. S. McDonald
Director
LMFBR Programs

JSM:bw

GENERAL COUNSEL OF THE
UNITED STATES DEPARTMENT OF COMMERCE
Washington, D.C. 20230

JAN 29 1982

Mr. Wallace R. Kornack
Office of Nuclear Reactor Programs
Office of the Assistant Secretary for
Nuclear Energy
U. S. Department of Energy
Washington, D. C. 20545

Dear Mr. Kornack:

This is in reference to your draft environmental impact statement entitled "Liquid Metal Fast Breeder Reactor Program." The enclosed comments from the National Oceanic and Atmospheric Administration are forwarded for your consideration.

Thank you for giving us an opportunity to provide these comments, which we hope will be of assistance to you. We would appreciate receiving four copies of the final environmental statement.

Sincerely,

Robert T. Miki
Director of Regulatory Policy

Enclosure: Memo from Edward P. Myers
Office of the Administrator
National Oceanic and Atmospheric Administration

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Washington, D.C. 20230

OFFICE OF THE ADMINISTRATOR

January 19, 1982

ME:EPM

TO: PP/EC - Joyce Wood

FROM: ME - Edward P. Myers

SUBJECT: DEIS 8112.23 - Liquid Metal Fast Breeder Reactor Program

My comments on this DEIS address only the discussion of Ocean Thermal Energy Conversion (OTEC), pages 106-107 and 213-216. They are as follows:

(1) The format of the discussion is different from that of other items in this section of the report (e.g., wind energy conversion, solar photovoltaic conversion, solar thermal conversion). A consistent format would aid the reader.

(2) In accord with point (1), a description of the OTEC process should be the first item of discussion, followed by mention of the pros and cons. Starting with "Problems" seems misleading.

(3) Under "Institutional" on page 106, the reference to "licensing requirements" needing to be examined should be deleted since NOAA has published the licensing requirements for commercial OTEC plants (15 CFR Part 981).

(4) In discussing work conducted to date, the Mini-OTEC and OTEC-1 projects should be discussed.

(5) The paragraph starting with "Research and development---" at mid-page on page 107 is another topic and should be differentiated with an appropriate heading.

(6) The authors admit that the numbers in Table 11 on page 214 are very rough. Accordingly, I feel that the last statement on page 213,

> "It can be inferred from this table that the environmental impact associated with construction will be much less for the LMFBR than for most other long-term technologies."

is misleading. Furthermore, to make such a broad statement about environmental impacts based on a comparison of land use, water use, and construction materials is erroneous. There are many other factors to consider.

Thank you for the opportunity to review the DEIS. I hope my comments prove helpful.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

February 1, 1982

OFFICE OF THE ASSISTANT DIRECTOR FOR ASTRONOMICAL, ATMOSPHERIC, EARTH AND OCEAN SCIENCES

Mr. Wallace R. Kornack, NE-6 GTN
Office of Nuclear Reactor Programs
Office of Assistant Secretary for Nuclear Energy
U.S. Department of Energy
Washington, DC 20545

Dear Mr. Kornack:

The National Science Foundation has reviewed the Department of Energy's supplemental draft EIS on the Liquid Metal Fast Breeder Reactor Program (DOE/EIS-0085-DS) and submits the enclosed comments.

Sincerely,

Adair F. Montgomery, Chairman
Committee on Environmental Matters

Enclosure

NSF Comments on Liquid Metal Fast Breeder Reactor Program

1. This report provides a highly technical assessment of the advantages associated with the early development of Liquid Metal Fast Breeder Reactor (LMFBR). Comparisons are made with other high technology future energy sources (fusion and solar conversion). A strong case is presented although complete documentation is not always provided for the non-expert reader. Moreover, a number of statements of a subjective nature are sprinkled throughout the text.

2. The issue of adverse public reaction to nuclear power is not addressed. More detailed discussion of the recent and continuing problems of the nuclear industry would be helpful.

3. It is recognized that the LMFBR Program has been dependent upon appropriations. The present status and future schedules are adequately presented. In the intervening time, certain aspects of the LMFBR project have advanced. On the Clinch River Breeder Reactor Plant (CRBRP), the design work is about 90 percent complete, and about 60 percent of the hardware has been delivered or is on order. The environmental issues on health effects, reactor safety, safeguards, and waste management have been put into a better focus. In part, this has been due to advances and progress of the test programs and specific studies and efforts. As a result, the CRBRP can proceed with site preparation and construction after specific authorizations, approvals, and contracts are let.

4. The results of the operations of the early test facilities and the Fast Flux Test Facility have provided needed information in support of the CRBRP.

5. This supplemental EIS covers briefly work progressing in several foreign countries. If an interchange of information has not been established with the United States, it would seem to be advantageous to do so.

6. The alternatives within the LMFBR and those of long-term technologies are covered in sufficient detail to be meaningful.

7. On the matter of safeguards and security, the report deals with the activities of DOE and NRC. It seems that many other Federal agencies have experience here that should be taken into account.

8. The matter of a trained workforce is one that the nuclear component of the country and the universities should bring into focus. The National Science Foundation supports basic and engineering research in the nuclear areas which results in a limited number of trained scientists and engineers.

9. It appears sensible that the LMFBR Program should proceed with the CRBRP and that the Large Developmental Plant (LDP) ought to be based in part upon some operational time of the CRBRP. The LDP effort also ought to take into account the progress and success of the foreign programs.

10. The NSF transferred lead responsibility for solar and geothermal energy research to ERDA in 1975. Thus on page 107, reference to current NSF activities in these areas is incorrect.

NORTHEAST UTILITIES

P.O. BOX 270
HARTFORD, CONNECTICUT 06101
(203) 666-6911

February 2, 1982

Mr. Wallace R. Kornack, NE-6 GTN
Office of Nuclear Reactor Programs
Office of the Assistant Secretary for Nuclear Energy
U. S. Department of Energy
Washington, D.C. 20545

Dear Mr. Kornack:

Re: DOE/EIS - 0085 - DS (December 1981)

Northeast Utilities has given strong support to development programs for the LMFBR, for other advanced nuclear reactor designs, and for new energy technologies in general. Therefore, our brief review of the referenced Draft Environmental Impact Statement Supplement for the LMFBR program gives us concern for the balance of the viewpoint evident in its content.

The DRAFT EIS Supplement considers only two advanced alternatives to the LMFBR: fusion and solar electric. There are a number of other nuclear alternatives which are equally, or nearly equally, credible alternatives. These include:

- advanced Light Water Reactors (easing U-demand);
- the Light Water Breeder Reactor;
- advanced converters, principally the High Temperature Gas Cooled Reactor (easing U-demand);
- the Gas-Cooled Fast Breeder Reactor;
- the fusion-fission hybrid breeder, as a "fissile fuel factory."

The credibility of the EIS would be inhanced if these (and other) alternatives were fairly assessed vis-a-vis the LMFBR.

Sincerely,

Jerald L. Holm
Senior Scientist
Nuclear Energy Conversion Research

JLH/m
cc: S. H. Law

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

February 8, 1982

Mr. Wallace R. Kornack
Office of Nuclear Reactor Programs
Office of the Assistant Secretary
for Nuclear Energy
U. S. Department of Energy
Washington, D.C. 20545

Dear Mr. Kornack:

Pursuant to your request published in the Federal Register on November 2, 1981, enclosed are comments on DOE's draft supplement to the Environmental Impact Statement on the Liquid Metal Fast Breeder Reactor Programs.

If further comments are received from our reviewers, they will be forwarded to you immediately.

Paul S. Check, Director
CRBR Program Office
Office of Nuclear Reactor Regulation

Enclosure:
As stated

NRC COMMENTS ON DOE/EIS-0085-D DRAFT SUPPLEMENT
TO ERDA-1535, THE EIS ON THE LMFRB PROGRAM

3-4 Cost-Benefit Analysis - We suggest that DOE prepare an updated cost benefit analysis for the LMFBR program. Although many of the key parameters in a cost benefit analysis are uncertain, the resulting analysis could rely on a reasonable range of values for key parameters and results could be clearly identified as uncertain. At a minimum, DOE could provide a summary of all costs and benefits with a qualitative/quantitative discussion (when possible) of each item.

22 last line: Please define "lifetime of the radioactive materials." Is this ten half-lives, or the biological half-life, or some combination of the radiological and biological half-lives?

36 first sentence - the text incorrectly states that the lifetime uranium requirements for a LWR varies between 140 and 200 ST U_3O_8. This is the annual uranium requirements for a LWR. The calculations that follow in the Supplement all reflect this latter relationship.

43-44 Risk of Delay - The Supplement uses economic arguments to justify the timing of the LMFBR program. The cost of not having the LMFBR when needed is quantified and indirect benefits foregone are also identified. Alternatively, the cost of bringing it on too early is simply identified as being a function of the direct cost, the cost of money, and time. This side of the equation should also be quantified and indirect costs such as increased gov't deficits and inflationary pressures should be identified. Finally, for the "too early" vs. "too late" scenarios to be comparative, they must be brought to the same point in time via an appropriate discount rate.

192 para. 2: Reasons are given as to why all of the source term is assumed to be released to the atmosphere. It would improve the argument to include an analysis to show that the contribution from the aqueous pathway to human exposure (& health effects) will be significantly less than the atmospheric pathway. With respect to the accident contribution to the source term, a cross reference to p. 134 and the footnote thereon would be useful.

195 para. 2: Terrestrial Dispersal - it is acknowledged that the assumption of uniform distribution of TRU over the U.S. will underestimate the deposition immediately downwind from the source, and may underestimate the TRU reaching man via food chains. It would be appropriate here to make a statement as to the possible magnitude of the underestimate.

196 para. 2: It was assumed that the concentration of TRU in food resulting from LMFBR releases will be 1 percent of the concentration in the top 20 cm of soil. What is the range of uncertainty in this estimate?

200-211 The comparisons of estimated exposures from other sources in Table 8 are very useful as is the discussion of uncertainties in health effects estimates which follow.

207 para. 1: What is the basis for the assumed AMAD of 0.3 μm?

209 first full paragraph: How would the possible 10-fold variation in the quantity of TRU inhaled affect the estimates of doses to the population?

214 The relative environmental impacts of alternative technologies are not supported in the text. For example, there is no basis for the different acreages reported for transmission lines. Water use for OTEC is reportedly very large and yet there is probably little or no actual consumption, as compared to, say, LMFBR cooling towers. The table is misleading.

D-1 para. 4: Evidence, or a reference, should be cited to show the conservatism of the soil-plant-man pathway mentioned here.

D-5 para. 2: What is the basis for the statement that the 50-year exposure period will overestimate actual exposure?

F-6 Second paragraph, third sentence - Apparent typo - Sentence ("In 1980, coal... using oil.") does not make sense in its current form.

F-7 Type - bottom of page "3.3$" should be 3.3%.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

FEB 8 1982

OFFICE OF THE ADMINISTRATOR

Mr. Wallace Kornack
NE-6, Room H-404
Office of Nuclear Reactor Programs
U.S. Department of Energy
Germantown, Maryland 20545

Dear Mr. Kornack:

In accordance with Section 309 of the Clean Air Act, as amended, the U.S. Environmental Protection Agency (EPA) has reviewed the draft supplemental Environmental Impact Statement (EIS) for the U.S. Department of Energy's (DOE) Liquid Metal Fast Breeder Reactor Program. This EIS has been issued to consider the environmental aspects of changes to DOE's liquid metal fast breeder reactor program since an earlier EIS (ERDA-1535) was issued in December, 1975.

EPA commends DOE for presenting this information to the public. The EIS adequately considers the environmental aspects of DOE's program changes. It is our expectation that DOE or NRC will continue to issue site specific EISs for facilities constructed as part of this program.

In keeping with our procedures EPA has rated this EIS LO-1 (lack of objections and an adequate analysis). Should you have any questions on our review, please call Dr. W. Alexander Williams (755-0790) of my staff.

Sincerely yours,

Paul C Cahill

Paul C. Cahill
Director
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February 8, 1982

Mr. Wallace R. Kornack
Office of Nuclear Reactor Programs
Office of Assistant Secretary
for Nuclear Energy
U.S. Department of Energy
NE-6, Room H-404
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Comments on the Draft Environmental Impact Statement,
Liquid Metal Fast Breeder Reactor Program
(Supplement to ERDA-1535) (December 1981)

Dear Mr. Kornack:

We are writing on behalf of the Natural Resources Defense Council ("NRDC") to present our comments on the draft supplemental environmental impact statement, "Liquid Metal Fast Breeder Reactor Program", (the "DEIS") released by the U.S. Department of Energy on December 17, 1981.

On August 21, 1981, we wrote to Secretary of Energy James Edwards requesting that the Final Environmental Impact Statement on the Liquid Metal Fast Breeder Reactor (the "LMFBR") Program (ERDA-1535) be "thoroughly reevaluated and revised to reflect the significant new information and changes

in conditions" since it was issued in 1975.*/ In the letter, we discussed in detail five areas in which there was a particular need for substantial updating: siting, accidents, economic costs and benefits, safeguards, and management of radioactive waste. In response to the notice of intent to prepare the DEIS (46 Fed. Reg. 54397, November 2, 1981), we again submitted a copy of our August 21st letter and reemphasized the need for a revision of the cost-benefit analysis for the LMFBR program.**/

The DEIS appears to be a half-hearted attempt by DOE to comply with the requirements of the National Environmental Policy Act, 42 U.S.C. §§ 4321 *et seq*. The DEIS fails to address all of the issues and many of the relevant studies identified in our August 21st letter. The benefits of nuclear power are highlighted, while the serious problems with this technology are either ignored or downplayed. Alternatives to the LMFBR Program are either not identified or not meaningfully discussed. As a result, the DEIS lacks the objectivity and comprehensiveness required to provide a reasoned basis for a decision to proceed with the LMFBR Program.

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*/ Letter, dated August 21, 1981, from Barbara A. Finamore, S. Jacob Scherr, and Thomas B. Cochran to James Edwards, Secretary of Energy.

**/ Letter, dated November 23, 1981, from S. Jacob Scherr, NRDC, to Wallace Kornack, DOE.

In Part I of these comments, we discuss the failure of the DEIS to update the cost/benefit analysis for the LMFBR and to consider all reasonably foreseeable consequences of the Program. In Parts II-V, we provide specific criticisms of the treatment in the DEIS of the following issues: Purpose and Need for the LMFBR Program; Alternatives; Environmental Consequences -- Reactor Safety, Safeguards, Waste Management, and Health Effects; and CRBR Siting.

I. MAJOR INADEQUACIES OF THE DEIS

A. Need for a Cost/Benefit Analysis

One glaring deficiency of the DEIS is its failure to revise the woefully outdated 84-page FES economic cost/benefit analysis of the LMFBR program. This deliberate omission of material already in existence and vital to a full understanding of the program violates the National Environmental Policy Act (42 U.S.C. §4321 et seq.) ("NEPA"), including its mandate that all agencies comply with its provisions in good faith and to the fullest extent possible. Given the massive and complex nature of the fast breeder program, the lack of any meaningful comparison of program costs and benefits renders the DEIS virtually unusable as a decisionmaking tool. Full NEPA compliance requires that DOE prepare and circulate a revised LMFBR cost/benefit analysis to allow full public discussion and critique of the figures the agency appears so anxious to hide.

The idea of an LMFBR cost/benefit analysis is not new; indeed, DOE and its predecessors have been preparing such documents since 1969*/. Both the Draft**/ and Proposed

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*/ U.S. Atomic Energy Commission, Division of Reactor Development and Technology, "Cost-Benefit Analysis of the U.S. Breeder Reactor Program ," WASH-1126 (April 1969). See also U.S. Atomic Energy Commission, Division of Reactor Development and Technology, "Updated (1970) Cost-Benefit Analysis of the U.S. Breeder Reactor Program," WASH-1184 (Jan. 1972); U.S. Energy Research and Development Agency, "The LMFBR-Its Need and Timing," ERDA-38 (May 1975).

**/ U.S. Atomic Energy Commission, "DRAFT Environmental Statement, Liquid Metal Fast Breeder Reactor Program," WASH-1535, Chapter II and Appendix III-B (March 1974).

Final LMFBR Environmental Impact Statements ("PFES")*/ submitted by the Atomic Energy Commission contain substantial cost/benefit analyses of the breeder program. The latter analysis received extensive public comment **/ and careful scrutiny by the Energy Research and Development Administration (ERDA) and its Internal Review Board. The Internal Review Board declared that "analysis of economic costs and benefits of the LMFBR program" was a major issue, and that rigorous cost/benefit analysis is necessary if the PFES is to provide "a sufficient basis for determining the acceptability of the environmental and economic aspects of the LMFBR Program."***/ As a result, the final Environmental Statement was revised to contain a comprehensive 84-page cost/benefit analysis designed to "clarify the principal issues regarding the economic feasibility of the LMFBR."****/

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*/ U.S. Atomic Energy Commission, "Proposed Final Environmental Statement, Liquid Metal Fast Breeder Reactor Program," WASH-1535, Chapter 11 and Appendix IV-D (December 1974).

**/ See, e.g., Environmental Protection Agency, Environmental Statement Comments, Liquid Metal Fast Breeder Reactor Program, EPA # D-AEC-00106-00 (April 1974), reprinted in PFES, Vol. VII, pp. 53-31 to 53-84.

***/ Report to the Administrator on the Proposed Final Environmental Statement for the Liquid Metal Fast Breeder Reactor Program by the Internal Review Board, pp. 8, 29 (June 20, 1975).

****/ U.S. Energy Research and Development Administration, Final Environmental Statement, Liquid Metal Fast Breeder Reactor Program. ERDA-1535, Section III F (December 1975).

ERDA felt that FES revisions were necessary since in the one year since the PFES was issued, estimates of future electrical energy requirements, uranium enrichment costs, uranium ore costs, nuclear plant capital costs and R & D costs had all changed substantially */. ERDA Adminstrator Robert C. Seamans, Jr. recognized that such estimates would continue to change as significant new information develops, and that such changes should be reflected in later EIS supplements or "even a new Statement." **/ Seamans agreed with the ERDA Internal Review Board that "[f]uture events will narrow the bands of uncertainty and permit a more reliable verdict on the LMFBR economics."***/

There have in fact been dramatic changes since 1975 in estimates of the capital cost of breeders, electricity demand, the role of nuclear power, and uranium availability necessitating changes in vitually every section

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*/ FES at p. III F-20.

**/ Administrator's Findings on the Liquid Metal Fast Breeder Reactor Program Proposed Final Environmental Statement, p. 8 (June 30, 1975)

***/ Internal Review Board Report at 28.

of the FES cost/benefit analysis to bring it up to date */. These changes have been documented in a plethora of LMFBR cost/benefit analyses prepared since 1975**/, several of which were authored by DOE and submitted to Congress for use in

*/ See, e.g. Ross & Williams, Our Energy-Regaining Control, McGraw-Hill (1981); Gibbons & Chandler, Energy: The Conservation Revolution; National Audubon Society Energy Plan (April 1981); Union of Concerned Scientists, Energy Strategies (1980); Demand and Conservation Panel of the Committee on Nuclear and Alternative Energy Systems, Alternative Energy Demand Futures to 2010 (1979); Rodberg, Employment Impact of the Solar Transition (1979); Sant, et al., The Least-Cost Energy Strategy: Minimizing Consumer Costs Through Competition (1979); The E235 Alternative Energy Futures Study Team, Alternative Energy Futures: An Assessment of U.S. Options to 2025 (1979); Stobaugh & Yergin, Energy Future: Report of the Energy Project at the Harvard Business School, Harvard University (1979); Taylor, The Easy Path Energy Plan (1979); Leach et. al., A Low Energy Strategy for the United Kingdom (1979); Christensen, Craig, et. al., Distributed Energy Systems in California's Future (Interim Report) (1978); Brooks, Economic Impact of Low Energy Growth In Canada: An Initial Analysis (1978).

**/ See, e.g., Chow, Brian G., Economic Comparison of Breeders and Light Water Reactors. A Report Prepared for the U.S. Arms Control and Disarmament Agency by Pan Heuristics (Contract No. AC8NC113) (July 23, 1979); Sharefkin, Mark, "The Fast Breeder Reactor Decision: An Analysis of Limits and the Limits of Analysis, a Report Prepared for the Joint Economic Committee by Resources for the Future (April 9, 1976); Manne, Alan S., "ETA: A Model for Energy Technology Assessment," Bell Journal of Economics and Management Service, pp. 379-406 ("Autumn 1976); Richels, Richard G. and Plummer, James L., "Optimal Timing of the U.S. Breeder," Energy Policy, pp. 106-121 (June 1977); Chow, Brian G., The Liquid Metal Fast Breeder Reactor, An Economic Analysis (American Enterprise Institute, December 1975).

Congressional decisionmaking on the program.*/ In recognition of the wealth of new analyses, estimates, and data, NRDC requested on two separate occasions that DOE reverse its FES cost/benefit analysis.**/ Yet DOE has refused to include such revisions in the DEIS, based on the utterly remarkable assertion that "no such further cost/benefit analyses have been performed"(3).***/ This glaring omission is in complete violation of both the letter and spirit of the National Environmental Policy Act, 42 U.S.C. § 4321 et seq. ("NEPA").

*/ See, e.g., U.S. Energy Research and Development Administration, "A Review and Update of the Cost-Benefit Analysis for the Liquid Metal Fast Breeder Reactor (LMFBR)," A Study Prepared for the use of the Joint Economic Committee of the United States (May 27, 1976); U.S. Department of Energy, Office of Energy Research, "The Nuclear Strategy of the Department of Energy, DRAFT (Sept. 26, 1978; Editorial Revisions, Feb. 15, 1979); U.S. Department of Energy, "Nuclear Proliferation and Civilian Nuclear Power, Report of the Nonproliferation Alternatives Systems Assessment Program," DOE/NE-0001/5 (June 1980), For an example of the use of cost/benefit analyses as an essential part of DOE's legislative strategy, see Memorandum, dated April 10, 1979, from John M. Deutch, DOE, to Jim Free and Joe Kearney, "Draft Legislation Regarding the Clinch River Breeder Reactor."

**/ See Letter, dated Aug. 21, 1981, from Barbara A. Finamore, S. Jacob Scherr, Thomas B. Cochran, NRDC, to James Edwards, Secretary of Energy, entitled "EIS Required for the Liquid Metal Fast Breeder Reactor Program"; Letter, dated November 23, 1981, from S. Jacob Scherr, NRDC, to Wallace Kornack, DOE.

***/ Numbers in parentheses refer to page numbers in the DEIS.

The objective of NEPA's impact statement requirement is to aid the government decisionmaker and the public in making meaningful decisions whether to pursue a program or project. See Save Lake Washington v. Frank, 641 F.2nd 1330 (9th Cir. 1981); Suffolk County v. Secretary of Interior, 562 F.2d 1368 (2d Cir. 1977), cert. denied, 434 U.S. 1064 (1978). In specifically requiring that an impact statement be prepared for the LMFBR program, the District of Columbia Court of Appeals noted that an EIS "permits other interested parties -- public and private -- to evaluate the risks and benefits of the program on their own. Scientists' Institute for Public Information, Inc. ("SIPI") v. Atomic Energy Commission, 481 F.2d 1079 (D.C. Cir. 1973). The Court quoted with approval one commenter who stated:

> [T]he basic question is whether the public itself would be willing to assume these risks and burdens for the sake of obtaining the promised benefits.

Id. at 1098. The Court stated that NEPA has provided a means of answering this "basic question" by requiring full disclosure to the public and other governmental entities. Id. at 1099.

The detail and format required in the "full disclosure" impact statement is that which is sufficient to enable those who did not have a part in its completion to understand and consider meaningfully the factors involved in coming to an informed decision. Suffolk County, supra, at 1375. As recently stated by the Fifth Circuit:

> The EIS must contain enough information about a project's economic benefits to allow "the decision makers and other readers enough detail concerning all these costs and benefits to permit reasoned evaluation and decisions. Sierra Club v. Morton, 510 F.2d 813, 827 (5th Cir. 1975).

Environmental Defense Fund v. Marsh, 651 F.2d 983, n. 23 (5th Cir. 1981).

Thus, the question of whether an impact statement should contain a cost/benefit analysis, or other information, depends in large part on the nature and complexity of the project or program being considered. The larger, more complex and more unique the program, the more a formal comparison of costs and benefits is necessary to allow meaningful consideration of its merits. The Ninth Circuit recently adopted this position in Columbia Basin Land Protection Assn. v. Schlesinger, 643 F.2d 585 (9th Cir. 1981). Recognizing, as the DEIS points out (3), that compliance with NEPA does not require a formal cost/benefit analysis for every project, the court went on to state:

> This is not to say that a mathematical cost-benefit analysis is never required. If an alternative mode of EIS evaluation is insufficiently detailed to aid the decision makers in deciding whether to proceed, or to provide the information the public needs to evaluate the project effectively, then the absence of a numerically expressed cost-benefit analysis may be fatal.

Id.

Any attempt by DOE to argue that a formal cost/benefit analysis is not required for a meaningful decision on the LMFBR program stands on extremely weak ground. The DEIS itself characterizes the LMFBR program as "a complex undertaking that still requires years of intensive work before its technology is developed to a point of acceptable commercial risk" (7). The agency and its predecessors have repeatedly prepared such cost/benefit analyses for their own use and that of Congress, in implicit recognition that formal economic studies are essential for LMFBR decisionmaking purposes. Furthermore, the DEIS recognizes that any decision on the appropriate scope of the LMFBR development program depends in large part on its economic attractiveness (6). DOE's blatant refusal to include a cost/benefit analysis renders such decisionmaking nearly impossible, and serves only to obfuscate the fact that the LMFBR program is no longer economically viable.

DOE's refusal to include information readily available from sources including its own files violates NEPA's overriding statutory mandate that agencies make a "good faith effort" (SIPI at 1092) to comply with impact statement procedures to "the fullest extent possible." 42 U.S.C. §4322. See Calvert Cliffs' Coordinating Committee v. U.S. Atomic Energy Commission, 44 F.2d 1109, 1114-15 (D.C. Cir. 1971). Such a refusal is particularly egregious in the case of a project such as this one, which involves billions of taxpayer dollars. As the D.C. Circuit noted in regard to the LMFBR program:

> [T]he Commission may well be expected to devote more resources toward preparation of

> an impact statement for its multi-billion dollar program than it would for a project involving a federal investment many times smaller.

SIPI at 1092.*/

*/ According to the DEIS, DOE's failure to update the cost/benefit analysis constitutes a representation that the previous FES analysis remains valid (3). Such a representation given DOE's admission that all the parameters of the cost/benefit analysis have changed (Sections III, IV, and Appendix F), renders the entire document misleading as well as incomplete. This failure violates the Council on Environmental Quality's requirement that each section of an impact statement must be updated as significant new information becomes available. 40 C.R.F. §1502.9.

B. Failure to Discuss Reasonably Foreseeable Consequences of The LMFBR Program.

The DEIS also violates NEPA in its failure to discuss all reasonably foreseeable consequences of the LMFBR Program particularly the effects of a commercial LMFBR economy. The 1975 FES provided a "broad overview of the many implications of LMFBR Program implementation, up to and encompassing a fully developed LMFBR power plant economy." FES at II-3. This overview included discussions of the cumulative environmental effects of LMFBR operation to the year 2020, the decommissioning of LMFBRs and fuel cycle facilities upon the completion of their useful life, and the irreversible and irretrievable commitments of resources that will accompany implementation of an LMFBR economy. Id.

ERDA included this discussion despite its acknowledgement that the "fully developed LMFBR power plant economy" it was describing and evaluating would in all probability be a "solely commercial industry." Id. at I-6.*/ This approach is mandated by NEPA, which requires that impact statements discuss all "reasonably foreseeable consequences of the proposed

*/ In fact, the FES included in its reference plan substantial discussion of the "CBR-1," described as "the first LMFBR project initiated by reactor vendors, perhaps with government financial assistance." FES at I-6.

federal action. See, e.g., Carolina Environmental Study Group v. U.S., 510 F.2d 796 (D.C. Cir. 1975).

The DEIS attempts to cut off all discussion of the environmental implications of an LMFBR economy by circumscribing its definition of the "LMFBR program." DOE claims that since "the decision on deployment and commercialization of the LMFBR will be made by the utility industry" rather than the Federal Government, the government role (and hence the scope of the DEIS) should be limited to "early development of the technical, engineering and industrial base needed to lower risks and uncertainties to levels consistent with normal commercial ventures" (2-3). Yet the "free market" alone will never determine the course of commercial deployment of the breeder. Is DOE now suggesting that the U.S. Government will not have a substantial role in licensing waste disposal and safety research in connection with private operation of breeders? Given the history of LWRs in the U.S., this is simply inconceivable.

Even admitting, for purpose of argument, that the scope of the federal project has indeed changed,*/ it nowhere follows that DOE need consider only the immediate impacts of that program. As noted above, NEPA requires discussion of all

*/ Although the original LMFBR program called for the ERDA Administrator to determine whether the LMFBR technology had become acceptable (in terms of safety, reliability, and maintainability) for commercial use, presumably the industry would have to decide on its own whether to accept ERDA's determination before it would invest in a completely commercial facility.

reasonably foreseeable future actions caused by a federal proposal (40 C.F.R. §1508.7), including both short and long-term effects (40 C.F.R. §1508.27), indirect effects (40 C.F.R. §1508.8), and cumulative impacts, "regardless of what agency or person undertakes such other actions. ... over a period of time" (40 C.F.R. §1508.7)(emphasis added). These regulations combine to require DOE to consider the environmental impacts of a commercial LMFBR industry, even if undertaken solely by the private sector, as long as LMFBR commercialization can be considered a "reasonably foreseeable" consequence of the LMFBR program.

Such a conclusion is surely the case here. In fact, if one accepts the statements in the DEIS regarding the advanced state of LMFBR technology, its lack of significant environmental effects, and its favorable economics, ultimate commercialization appears almost inevitable. Conversely, if DOE does not anticipate that LMFBR commercialization is reasonably foreseeable, it has no business proposing expenditures of over $20 billion to pursue the venture. In either case, a reasoned decision on whether to proceed along the LMFBR path must be based on an up-to-date analysis in the

DEIS, similar to the FES discussion, of the environmental effects of a commercial LMFBR economy.*/

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*/ This approach is consistent with that mandated by the D.C. Circuit concerning the original LMFBR impact statement:

> Reasonable forecasting and speculation is thus implicit in NEPA and we must reject any attempt by agencies to shirk their responsibilities under NEPA by labeling any and all discussion of future environmental effects as "crystal ball inquiry."

Scientists' Institute for Public Information, supra, at 1092.

II. PURPOSE AND NEED FOR THE LMFBR PROGRAM */

A. Role of Nuclear Energy

The DEIS asserts that the "the most urgent problem is the replacement or oil and natural gas..." (28). The claim is not supported by any technical, legal, or policy analysis. In fact, it is not supported by other U.S. Government policies. Congress has not placed any new taxes on gasoline or on oil or gas imports to discourage their use, nor have new automobile efficiency standards been set. Long-term restrictions on the use of natural gas by utilities were lifted with the concurrence of the Administration in July 1981. The most thorough statements of Administration energy policy, the July 1981 National Energy Policy Plan, specifically downgraded the oil import issue as a basis for government policy.**/ This lack of clear policy direction towards reducing oil and gas use in other areas hardly argues for its paramount importance in the context of the LMFBR program.

The opportunity to displace oil in nuclear power is very limited. Only twenty-five percent of electricity in the United States is generated by oil and gas***/, and this amount has been and will continue to be declining over time due to

*/ This part was prepared with the assistance of David Goldstein and Alan Miller, NRDC.

**/ DOE, National Energy Policy Plan, at 2 (1981).

***/ See DOE, Monthly Energy Review (December 1981).

increased power pooling and coal conversion. Less than 15% of national oil use is for generation of electricity. Thus, it is very unlikely that by the time the LMFBR may be available for commercial deployment, there will much oil or gas to displace.

The displacement of oil and gas by electricity in end use applications is even more questionable. The electric car, mentioned as an example (28), is promptly and properly ruled out (29). In regard to heating, displacing gas and oil with electricity would involve massive price increases,*/ which would negate the role proposed for electricity in the DEIS of allowing economic growth (30-32, Appendix F). The rationale of developing the LMFBR to replace oil and gas is very weak. It would be economically irrational in most uses, infeasible in others, and would have only small effects in the areas where it is possible.

The central thesis of this section is that coal and nuclear power are in effect the only short-run alternatives for electric power production. Yet there is no discussion of other alternatives, such as solar photovoltaics, wind, solar thermal, and geothermal power, which are already commercially available or in relatively advanced stages of development,**/ at least

*/ Electricity at 10¢ per kwh, a concentrative estimate of the cost of producing and distributing nuclear-generated electric power to residences, is equivalent to oil at $125 a barrel. Using nuclear electricity to replace oil for heating would result in an almost threefold price increase.

**/ California Energy Commission, Electricity Tomorrow, Chapter 2 (1981).

when compared with the LMFBR. As an example, the DOE solar photovoltaics program has a goal of $700/peak KW by 1986, which would make photovoltaics competitive for central station utility applications.*/

Most egregious is the failure of the DEIS to discuss energy conservation or end-use efficiency measures. NRDC has demonstrated that 150,000 MWE of electricity can be saved through presently identified improvements in home appliances**/ Large additional savings can be supplied in other end uses. Efficient commercial lighting could save over 100,000 MWE of electricity by the year 2000, with additional savings from reduced cooling energy***/. Industrial process efficiency improvements and cogeneration can also produce large amounts of power****/. These conclusions are even more important if one

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*/ Photovoltaics are competitive at a much higher price for peaking applications in the Southwest, where sunshine and peak demand are coincident due to air conditioning.

**/ Statement of D.B. Goldstein to the House Committee on Energy and Commerce, Subcommittee on Energy Conservation and Power, Concerning the Need for Federal Appliance Efficiency Standards.

***/ Solar Energy Research Institute, A New Prosperity: Building a Sustainable Energy Future (1981). This study predicts 50 billion square feet of commercial floor space in the year 2000. If average lighting power is reduced from current levels at about 3 watts/ft^2 to 1 watt/ft^2 through more efficient lighting systems, task lighting, daylighting, and reductions in light intensity, 100,000 MWe will be saved.

****/ Id.

assumes some improvement in conservation technology. The DEIS assumes that the LMFBR need only be compared with other supply technologies. This is an unreasonably narrow assumption because if demand is reduced to manageable proportions, significant new sources of supply would become unnecessary.

The DEIS treats conservation as an exogenous matter, dependent upon facters beyond government control or research (Appendix F). This is absurd. DOE has for year undertaken conservation research, in some cases already resulting in commercial products like improved light bulbs and the heat like improved light bulbs and the heat pump water heater. Conservation technologies must be compared with supply technologies because they serve the same function.

The DEIS makes a very weak case for the continued need for new electric supplies. It does not address the substantial recent accumulation of evidence that efficiency improvements can largely displace any need for additional central station powerplants for at least two decades*/.

The DEIS mentions the environmental concerns which may limit U.S. commitment to the expanded use of coal (29-30), but fails totally to mention the economic, social, and

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*/ See, e.g., Solar Energy Research Institute, A New Prosperity: Building a Sustainable Energy Future (1981), and R. Sant and S. Carhart, Eight Great Energy Myths (Energy Productivity Center Report No. 4, 1981).

environmental problems plaguing the present generation of nuclear power plants. There has not been one new order for a nuclear power plant in the United States since 1975, while over 60 nuclear plants on order or under construction have been cancelled. There are also de facto moratoria on new nuclear power plant orders in Germany, Netherlands, Sweden, Ireland, Belgium, Switzerland, and Canada. The development of nuclear power has been deferred or abandoned in Austria, Denmark, Australia, and New Zealand. This downturn in nuclear power plant construction is due to economics*/ and growing public concern about nuclear safety, particularly in wake of the Three Mile Island accident. Only in highly-centralized societies, such as France and the U.S.S.R., is there sufficient bureaucratic power to overide these difficulties.

B. Energy and the Economy

The discussion in the DEIS of the linkage between energy and economic growth relies largely in obsolete theories (30-32, Appendix F). The basic argument is since energy use in the U.S. has paralleled the growth of GNP in the past, it must continue to do so in the future. The most direct refutation of

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*/ The most thorough statistical analysis to date of light-water reactor (LWR) costs indicates that LWRs are likely to remain uncompetitive with coal-fired power plants in the United States for the next decade. C. Komanoff, Power Plant Cost Escalations: Nuclear and Coal Capital Costs, Regulation and Economics (1981)

the energy/GNP link is provided by comparisons with other nations, which shows that some nations, including Japan and West Germany, use half as much energy per unit of GNP then the U.S.*/, while maintaining vigorous economic growth. This decoupling of energy and GNP is even more striking for electricity.**/

Similar variations occur among states in the U.S. For example, California in 1979 used 18% less energy per capita than the national average, but has a 14% higher personal income.***/ Even if the historic data were more convincing, past trends do not dictate the future. Past trends from early American history through 1970 indicated a steady flow of population from rural areas to cities. This trend was reviewed in 1980****/. Historic data also indicate a near constant rate of auto accidents per unit of GNP*****/, as well as correlations between the consumption of alcohol and tornadoes. Yet asserting that such trends must continue is absurd.

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*/ See, D.B. Goldstein and A.H. Rosenfield, "Conservation and Peak Power--Cost and Demand" (Lawrence Berkeley Laboratory, LBL-4438, 1975).

**/ Id.

***/ See, Statistical Abstract of the U.S. (1980) and California Energy Commission, Electricity Tomorrow (   ).

****/ Statistical Abstract for the U.S. (1980)

*****/ Id.

The DEIS implies that a steady growth in energy consumption is needed to assure a healthy, growing U.S. economy. However, detailed analyses of the fast-growing West Coast regions show zero or even negative growth in energy use would achieve the same economic objectives at a lower cost*/. A low-cost solution means little or no electicity growth, because inordinate amounts of gross private domestic investment must go into building power plants. A policy directed towards increased growth will therefore either waste capital on excess capacity, a drag on the economy, or siphon capital away from more productive efficiency improvements.

C. Rationale for LMFBR Development

The DEIS fails to provide any meaningful rationale for the LMFBR program. In effect, it states that the LMFBR is one of a number of long-term supply options and that all such options should be preserved (32-33). Given the restraints place upon the federal budget for energy research and development, it is impossible to pursue vigorously all available options. This constraint is implicit in the Administration's proposed FY 83

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*/ R.C. Cavanagh, et. al., Choosing an Electrical Energy Future for the Pacific Northwest: An Alternative Scenario (NRDC, 1980); D.B. Goldstein, et. al., Preliminary Comments of the Natural Resources Defense Council, Inc. on a Cost-Effective Regional Energy Conservation Program for the Pacific Northwest (NRDC, 1981); and L.B. King, et. al., Moving California Toward a Renewable Energy Future (NRDC, 1980).

budget, which virtually eliminates solar and conservation R&D. Some detailed rationale for the singling out of the LMFBR program must be provided. The DEIS should demonstrate why enormous expenditures on the LMFBR program ($500-750 million per year) are more cost effective than expenditures on alternative programs. The DOE's Energy Research Advisory Board (ERAB) just conducted such a review on R&D priorities and ranked the Clinch River Breeder Reactor, the focal point of the LMFBR program, third from the last among 56 energy R&D programs within DOE*/. The ERAB report states that:

> "The ERAB believes that construction of the a breeder reactor demonstration at this time is not an urgent priority and, thus, recommends that, under current budget constraints, that such a demonstration be delayed until a further time."**/

Since the only purpose of the LMFBR is to extend and eventually replace uranium supplies, any rationale for the LMFBR would have to rely on a projected shortage of uranium fuel. The discussion in the DEIS of uranium resources shows that there are enough inexpensive domestic uranium supplies to

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*/ DOE, Report of the Energy Research Advisory Board, November 1981.

**/ Id., at 19, 43.

fuel 215 reactors for their entire lifetimes*/. This number substantially exceeds the total number of reactors now being built or considered by U.S. utilities--165 reactors**/. As noted earlier, there have been no new reactor orders for five years and over 60 cancellations.

The rationale for the LMFBR Program depends on the assumption of vigorously revived domestic market for LWRs. Without at least a tripling of the number of LWRs, there is not a significant danger of exhausting domestic uranium supplies. Yet the DEIS provides no reasons for such a prediction. It is inconsistent to rely on continuations of past trends in some areas (energy growth as a condition of economic growth) while forecasting dramatic reversals of trends (nuclear plant orders) in others. In fact, forecasting a revival of nuclear plant orders would also require the reversal of another trend---the greater than 10% annual cost escalation (over and above inflation) of nuclear reactors (and other central power

*/ This assumed 1,257,000 tons of uranium reserves under $50 per lb., 200 tons per reactor-year, and a 30-year reactor lifetime.

**/ DOE, Monthly Energy Review, December 1981, corrected for two Washington State units cancelled in January 1982.

plants).*/ With these factors weighing against it, a detailed exploration for projected growth in nuclear capacity is required.

Properly framed, the concern over a potential shortage of uranium fuel must be addressed in the context of an economic analysis of the LMFBR versus the light-water reactor (the "LWR") which considers the other equally important parameters, the capital cost difference between the LMFBR and LWR, future commitments to LWRs, and improvements in the efficiency of uranium utilization in LWRs.

The DEIS totally ignores the new data available concerning the capital cost differential between the LMFBR and the LWR. The best data comes from the French experience with the construction of the Super Phoenix 1200 MWe breeder reactor. The French are now estimating that the Super Phoenix will cost 2.3 times the cost a French LWR. The "target" of the French breeder program is to bring the cost of "mature" breeders down to 1.75 times the cost of French LWR. At this cost differential, the plutonium breeder would drive electricity generating prices up by about 40-50 percent. Uranium would have to rise to more than \$150/lb.U_3O_8-- some 5 times the

*/ A 13.5% real cost escalation rate from 1971-78 is calcualted in C. Komanoff, Power Plant Cost Escation: Nuclear and Coal Capital Costs, Regulation and Economics (1981). Also, Steam Station Cost Surveys in Electric World have shown real escalation rates for all types of power plants exceeding 10% per year from 1970 to the present.

current price*/ -- before breeders would be competitive with LWRs.**/ If uranium utilization efficiency in LWRs is improved by 50 percent, which is likely to occur during the LMFBR development period, the uranium break-even price would climb to about $300/lb. At these prices, the breeder is unlikely ever to be economical.

The DEIS has ignored uranium stockpiling as more cost effective "insurance policy" against the economic or security risks associated with the commercial availability of the LMFBR beyond the date at which it would be competitive with LWRs. It should be noted that using the French "target" of an LMFBR costing 75% more than on LWR, it would cost approximately $900 million more than today's reactors. For this amount, the United States could purchase 15,000 of uranium oxide at current prices, some 2.5 times the lifetime fuel requirements of today's LWR and 5 times the requirement of an advanced LWR design that could be marketed much sooner than the breeder.

The question of the timing of the LMFBR program is superfically treated in the DEIS and more properly belongs

*/ With lack of reactor sales, the uranium market is sagging and prices can be expected to go still lower.

**/ This assumes that economies of scale will materialize in the breeder fuel cycle--a highly unlikely even in that breeders will not be introduced into the market rapidly enough to justify the financial risks associated with constructing large supporting fuel cycle facilities.

within the context of an economic analysis (39-46). The conclusion that the economic penalty from early development of the LMFBR far outweighs the penalty from late development is completely at odds with the recent study of Brian Chow, which concluded that:

> "the penalty of delaying commercial breeder introduction to the year 2030 is small and well within the noise level of long-term planning."*/

The risk of delay in the LMFBR Program is by no means "one-sided"(43). The development of the breeder before it is needed would involve a dimension of scarce technical and financial resources from the development of more cost-effective alternatives. The pace of the LMFBR program should be based upon economic realities, not upon institutional inertia. An examination of the French-British experience with the Concorde should make DOE more wary of following France's rush to develop the LMFBR. The premature development of the breeder also may involve a significant penalty in terms of an unnecessary, an increased risk of nuclear weapons proliferation.**/

*/ Brian Chow, "Economic Comparison of Breeders and Light-Water Reactors" (Pan Heuristics for the ACDA, 1981).

**/ For further discussion, see Part IV C infra.

III. ALTERNATIVES INCLUDING THE CURRENT LMFBR PROGRAM

Much of the earlier discussion in these comments indicates that the DEIS does not provide a satisfactory basis for decisions as to alternatives to meet our "nation's need for stable, secure, domestic energy sources"(28). Without an updated cost/benefit analysis and outside of the context of today's realities, the consideration of alternatives in the DEIS (49-110, 213-224) seems unreal. The following additional shortcomings should be taken into account in revising the DEIS:

(1) The DEIS discusses alternatives without reference to the impact of committing the same level of resources required for the LMFBR. The implicit assumption is that the current status and projected impact of solar systems and other alternatives -- including conservation and improved LWR efficiency -- would not be affected by investing additional resources, a patently absurd proposition.

(2) The DEIS fails to discuss alternatives in combination. By discussing each one individually, their potential for substitution when viewed in toto is ignored. For example, Hawaii, which has no fossil fuel resources, has a state plan to become self-sufficient in electricity by the year 2000. In order to meet this goal, the state is pursuing numerous different renewable energy technologies simultaneously, including wind, geothermal, and biomass. (Neither of the

latter two technologies is even mentioned in the DEIS.)*/ No one technology can meet the electrical needs of Hawaii (or indeed the U.S.), but together they offer realistic long-term alternatives to the LMFBR.

(3) Even the minimal discussion of renewables in the DEIS is misleading. Problems of different dimensions are set forth as if they were comparable. The engineering required to make a blade stay on a windmill is not equivalent to the safety problems to be addressed in the LMFBR Program. The DEIS should at least recognize qualitative differences in risks between energy sources and the different likelihoods of success in addressing those risks.

(4) The DEIS omits any discussion of the vulnerability of various energy sources to disruption and the implications for the economy and national security.**/

(5) In regard to the discussion of wind energy conversion (99-100), the DEIS implies that windmills are still experimental. In fact, Hawaii Electric has entered into a contract for 80 MWe and the California Water Resources Board has a commitment for 350 MWe.

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*/ See Solar Age (May 1981).

**/ See, e.g., Dispersed, Decentralized and Renewable Energy Sources: Alternatives to National Vulnerability and War, Final Report of the Energy and Defense Project for the Federal Emergency Management Agency (1980).

IV. ENVIRONMENTAL CONSEQUENCES

A. Reactor Safety

The DEIS poses a number of important questions regarding the safety of LMFBRs, including: How safe is the plant? Is the plant safe enough? What is the probability of "events," "failures" and "accidents"? Is the plant designed to forestall accidents or accomodate the consequences of accidents? (114-115). The DEIS then asserts: "A great wealth of LMFBR safety technology is available today as a result of past safety program efforts to obtain this information for present and future LMFBR plants" (115). The impression is given that adequate answers to these questions have already been developed or will be in the future. Yet a careful reading of the remainder of this section (116-144) and a review of evidence which has been ignored by authors of the DEIS (e.g., the NRC position with regard to the design margins for the CRBR) make it clear that such optimism is not well grounded.

What is obvious is that the authors of the DEIS have systematically attempted to present the LMFBR safety issue in the most favorable light by focussing upon only those areas where in their view "substantial progress" has been made, while either downplaying or excluding data casting doubts upon the safety of breeders.

While admitting there still are serious questions as to the explosive potential of large breeders (117, 119, 126-127, 135),

the DEIS fails to acknowledge that these and other safety issues are not unresolved as to even the smaller demonstration-sized plants. The DEIS does not consider:

(1) the disagreement between NRC and DOE with regard to what constitutes an "adequate energetic consequence envelope for use in specifying the Structural Margins Beyond the Design Basis"*/. Other issues apparently in dispute include:

a. HCDA energetics
b. Decay heat removal
c. Design basis leak for air-filled cells
d. Design basis leak for inerted cells
e. Environmental qualification of I-E equipment
f. Reliability of safety systems.**/

According to DOE staff, items (a) and (b) could "have much effect upon Project cost" in that "modifications which might have to be made would depend on results of interchange with the NRC technical staff."***/

(2) The approximately 100 outstanding safety issues compiled by the NRC staff with regard to the CRBR.****/

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*/ NRC, "An Analysis and Evaluation of the Clinch River Breeder Reactor Core Disruptive Accident Energetics," (NUREG-0122, March 1977); Letter, dated May 6, 1976, from Richard Denise to Lochlin W. Caffey.

**/ Draft letter, dated March 15, 1979, from L.W. Caffey, DOE, to J. Bartells.

***/ Id.

****/ Letter, dated November 9, 1978, from William P. Gammill, NRC, to Lochlin W. Caffey, DOE.

(3) The discussion and conclusions regarding CRBR safety addressed in the report issued by the White House on May 11, 1979, entitled "The Clinch River Breeder Reactor Project: An End to the Impasse." It concluded that:

> LMFBR technology presents significantly greater safety challenges than does the conventional light water reactor.

(4) The fact that one of the principal issues in the CRBR licensing proceeding before the NRC is whether a core disruptive accident (i.e., nuclear explosion) should be a design basis accident.*/

The DEIS refers to the Three Mile Island accident in regard to the "man-machine interface" (127) and emergency response (128). However, there is no discussion of other important lessons learned from the TMI accident. In particular, attention should be given to the implications for LMFBRs of concerns regarding systems interaction and containment of degraded core accidents (another term for core disruptive accidents), including whether venting is an appropriate means of accomodating hydrogen buildup inside the containment. It is hard to believe that DOE does not yet appreciate the following

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*/ See Contention 2 of NRDC and the Sierra Club, In the Matter of U.S. Department of Energy, Project Development Corporation, and Tennessee Valley Authority (Clinch River Breeder Reactor Plant), Docket No. 50-537.

post-TMI NRC rules and standards that may have profound effects upon the licensability of the CRBR and other LMFBR plants:

1. Licensing Requirements for Pending Construction Permit and Manufacturing License Applications, 47 Fed. Reg. 2286-2303 (January 15, 1982) (based upon NUREG-0718);

2. Interim Requirements Related to Hydrogen Control- Proposed Rule, 46 Fed. Reg. 62281-5 (December 23, 1981);

3. Standards for the Reduction of Risk from Anticipated Transients Without Scram (ATWS) Events for Light Water Cooled Nuclear Power Plants, 46 Fed. Reg. 57521-32 (November 24, 1981).

We are very dismayed by the continued reliance in the DEIS upon the Rasmussen Report, WASH-1400. The DEIS applies the same comparative risk approach used in the WASH-1400 Executive Summary to the CRBR (Appendix C), while it completely ignores the number of critical analyses of WASH-1400, especially the Lewis Report*/ and the subsequent decision of the NRC to withdraw its endorsement of the WASH-1400 Executive Summary.

Among the major failings of WASH-1400 identified by the Lewis Report and singled out by the NRC were:

> The Executive Summary: The Review Group concluded that "the Executive Summary of the

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*/ H.W. Lewis, et. al, "Risk Assessment Review Group Report to the U.S. Nuclear Regulatory Commission", NUREG/CR-0400 (September 1978). Other critiques not addressed in the DEIS include S. Yellin, "The Nuclear Regulatory Commission's Reactor Safety Study," The Bell Journal of Economics 317-319 (Spring 1976); Henry W. Kendall, "Comments on the Reactor Safety Study WASH-1400 (NUREG-75/LO4) (Union of Concerned Scientists, June 11, 1976); Daniel F. Ford, "A History of Federal Nuclear Safety Assessments: From WASH-740 through the Reactor Safety Study (Union of Concerned Scientists, April 1977).

RSS is a poor description of the contents of the report, should not be portrayed as such, and has lent itself to misuse in the discussion of reactor risks." The Review Group indicated the Executive Summary does not adequately indicate the full extent of the consequences of reactor accidents and does not sufficiently emphasize the uncertainties involved in the calculations of their probability. As a result, the reader may be left with a misplaced confidence in the validity of the risk estimates and a more favorable impression of reactor risks in comparison with other risks than warranted by the study.

Accident Probabilities: The Review Group was unable to determine whether the absolute probabilities of accident sequences in WASH-1400 are high or low, but believes that the error bounds on those estimates are, in general, greatly understated. This, the Report said, is true in part because there is in many cases an inadequate data base, in part because of an inability to quantify common cause failures, and in part because of some questionable methodological and statistical procedures.*/

The NRC Commissioners took the following actions based primarily on the Lewis Report:

(1) The NRC withdrew any explicit or implicit past endorsement of the Executive Summary of WASH-1400; and

(2) The NRC accepted the Lewis Report conclusion that the absolute values of risks presented in WASH-1400 should not be used uncritically either in the regulatory process or for public policy purposes.**/

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*/ NRC Statement on Risk Assessment and the Reactor Safety Study Report (WASH-1400) in Light of the Risk Assessment Review Group Report (Jan. 18, 1979).

**/ Id.

B. Safeguards

The discussion of safeguards and proliferation in the DEIS is so abstract as to be of little value in evaluating the nature of the security risks posed by the LMFBR program and the effectiveness of DOE and international safeguards program. At the outset, the DEIS must make clear that the breeder fuel cycle differs substantially in regard to security risks from the de facto "once-through" LWR fuel cycle now in place in the United States. In regard to breeders, reprocessing is not optional and fresh breeder reactor fuel is a source of weapons material with a relatively straightforward and low cost chemical treatment.*/ DOE's Non-Proliferation Alternative Systems Assessment Program (NASAP) found that:

> ...the light water reactor fuel cycle with spent fuel discharged to interim storage does not involve weapons-usable material in any part of the fuel cycle and is a more proliferation-resistant nuclear power fuel cycle than other fuel cycles which involve highly enriched uranium or pure plutonium."**/

In regard to domestic safeguards on LMFBRs, the DEIS lacks qualitative data on projected safeguard goals and capabilities. Yet the DEIS indicates that extensive studies

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*/ The Atlantic Council of the U.S., Nuclear Fuels Policy Working Group, Nuclear Power and Nuclear Weapons Proliferation, Vol. I at 87.

**/ DOE, Nuclear Proliferation and Civilian Nuclear Power: Report of the NASAP, Executive Summary 5 (June 1980).

have already been performed on the design of safeguard systems for LMFBR fuel cycle facilities (158). The DEIS should contain: (a) specific information on defined threats for LMFBR fuel cycle facilities and transportation links, (b) an assessment of the capability of the proposed safeguards systems to counter these threats, (c) assessments of safeguards systems and timetable for improvements based on proposed scenario for LMFBR deployment with inclusion of projected materials flows in fuel cycle, and (d) safeguard system costs for various levels of threat countering capability.

Quantitative goals of the safeguards system should be specified and capability to achieve goals should be assessed. For example, in discussing materials accountancy at reprocessing and fuel fabrication plants, design goals for uncertainties in materials balance should be stated along with an assessment of the ability to detect diversion of significant quantities of materials in an evolving LMFBR system.

The DEIS mentions that the Barnwell Nuclear Fuel Plant (BNFP) is being used to develop advanced safeguards concepts and the latest measurement and control technology (161). Two questions to be addressed are: To what extent is the BNFP to be incorporated in the LMFBR program? Is it designed for fully remote reprocessing and the utilization of advanced safeguards technologies?

During the last five years, there have been a series of U.S. Government Accounting Office (GAO) studies critical of

existing security measures to protect nuclear weapons, nuclear materials, and nuclear plants.*/

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*/ "Unclassified summary of a classified report entitled, "Shortcomings in the Systems Used to Control and Protect Highly Dangerous Nuclear Material" (7/22/76);

"Security at Nuclear Powerplants--At Best, Inadequate" (4/7/77);

Unclassified summary of a clasified report entitled, "Safety and Transportation Safeguards at Rocky Flats Nuclear Weapons Plant" (5/2/77);

Unclassified summary of a classified report entitled, "Commercial Nuclear Fuel Facilities Need Better Security" (5/2/77);

Letter to Chairman, John Dingell, U.S. House of Representatives, Re: unaccounted for nuclear material (5/5/78);

Unclassified summary of a classified report entitled, "States of Physical Security Improvements to ERDA Special Nuclear Materials Transportation" (5/7/79);

"Federal Actions are Needed to Improve Safety and Security of Nuclear Materials Transportation" (5/7/79);

Unclassified summary of classified report entitled, "U.S. Nuclear Safeguards--A National Strategy is Needed"(2/19/80);

"Nuclear Fuel Reprocessing and the Problems of Safeguarding Against the Spread of Nuclear Weapons" (3/18/80);

Letter to Rep. Tim Wirth, Re: Alleged missing material from DOE's Rocky Flats weapons production plant (10/1/80);

Unclassified summary of a classified report entitled, "Security of U.S. Nuclear Weapons Overseas--Where Does it Stand?" (11/3/80);

"Nuclear Diversion in the U.S.? 13 years of Contradictions and Confusion" (12/18/78) Classified Report with no unclassified summary.

Given the failure of the U.S. Government and commerical operators to provide adequate protection for nuclear materials and facilities, what is the basis for the apparent optimism in the DEIS that DOE will be able to develop and implement an effective safeguards system for an LMFBR fuel cycle which would require much more extensive handling and transportation of weapons-usable materials?

While there is no technical fix to the problem of nuclear weapons proliferation, the DEIS fails to reflect the conclusion of NASAP noted above that the "once-through" LWR cycle is most proliferation-resistant. The DEIS appears to assume that there is a "technical fix" to the difficulties of maintaining international safeguards on the massive amounts of plutonium and the sensitive bulk-handling facilities that would be associated with breeder programs in non-weapons states. Given the fact that plutonium can be used directly in the fabrication of nuclear weapons, the ability of International Atomic Energy Agency (IAEA) safeguards to provide "timely warning" of a diversion is reduced.*/

The adequacy of the existing international safeguards system has been seriously questioned. In 1975, GAO pointed

*/ See, eg., Albert Wohlstetter, et. al., Moving Toward Life in a Nuclear Armed Crowd? (Pan Heuristics, ACDA/PAB-263, 1976).

out a number of serious deficiencies in IAEA safeguards.*/ While some of these problems related directly to technical inadequacies, most of them involved institutional, political, and manpower constraints. The GAO concluded that the U.S. "may be relying on international safeguards which are not being adequately carried out."**/

In May 1981, the GAO reported that while efforts had been made to address some of the safeguards deficiencies noted in the 1976 study:

> the magnitude of IAEA safeguards responsibilities have outpaced these efforts and the IAEA continues to encounter the same basic problems.***/

Also in 1981, the NRC Commissioners expressed doubt that "the IAEA safeguards system will not detect a diversion in at least some types of facilities," presumably including reprocessing and plutonium fuel fabrication plants which would be required by the LMFBR.****/

*/ GAO "Assessment of U.S. and International Controls over the Peaceful Uses of Nuclear Energy" (Report No. 10-76-60, September 1975).

**/ Id.

***/ GAO, "The Nuclear Non-Proliferation Act of 1978 Should be Selectively Modified" 47 (Report No. OCG-81-2, May 21, 1981).

****/ Letter from NRC Commissioners to Senator Simpson, November 27, 1981.

The NASAP Report notes that:

> ...although commercial deployment of the fast breeder reactor is several decades away, both here and abroad, proliferation risks associated with the breeder are not. Research, development, and demostration programs require the use of sensitive facilities and materials which, although not of the same magnitude as those of a commercial-breeder economy, represent significant proliferation vulnerabilities.*/

The DEIS does not consider the very real danger that decisions by the U.S. Government to abandon its restraint concerning the commerical use of plutonium will legitimize and stimulate perhaps even the premature and unnecessary introduction of reprocessing facilities in non-weapons states. A breeder R & D program would provide a perfect cover for the acquisition of technology and materials needed for a nuclear weapons program. As recent events have confirmed, we are living in an unstable world where friendly nations can become enemies virtually overnight and where terrorists can work hand-in-hand with national governments. By turning a blind eye to the technical underpinnings of nuclear weapons acquisition, the United States may be accelerating the movement towards a much more dangerous world where nuclear weapons are readily available. The implications of further nuclear weapons proliferation for our national security and indeed human survival are profound.

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*/ DOE, Nuclear Proliferation and Civilian Nuclear Power: Report of the NASAP, Executive Summary 22 (June 1980).

C. Waste Management*/

The DEIS seeks to gloss over the waste management issue with a brief and glowing discussion of the great progress that has been and is being made toward developing permanent waste repositories that will be necessary to protect humanity for the tens and hundreds of thousands of years that the wastes will remain dangerous. The DEIS in this area is inaccurate and grossly misleading.

The DEIS places great emphasis on the choice of geologic disposal as the best means of handling radioactive wastes. In so doing, it attacks a strawman, while essentially ignoring major areas of dispute and leaving a false impression of this history of waste management efforts in this country. In fact, the status of waste management efforts to date is such that the DEIS must assume a continuing serious threat and long-term significant likelihood of substantial exposure to high-level LMFBR wastes as a serious impact on the quality of the human environment that would be caused by the LMFBR program.

Most of the assertions made in the DEIS were strongly criticized by NRDC and other public interest organizations involved in the Waste Confidence Rulemaking Proceeding initiated by the Nuclear Regulatory Commission. They were also criticized by virtually all of the states participating in that proceeding, most notably New York, Caifornia, Illinois,

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*/ This section was prepared by William Jordan, Esq.

Wisconsin, and Ohio. It is incredible and seriously misleading that the DEIS should give virtually no hint of this disagreement with and opposition to its optimistic assertions concerning the long-term management of high level nuclear wastes. The Waste Confidence Rulemaking comments of those organizations and states should be referred to at length in the preparation of the Final Environmental Impact Statement and in reaching a final decision on the LMFBR program. In particular, the discussion to follow will rely heavily on material included or referenced in the Statement of Position of the Natural Resources Defense Council (filed July 7, 1980), and the Joint Cross-Statement of Position of the New England Coalition on Nuclear Pollution and the Natural Resources Defense Council (filed September 10, 1980).

1. Lack of DOE Commitment Necessary To Achieve a Waste Disposal Solution

The introduction to the discussion of waste management in the DEIS reflects what is probably the fundamental underlying reason that the Department of Energy, its predecessors, and the nuclear industry have failed to achieve a safe long-term disposal solution for high-level radioactive wastes nearly forty years into the nuclear era. Their interest in the development and expansion of nuclear technology has overriden their commitment, to the extent that one has existed at all, to assure the long-term safety of radioactive wastes.

Responding to suggestions that the LMFBR program be delayed until a definitive permanent disposal method has been demonstrated, the DEIS argues that LMFBR wastes are essentially the same as those of other nuclear fuel cycles and will be a relatively small amount of the total until well into the twenty-first century. The logic seems to be that since we are producing reactor wastes, we already have the problem in spades, so we can go ahead and produce similar wastes with the LMFBR program. This logic is bankrupt, and it ignores the character of the decision that is being made in pursuing the LMFBR program.

As we discuss below, and as even the DEIS admits, if carefully read, we are far from achieving a safe permanent disposal solution for high-level wastes. The effort to find such a solution is a massive undertaking the DEIS asserts has been underway for many years, yet it has not yet succeeded. The technical expertise exists to do virtually all of the studies and site exploration that DOE says remain to be done, yet the pace has lagged. The reason, very likely, is that neither DOE nor the nuclear industry has ever had any significant incentive to invest the time and resources that are required. They have never been told that they could not proceed with a reactor or a nuclear program of any sort until they solved the waste problem. It is hardly surprising that they have concentrated on the potentially profitable commercial applications of nuclear technology and on producing weapons, rather than giving their full attention to their most intractable problem, waste management.

The other programs have drained the necessary resources, and the fact that they have been allowed to proceed has eliminated any sense of urgency from the waste management effort. A decision to proceed with the LMFBR program, no matter how small its initial waste production will be, would simply be another indication that there is no real need to solve the waste problem and will further erode the minimal incentives and commitments that exist today. If the LMFBR program is necessary and in the national interest, as DOE presumably believes, perhaps the single greatest contribution that could be made to the search for safe waste disposal would be to prevent the program from proceeding until safe disposal is achieved.

The assertion that we need not be concerned with LMFBR wastes because they will constitute a small amount of the total for the next century ignores the type of decision that the DEIS is intended to address. This is not simply another reactor that would produce a few tons of high level wastes a year. It is an entire program for the development of a new generation of nuclear technology, which it is hoped will spread across the country, and perhaps the world. If the program is successful,

the result will be a constantly growing industry that develops a huge and unstoppable momentum that eclipses existing nuclear programs, and that produces enormous quantities of high-level wastes. The nation simply will not be able to say in twenty or fifty years that we should stop the LMFBRs because we still have not found a safe place to put the wastes. It will be too late.

The time is now to demand that the permanent safe disposal of high-level radioactive wastes be demonstrated before new nuclear programs are allowed to begin. In the words of Judge Tamm's concurring opinion in NRDC v. NRC, 178 U.S. App. D.C. 336, 361, 547 F.2d 633, 658 (1976):

> NEPA requires the Commisson fully to assure itself that safe and adequate storage methods are technologically and economically feasible. It forbids reckless decisions to mortgage the future for the present, glibly assuring critics that technological advancement can be counted upon to save us from the consequences of our decisions.*/

2. Failures and Deficiencies that Have Prevented Successful Waste Management To Date and that Preclude a Finding that the Public Will Be Protected from LMFBR Wastes

According to the DEIS, the waste management program is proceeding apace with essentially no obstacles to the development of the first permanent waste disposal repository by

*/ For further discussion, see NRDC PS at 82-87.

the late 1990s. In fact, it appears that this progress has been continuous at least since the National Academy of Sciences became involved in 1955, and that there will be no problem finding sites that meet stringent safety criteria in the three media under serious investigation. That story is entirely fictitious. NRDC and others demonstrated at length in the NRC's Waste Confidence Proceeding that there has been a history of failure, that there is no basis for believing that acceptable sites have been identified, and that the DOE program depends upon invalid assumptions and approaches. It is incredible that the DEIS does not reflect these disputes at all or indicate in any way that there may be serious doubts about our ability to achieve a waste management solution in the near future, or even in the next century. Again, NRDC's Statement of Position and Joint Cross-Statement in the Waste Confidence proceeding is incorporated by reference in this filing and should be reviewed carefully by the decisionmakers for a balanced presentation on waste management issues.

a. DOE's Waste Management Program must be Viewed in Light of Its History of Consistent Failure

The DEIS emphasizes two points most strongly. First, mined geologic disposal is the best approach. Second, DOE has a program in place to develop the necessary repositories by the late 1990s. Although the issue of whether to choose mined geologic disposal receives the most attention, it is the least important. Virtually everyone agrees that it is the only

reasonably viable option in the next several decades. The question is not whether mined geologic disposal should be attempted, but whether it will be achieved such that the public health and safety will be protected. DOE's "program" is crucial to that issue, and based on the progress of this and previous Federal programs dealing with waste management issues, there is no reason to believe that a safe waste disposal solution will be achieved in the near future, or even by the time, well into the twenty-first century, when the LMBFR program will be producing substantial quantities of high level wastes.

To date, Federal efforts to achieve the safe disposal of high level radioactive wastes have been characterized by a lack of understanding of the complexity of the issues involved, including particularly the fact that social, economic, and political matters bear on the ultimate decision.*/ Indeed, the Federal waste disposal program has had a history of "unbroken failure to produce an acceptable method of waste disposal."**/

This is not to say that no research has been undertaken in this area. To the contrary, the research has been undertaken,

*/ R.G. Hewlett, Chief Historian, U.S. DOE, "Federal Policy for the Disposal of Highly Radioactive Wastes from Commercial Nuclear Power Plants, an Historical Analysis," (March 9, 1978), at 3, 18.

**/ G. Speth, "Mandate for the Future: Nuclear Wastes and the Public Trust," AAS, Houston, Texas, January 5, 1979, at 7.

and in the most significant areas the proposals and research results have led to blind alleys. The research to date has shown promising concepts and sites to be unacceptable, but it has not yet succeeded in achieving the most important initial goal, the identification of an acceptable disposal site.*/ As recently as 1977, a report prepared by the Jet Propulsion Laboratory for the President's Office of Science and Technology Policy concluded that "...the U.S. program for high-level waste management has significant gaps and inconsistencies."**/

Viewed in light of this history, there is no reason to believe that the "program" described in the DEIS will be carried out. The DEIS points to the proposed Test and Evaluation facility as apparently a major development in waste management and states that it is scheduled to be in operation by 1989. Assuming the facility will meet that deadline, which is far from certain, it is shocking in the extreme that this has not been done before in the long history of American production of highly radioactive wastes. The slightest knowledge and understanding of virtually any technological development will confirm that such a facility represents only

*/ See NRDC PS at 20-26.

**/ T. English, et al., "An Analysis of the Back End of the Nuclear Fuel Cycle with Emphasis on High-Level Waste Management," Jet Propulsion Laboratory Pub. 77-59 (August 12, 1977) at viii.

the very early stages of an effort that may not reach fruition for years to come. It is also such an experimental stage that we can expect significant reverses before solutions are found. But the most telling point is that DOE seems to believe that the results of the testing and evaluation done at the facility will be uniformly favorable, and that we will learn nothing that would set back the disposal schedule or render proposed methods unacceptable. This is the height of arrogance and contrary to the purpose of the T&E facility. By its very definition a Testing and Evaluation facility is intended to perform unbiased tests, not to prove the previously established assumptions of the Department of Energy. If the facility is operated honestly, it will, no doubt, disprove some of those assumptions.

With the intense pressure now being brought to bear to find a solution to the waste disposal problem at all costs, we are concerned that the T&E facility represents a grave danger to the integrity of the waste management program. Whle some such facility is clearly necessary to undertake the necessary experimentation, if it is abused, it will provide misleading information. Equally important, once such a facility is in place, the pressure may become unbearable to expand it into a permanent facility, although the site and the facility will not have been chosen or designed with that in mind. To a large extent, the T&E facility is in danger of becoming a political football rather than a legitimate aspect of a comprehensive and integrated waste management program.

Under today's conditions, and with this background, it is unreasonable to conclude that a repository will be in place by the late 1990s or at any time in the reasonably near future. Any decision concerning the LMFBR program must assume a high risk that the high level wastes that it will generate will not be disposed of safely in the near term and will pose a serious threat to the public health and safety for generations to come.

b. Lack of a Basis for Concluding that an Acceptable Site Has Yet Been Identified

The history of site selection and characterization efforts provides the clearest example of the failures of the waste management program to date. The DEIS cites the Lyons, Kansas experience as simply one step in a long series of experiments intended to provide useful information. This is a mischaracterization. In fact, the Lyons case demonstrates that even when a site is viewed as a very favorable location, further investigation may well show that it is unacceptable. That is precisely what happened. The Environmental Impact Statement on the Lyons Project concluded that

> The proposed facility will safely contain these wastes for the required period of time without any significant impact on the environment.*/

*/ U.S. Atomic Energy Commission, Environmental Statement, Radioactive Waste Repository, Lyons, Kansas (June, 1971), at 1.

Yet as site evaluation continued, it became clear, as the DEIS admits, that Lyons was unacceptable due to human intrusion.

The same was true of the Palestine Dome, which was recently disqualified as a potential site,*/ and recent discoveries of brine deposits will almost certainly disqualify the Waste Isolation Pilot Project site in New Mexico unless they are overridden for political reasons.**/ The real point that this program has reached is that it now has the ability to disqualify unacceptable sites for many reasons. We do not know whether it can actually find an acceptable site until that occurs and full *in situ* testing is performed. We certainly cannot know whether an acceptable site will be seleced by 1988 and in full operation by 1998, as the DEIS suggests.

c. Failure of the DOE Waste Management Program To Follow the Concepts of a Systems Approach and Defense-in-Depth

Although the DEIS argues strongly that a systems approach relying on the concept of multiple barrier defense-in-depth is essential to developing a safe and acceptable repository, the DOE waste management program meets neither of those criteria. Rather, DOE's concept of a systems approach seems to be one in which all aspects of the system can be changed to fit with the

*/ DOE Statement of Position at II-106.

**/ New York *Times*, December 6, 1981, at 41.

other aspects, as long as DOE is still allowed to reach the ultimate conclusion that its proposed repositories are safe and acceptable. In other words, DOE is drawing the target after shooting the arrow. To do so, it relies upon a lack of real and stringent site selection criteria and on risk assessment and mathematical modeling techniques that allow DOE to trade a lack of protection in one area for allegedly greater protection elsewhere, that are based on inadequate data, and that have yet to be verified scientifically.

DOE particularly emphasizes the use of the multiple-barrier defense-in-depth approach in the area of site selections, stating that

> A suitable site is one at which a repository would meet predetermined criteria and which would provide a high degree of assurance that radioactive wastes can be isolated from the biosphere for periods of thousands of years. (181).

We agree with that statement, properly applied. Unfortunately, DOE's site selection does not comply with that approach.

The key to site selection is the use of predetermined criteria, so that the site is chosen independently and solely on the basis of whether the site itself would be an effective barrier. Otherwise, trade-offs are possible that would allow the integrity of the site to be compromised based on some theoretical compensatory measure taken in the engineering aspects of the repository. However, the process is a sham unless the criteria are stringent enough to require that the

site actually be chosen as an independent barrier and to preclude irrelevant considerations, such as whether or not the land is already in federal ownership.

In fact, DOE has thus far proceeded without predetermined criteria, and sites have been chosen primarily for political reasons.*/ The entire discussion in the DOE Statement of Position in the Waste Confidence Rulemaking Proceeding is based on self-established criteria designed to allow DOE to do whatever it wished, while ignoring the draft critetia that had been proposed by the Nuclear Regulatory Commission.**/ Beyond that, even the proposed NRC criteria are so weak as to be meaningless in restricting the choice of sites to assure safety.***/ Accordingly, what DOE terms a systems, defense-in-depth approach is nothing of the sort and cannot form the basis for a conclusion that LMFBR wastes do not pose a serious threat to the environment.

One of the few requirements of the NRC criteria is that DOE present evidence of the exploration of three separate media. According to the DEIS, those are salt, basalt, and tuff. However, the viability of salt is rapidly diminishing with the

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*/ See e.g., NRDC PS at 39.

**/ See NRDC PS at 27-30, Joint CS at 15-23.

***/ See Comments of the Natural Resources Defense Council, Inc., on Proposed Rule For Disposal of High-Level Wastes in Geological Repositories, Proposed Rule, 46 FR 53280, filed November 18, 1981, at 8-9.

brine and intrusion discoveries discussed above and the fact that salt is a valuable resource that will attract intrusion in the future. Therefore, the facts will demand that salt be rejected as an acceptable medium. However, since budgetary reasons preclude significant investigation of other geological media (185), such pressures will also require salt to remain as one of the three media studied for the NRC. The result will be either that DOE will be unable to comply with the NRC criteria, or that the hazards of salt will be ignored, to the detriment of the public health and safety.

In its effort to demonstrate that its waste disposal effort will succeed, DOE attempts to bound the various uncertainties and then demonstrate through mathematical modeling that the risk of permanent waste disposal as currently envisioned will be acceptable. (182) The attempt fails on its face because the DEIS is forced to admit that some uncertainties cannot be bounded and will have to be resolved during repository construction. It necessarily follows that it may not be possible to resolve those uncertainties satisfactorily when we reach the point of actual construction. It is sheer speculation to assume the contrary. This point, alone, could delay or prevent waste disposal for decades and more into the next century.

The reliance on risk assessment and mathematical modeling is particularly troubling for two basic reasons. First, by its

very nature it is contrary to the approach of requiring multiple independent barriers to achieve defense-in-depth. The concept of risk assessment assumes complete knowledge of the systems involved and permits trade-offs among them so that one system or barrier can be less than acceptable as long as the efficiency is compensated for elsewhere to achieve an acceptable overall risk. Second, the information and understanding simply do not exist to allow reliable risk assessment modeling of permanent waste disposal. According to Dr. Fred Dornath:

> The accuracy of the risk assessment will be directly proportional to the degree of understanding of the system under analysis, the adequacy of mathematical models to describe phenomena of significance to the system, and the completeness and accuracy of the data....Given the uncertainties associated with our predictive capabilities in the earth sciences, with the necessary mathematical oversimplification of complex processes, and with the variability of rock properties and hydrogeologic characteristics, a precise risk assessment of nuclear waste disposal in deep geologic formations may never be possible.*/

At this stage of knowledge of waste disposal, with a virtual absence of site specific data from in situ explorations, and

*/ Fred A. Dornath, "The Role of Scientific Advisory Groups: Disposal of High Level Nuclear Waste," Report of the GSA Committee on Geology and Public Policy, Geological Society of America (August 1979) at 16.

with mathematical models that have not yet been validated, risk assessment is an utterly unreliable basis for judging the safety of permanent waste disposal.*/

3. Unacceptability of Indefinite Above-Ground Storage as a Long-Term Waste Management Option

Since there is no assurance that a safe permanent disposal repository will be available for LMFBR waste until well into the next century, if then, the DEIS must assume that LMFBR wastes will be stored in short-term facilities. To date, those facilities are all actively managed water-filled spent fuel pools. The use of these "short-term" facilities will become long-term, however, as the search for a permanent respository continues to be fruitless.

Long-term above-ground storage is both practically and legally unacceptable. Reliance on interim storage for an indefinite period has been rejected by the Environmental Protection Agency because it would interfere with the permanent respository development.**/ Also it is unacceptable even to rely upon thoroughly-tested short-term storage techniques

*/ See NRDC PS at 60-64 and Joint CS at 32-38 for more detailed discussion of these points.

**/ Jet Propulsion Laboratory, "An Analysis of the Technical Status of High Level Radioactive Waste and Spent Fuel Management Systems," JPL Publication 77-69, 1977, at 6-44.

which involve active management, because this option cannot be relied upon for the periods of time that will be required.*/ Above-ground passive (e.g. dry storage) alternatives are unacceptable and have been similarly rejected as long-term options in that they are less safe than the geological storage option. At this point, it is illegal to proceed with any program that will rely on long-term above-ground storage of high-level wastes because the liabilities of such storage have never been examined as required by the National Environmental Policy Act.**/ Since this DEIS does not include such an analysis, it cannot be relied upon to support long-term storage.***/

4. Conclusion

The DEIS is woefully inadequate in examining the environmental risks posed by the production of high level wastes by the LMFBR program. Without reflecting in the slightest the substantial scientific disputes concerning the viability of the DOE program or the significant doubts concerning whether the program's timetable will be met, the

*/ See Joint CS at 77-79.

**/ See Id. at 13-15.

***/ See NRDC PS at 88-04 and Joint CS at 67-80 for further discussion.

DEIS essentially assumes that waste management issues will involve no environmental impacts that must be taken into account in deciding whether to proceed with the LMFBR program. This assumption is invalid. The EIS on the LMFBR program must include a more balanced presentation, must address the liabilities of the inevitable long-term above-ground storage, and must identify a significant risk of eventual human exposure to the LMFBR wastes as an environmental impact that must be taken into account.

D. Health Effects

The DEIS concludes that the health effects from release of transuranics associated with the LMFBR program is extremely low -- 0.0001 cancers per 1000 MWe/year (206). This conclusion is based upon a model which characterizes the potential releases of radioactivity to the environment, the principal pathways by which radioactivity is transmitted to humans, and the impact of radioactivity upon human health. The DEIS purports to describe the uncertainties in the estimates used in the model (189) and to be "conservative" in reaching the above-noted conclusion (191). Yet the DEIS (189-212, Appendix D) ignores the widely divergent views of experts regarding these uncertainties and its conclusions are by no means conservative. This results in a serious underestimation of the potential health effects of the LMFBR program.

1. "Most probable" and "conservative" estimates

The DEIS states that:

> The choice of values for the many parameters involved in the quantitative application of the model is often difficult. Where data are not available to support the choice of a "most probable" value, estimates have been made that are clearly "conservative." This approach leads to overestimates of transuranic deposition in man, which must be kept in mind in considering the final results (191).

While this may appear to be a valid statement, it is not statistically correct. As a matter of science, it is just plain wrong. A combination of "mean" and "conservative" parameters, when inserted into a model such as that used in the DEIS (190), does not insure that the results are conservative. Moreover, the values DOE has chosen as "most probable" and "conservative" are not viewed as "most probable" and "conservative" by a number of experts in the field. See Karl Z. Morgan, 33 American Industrial Hygiene Association 567 (Aug. 1975); Carl J. Johnson, "Cancer Incidence in an Area Contaminated with Radionuclides Near a Nuclear Installation," AMBIO Vol. 10, No. 4, pp. 176-192 (Aug. 1981); Bernd Frank, "Radiation Exposure and Health Damage Due to Nuclear Power Production -- The Question of Standards and the Need for Comparative Health Analysis" (presented at the Annual Meeting of the AAAS, Washington, D.C., Jan. 4, 1982); Mancuso, T.F., A Stewart, and G. Kneale, "Radiation Exposures of Hanford Workers Dying From Cancer and Other Causes," 33 Health Physics 369-85 (1977); Kneale, G.W., A.M. Stewart, and T.F. Mancuso, "Re-analysis of Data Relating to the Hanford Study of the Cancer Risks of Radiation Workers," pp. 386-412 (in Late Biological Effects of Ionizing Radiation, Vol. I, Vienna: International Atomic Energy Agency, 1978); Kneale, G.W., A.M. Stewart, and T.F. Mancuso, "Hanford Study III, A Cohort Study of the Cancer Risks from Radiation to Workers at Hanford (1944-1977) by the Method of Regression Models in Life-Tables," The British Journal of Industrial Medicine, Vol. 38, pp. 156-66

(1981); Kneale, G.W., A.M. Stewart, and T.F. Mancuso, "Analysis of the Hanford Data IV" (paper presented at the AAAS Meeting in Washington, D.C., Jan. 1982); Stewart, A.M., G. Kneale, and T.F. Mancuso, "The Hanford Data - A Reply to Recent Criticisms," AMBIO, Vol. 9, No. 2, pp. 66-73 (1980); Kneale, G., "Heterogeneity of Cancer Sensitivity and its Implications for the Problem of Estimating the Risks of Low Doses of Radiation" (Environmental Policy Institute, Radiation Health Information Project); Radford, Edward P., "Statement Concerning the Current Version of Cancer Risk Assessment in the Report of the Advisory Committee on the Biological Effects of Ionizing Radiation," in National Academy of Science, The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980, pp. 227-253 (National Academy Press, 1908) (BEIR III); Radford, Edward P., "Analysis of the Implications of the Reanalysis of the Revised Hiroshima Dose Data," 213 Science, 602 (Aug. 7, 1981); Gofman, John W., Radiation and Human Health (Sierra Club Books, San Francisco, 1981); Arthur R. Tamplin and Thomas B. Cochran, NRDC Supplemental Submission to EPA on Plutonium and the Transuranium Elements, Feb. 24, 1975; Tamplin and Cochran, Comments by NRDC on the Nuclear Regulatory Commission's Denial of Petition for Rulemaking [Docket No. PRM-20-5], Re: Petition to Amend Radiation Protection Standards as They Apply to Hot Particles (June 2, 1976); Tamplin and Cochran, Natural Resources Defense Council Critique of the

NAS-NRC Report "Health Effects of Alpha-Emitting Particles in the Respiratory Tract" (March 1977).

2. Source Term

The extremely small source term used in the model -- 0.31 mCu of alpha per 1000 MWe year (192) -- is nonconservative, and no uncertainty limits are provided. This source term is based on unvalidated assumptions regarding postulated release rates that represent goals for future technologies. In some instances, confinement factors are several orders of magnitude better than confinement factors for existing plants (Rocky Flats and NFS-Erwin), plants operated in the recent past (NFS-West Valley), or even proposed plants (Barnwell) (cf., Carl J. Johnson, supra, and discussion in the Public Hearing Record on the Proposed Final EIS on the Liquid Metal Fast Breeder Reactor Program, May 27-28, p. 338). In fact, the recent analysis correlating cancer incidence with plutonium contamination levels around the Rocky Flats plant (Carl J. Johnson, supra) indicates that DOE estimates of the contamination around existing plants, where the data is actual rather than hypothetical, are nonconservative.

Finally, the source term is based on the assumption that the cumulative releases from accidents will be smaller than the cumulative routine releases. There is no scientific or actuarial basis for a conclusion that this is a "most probable" or conservation assumption. The Rocky Flats plant is one example where this conclusion is wrong.

3. Environmental Dispersal

The DEIS fails to address a series of German studies which consider the uncertainties in data, models, and assumptions for pathway analyses of routine emissions from light water reactors (LWRs).*/ While these papers concern emissions from LWRs in the Federal Republic of Germany, their analysis is relevant to the LMFBR and associated fuel cycle facilities since the German pathway models and input parameters are based primarily on U.S. data. The final EIS should consider these studies and any reviews of them.**/

4. Estimate of Health Effects

The book by Gofman, supra, and the papers by Morgan, supra, and Johnson, supra, indicate that the assumptions in the DEIS concerning plutonium toxicity are nonconservative by at least two orders of magnitude. Recent experiments on the

*/ University of Heidelberg, Department of Environmental Protection, "Radiological Assessment of the Whyl Nuclear Power Plant (NRC Translation 520), May 1978, Revised July 1979; Bernd Frank, supra.

**/ See, e.g., NRC, "Staff Review of Radiological Assessment of the Light Nuclear Power Plant" (NUREG-0668, June 1980).

induction by radon of tumors in beagles were found to require exposures in excess of 13,000 WLM, as compared to 120-359 WLM for humans.*/ These findings add support to Morgan's thesis.**/ While we recognize there are uncertainties in extrapolating lung tumor incidence from radon exposure to other sites and isotopes, nevertheless the possibility that beagles are one or two orders of magnitude less sensitive than man cannot be ruled out. If a similarly large disparity in the sensitivity between humans and beagles applies to plutonium oxides and other transuranics, the DEIS estimates of health risks from transuranic exposures would be seriously underestimated.

The DEIS summarizes risk estimates from exposure to low LET radiation (Appendix H). However, it does not discuss either the widely divergent opinions on this subject, including those of Radford, Morgan, Mancusco, Steward, Kneele, Gofman, Bross, and Tamplin, supra, or the implications of the new Hiroshima and Nagasaki dose estimates for the BEIR III results.***/

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*/ F.T. Cross, et al., "Carcinogenic Effects of Radon Daughters, Uranium Ore Dust, and Cigarette Smoke in Beagle Dogs," 42 Health Physics 33-52 (January 1982).

**/ Letter, dated May 5, 1976, from Karl Morgan, Georgia Institute of Technology to Robert Alexander, NRC.

***/ 212 Science 900-3 (May 22, 1981); 212 Science 1364-65 (June 1981); and Letters to the Editor on this subject published in subsequent issues of Science.

The BEIR III estimates have been criticized as underestimating the actual risk, possibly by a factor of ten, because they neglect or dismiss certain studies of populations exposed to low doses of radiation, such as workers at Hanford, in which more cancers have been observed than could be predicted from the BEIR III estimates.

With regard to the "hot particle" hypothesis as proposed by Tamplin and Cochran, the DEIS states:

> [T]he so-called "hot particle problem" has been addressed by several specially appointed groups and international bodies. As detailed in Appendix D, these groups have, without exception, concluded that both on theoretical grounds, and on the basis of available experimental data, no special effects should be expected from these "hot particles." If anything, exposure from particles should be less hazardous than more uniform exposure. The lack of observed health effects in workers that have inhaled plutonium (usually in particulate form) also argues against any suprisingly large hazard due to these particles. The use of an average lung dose in this estimation of health risks is therefore considered an appropriate procedure, which does not underestimate risks [footnotes excluded] (207-208).

Yet this conclusion is inconsistent with that of the BEIR III report, which states (p. 326):

> The possible influence of "hot spots" of insoluble radioactive particles deposited in pulmonary tissues on cancer risk has been evaluated in a previous report. The evidence is still insufficient to determine whether aggregates of radioactivity that remain localized in specific regions of the lungs give a greater or smaller risk of lung cancer per average lung dose than uniformly deposited radiation. Preliminary experimental data indicate that a small fraction of inhaled insoluble particles may remain in the bronchial epithelial layer for long periods, but the significance of this local exposure on lung-cancer risk is still uncertain.

The above quote from the DEIS cites three principal reviews of the Tamplin-Cochran thesis, namely those of the National Council on Radiation Protection, National Academy of Science-National Research Council (NAS-NRC), and the Nuclear Regulatory Commission (NRC) (footnotes 8,9, 10 at 212). Although two of these reviews were critiqued by Tamplin and Cochran, supra, neither of these groups have responded to these criticisms. Indeed, both the NRC and the NAS-NRC reviews misrepresented the Tamplin-Cochran hot-particle hypothesis.*/

For the author(s) of this section to state that "exposure from particles should be less hazardous than more uniform exposure" is indicative of a failure to recognize that if tumor induction is proportional to particle number rather than organ dose, then experimental results, when analyzed on a tumor per nanocurie (or rem) basis, are not a refutation of the hot particle hypothesis. This is true even if the results appear consistent with the concept that uniform exposure carries a higher tumor risk than non-uniform exposure (see Arthur R. Tamplin and Thomas B. Cochran, "The Hot Particle Issue: A Critique of WASH 1320 As It Relates to the Hot Particle," November 1974, pp. 14-15). Finally, "the lack of observed

*/ See Tamplin and Cochran, "Comments by NRDC on NRC's Denial of Petition," supra at 4, and "NRDC Critique of NAS-NRC Report," supra at 8-16.

health effects in workers (presumably excluding the Hanford worker studies) that have inhaled plutonium" does not argue against the hot-particle hypothesis.*/

*/ Tamplin, Arthur R., and Thomas B. Cochran, "The Hot Particle Issue: A Critique of WASH 1320 as it Relates to the Hot Particle Hypothesis," November 1974.

V. CRBR SITE SELECTION

The discussion in the DEIS of the CRBR site selection process is hopelessly inadequate, contains no new information relevant to site selection other than unsubstantiated conclusions, and serves no purpose other than as an attempted justification of the selection of the Clinch River site over five years ago (Appendix G). Upon examination, this appendix contains nothing more than a description of the initial selection process. Given the new information on both the Clinch River and alternative sites that has been developed since the FES was issued, a well as the significant changes in the policy and requirements of the Nuclear Regulatory Commission (NRC) for siting of nuclear power plants, the DEIS falls far short of NEPA's requirements for a reasoned and thorough discussion of alternatives to the proposed project.

DOE attempts to foster the impression that it has thoroughly "reevaluated" its initial selection of the Clinch River site based on present circumstances. Yet none of the "subsequent reviews" mentioned in Appendix G occured less than five years ago. Since that time, factors such as site availability, site licensability, and the financial and management capability of various utilities has changed substantially. Yet nowhere does the DEIS take these factors into account. The only glimmer of recognition by DOE that a current reevaluation is necessary occurs when the agency baldly

asserts that previous conclusions regarding three candidate alternative sites are unchanged (G-6). Yet the DEIS gives no indication of the basis for these assertions, and thus totally fails to "provide sufficient data and reasoning to allow the reader to evaluate the analysis and conclusions of the agency, and to intelligently comment on the EIS." Natural Resources Defense Council, Inc. v. Callaway, 524 F.2d 79, 93 (2d Cir. 1975).

Examples of changed circumstances and new information on sites abound. For example, a number of sites initially earmarked for other nuclear plants are now available because of plant cancellations. Some of these sites, such as the Washington Public Power Supply System (WPPSS) Unit 4 in Hanford, Washington, may hold distinct cost advantages in light of the extensive site preparation activities already completed there. Also, significant new information on the hydrology, meteorology, ecology, and other aspects of the CRBR site (as detailed by DOE in recent amendments to its CRBR Environmental Report) should be included in any DEIS discussion of site suitability.

The most important change in the relative advantages of various sites, nowhere mentioned in the DEIS, is the recent shift in NRC policy and requirements for nuclear power plant siting in light of the accident at Three Mile Island. In August, 1979, the NRC Siting Policy Task Force recommended a number of changes to existing NRC policy on nuclear power reactor siting, including:

(1) reversal of present policy permitting plant design factors to compensate for unfavorable site characteristics, in favor of a new policy emphasizing site isolation; and

(2) use of selective siting to reduce the risks associated with accidents beyond the design basis.

U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, Report of the Siting Policy Task Force (NUREG-0625) (Aug. 1979). The NRC is presently implementing these policy changes in a proposed rule regarding the review of alternative sites under NEPA (45 Fed. Reg. 24168, April 9, 1980) and has directed DOE to use these rules as a guideline in reviewing alternative CRBR sites. See Letter, dated Nov. 30, 1981, from Paul S. Check, Director, CRBR Program Office, NRC, to John R. Longnecker, Manager, CRBR Licensing and Environmental Coordination Branch, DOE.*/

*/ This letter requires DOE to completely redo its previous analysis of alternative sites, including those outside the TVA region, based on new information and new NRC requirements.

NRC is also revising its own reactor siting criteria (45 Fed. Reg. 50350, July 29, 1980) as directed by Congress in the FY-1980 NRC Authorization Act (P.L. No. 96-265, 94 Stat. 780). The Authorization Act requires NRC to establish demographic requirements for facility siting, based on consideration of a full range of accidents, including those beyond the design basis. Finally, NRC has recently established new emergency planning regulations. 45 Fed. Reg. 55402 (Aug. 19, 1980); see also U.S. Nuclear Regulatory Commission and Federal Emergency Management Agency, Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants, (NUREG-0654, FEMA-REP-1, Rev. 1) (Nov. 1980).

These new requirements favoring site isolation necessarily reduce the attractiveness of the CRBR site in relation to other sites. The DEIS itself acknowledges that a "signficant difference between the Clinch River site and the three candidate sites is that these candidate alternative sites have a reduced population density relative to Clinch River" (G-6). This difference is more than cosmetic; it may ultimately serve to block the licensing of the Clinch River site. And, since a primary goal of the CRBR Project (and the LMFBR program as a whole) is to demonstrate the licensability of fast breeder reactors,**/ the DEIS must discuss all factors affecting licensability, and consider alternatives that could achieve that goal more readily. Natural Resources Defense Council, Inc. v. Callaway, supra, at 93. The DEIS fails abysmally in this respect.

**/ See Comments of the Natural Resources Defesne Council, Inc. and the Sierra Club in Opposition to Applicants' Exemption Request Under 10 CFR §50.12, pp. 15-18 (Jan. 18, 1982).

CONCLUSION

For the reasons set forth above, we beleive that the DEIS does not provide an adequate basis under NEPA for decisionmakers to determine whether and, if so, how to proceed with the LMFBR Program. The DEIS relies more on rhetoric and assertions than on facts and analyses. The obvious bias in the DEIS towards the LMFBR Program may be a reflection of the fact that all of the principal preparers of the draft are either nuclear engineers or nuclear scientists (iv-vii).

Due to the glaring omissions and inadequacies in the DIES, we submit that DOE should not now seek to prepare a Final EIS on the LMFBR Program. Rather the DEIS should be substantially revised and reissued so as to preserve a meaningful opportunity for public comment.

If we can be of any further assistance in the revision of the DEIS, please let us know.

Sincerely yours,

Barbara A. Finamore

S. Jacob Scherr
Counsel for NRDC

Thomas B. Cochran
NRDC Senior Staff Scientist

State of Missouri
OFFICE OF ADMINISTRATION
P.O. Box 809
Jefferson City 65102

Christopher S. Bond
Governor

Alden Shields, Director
Division of Budget and Planning

January 27, 1982

Mr. Wallace R. Kornack, NE-6 GTN
Office of Nuclear Reactor Programs
Office of the Assistant Secretary
for Nuclear Energy
U. S. Department of Energy
Washington, D. C. 20545

Dear Mr. Kornack:

Subject: 82010012 - Draft Environmental Impact Statement: Liquid Metal Fast Breeder Reactor Program (Supplement)

The State Clearinghouse, in cooperation with state agencies interested or possibly affected, has completed the A-95 review on the above project application.

None of the state agencies involved in the review had comments or recommendations to offer at this time. This concludes the State Clearinghouse's review.

A copy of this letter is to be attached to the application as evidence of compliance with the A-95 requirements.

Sincerely,

Lois Pohl
Lois Pohl
Chief, Grants Coordination

LP:bjm

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major

AZ STATE CLEARINGHOUSE

SIGNOFF

OMB Approval No. 29-R0218

FEDERAL ASSISTANCE

2. Applicant's application — a. Number: ; b. Date: 19 Year Month Day

3. State application identifier — a. Number: AZ 82-80-0002; b. Date Assigned: 19 82 01 13

Leave Blank: FEB 04 1982

Janice L. Dunn

1. Type Of Action (Mark appropriate box): ☐ Preapplication ☐ Application ☐ Notification Of Intent (Opt.) ☐ Report Of Federal Action

4. Legal Applicant/Recipient
a. Applicant Name: U.S. Dept. of Energy
b. Organization Unit: Office of Nuclear Reactor Programs
c. Street/P.O. Box: Office of Assist. Secretary for Nuclear Energy
d. City: Washington
e. County:
f. State: D.C.
g. Zip Code: 20545
h. Contact Person (Name & telephone no.): Mr. Wallace R. Kornack, NE-6 GTN

5. Federal Employer Identification No.

6. Program (From Federal Catalog)
a. Number: 81.999
b. Title: Unknown
U.S. Dept. of Energy

7. Title and description of applicant's project: Liquid Metal Fast Breeder Reactor Program-Draft EIS-Supplement to ERDA-1535 December 1975

Nuclear-generated electricity will play an increasingly important role in energy substitution as petroleum & natural gas become more scarce & expensive. Even though significant benefits are being derived from conservation measures, historical trends strongly indicate that future economic growth will be linked with increasing energy consumption. (over)

8. Type of applicant/recipient
A–State; B–Interstate; C–Substate District; D–County; E–City; F–School District; G–Special Purpose District; H–Community Action Agency; I–Higher Educational Institution; J–Indian Tribe; K–Other
(Specify): Federal Agency
Enter appropriate letter: k

9. Type of assistance
A–Basic Grant; B–Supplemental Grant; C–Loan; D–Insurance; E–Other
Enter appropriate letter(s): e

10. Area of project impact (Names of cities, counties, states, etc.): Statewide Arizona, Also Nationwide

11. Estimated number of persons benefiting

12. Type of application
A–New; B–Renewal; C–Revision; D–Continuation; E–Augmentation
Enter appropriate letter: a

13. Proposed Funding

a. Federal	$ .00
b. Applicant	.00
c. State	.00
d. Local	.00
e. Other	.00
f. Total	$ .00

14. Congressional Districts Of: a. Applicant; b. Project

15. Type of change (For 12c or 12e)
A–Increase Dollars; B–Decrease Dollars; C–Increase Duration; D–Decrease Duration; E–Cancellation; F–Other Specify:
Enter appropriate letter(s)

16. Project Start Date: 19 Year month day

17. Project Duration: Months

18. Estimated date to be submitted to federal agency: 19 Year month date

19. Existing federal identification number

20. Federal agency to receive request (Name, city, state, zip code)

21. Remarks added ☐ Yes ☐ No

Section II - Certification

22. The Applicant Certifies That
a. To the best of my knowledge and belief, data in this preapplication/application are true and correct, the document has been duly authorized by the governing body of the applicant and the applicant will comply with the attached assurances if the assistance is approved.
b. If required by OMB Circular A-95 this application was submitted, pursuant to instructions therein, to appropriate clearinghouses and all responses are attached:

	No response	Response attached
(1) Arizona State Clearinghouse	☐	☒
(2) Region II(PAG),III(NACOG),VI(SEAGO)	☐	☒
(3) (other will be forwarded when received)	☐	☐

23. Certifying representative — a. Typed name and title; b. Signature; c. Date signed: 19 Year month day

Section III - Federal Agency Action

24. Agency name

25. Application received: 19 Year month day

26. Organizational Unit

27. Administrative office

28. Federal application identification

29. Address

30. Federal grant identification

31. Action taken: ☐ a. Awarded ☐ b. Rejected ☐ c. Returned for amendment ☐ d. Deferred ☐ e. Withdrawn

32. Funding

a. Federal	$ .00
b. Applicant	.00
c. State	.00
d. Local	.00
e. Other	.00
f. Total	$ .00

33. Action date: 19 Year month day

34. Starting date: 19 Year month day

35. Contact for additional information (Name and telephone number)

36. Ending date: 19 Year month day

37. Remarks added ☐ Yes ☐ No

38. Federal agency A-95 action
a. In taking above action, any comments received from clearinghouses were considered. If agency response is due under provisions of Part 1, OMB Circular A-95, it has been or is being made.
b. Federal Agency A-95 Official (Name and telephone number)

424-101

Standard Form 424 Page 1 (10-75)
Prescribed by GSA, Federal Management Circular 74-7

Much of the future growth in energy supplies will likely be met by increased production of electricity. Of the fuel alternatives for electricity production only coal and uranium offer much potential for the generation of large amounts of affordable electric energy into the early part of the next century.

TO:

Mr. Tom Swanson, Exec. Dir.
Pima Association of Gov'ts.
405 Transamerica Building
Tucson, Arizona 85701

State Application Identifier (SAI)

JAN 13 1982 State AZ No. 82-80-0002

Transportation
Ag. & Hort.
Energy
Power
Health
Parks

6 Regions

FROM: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

This project is referred to you for review and comment. Please evaluate as to the following questions. After completion, return THIS FORM AND ONE XEROX COPY to the Clearinghouse no later than 17 WORKING DAYS from the date noted above. Please contact the Clearinghouse at 255-5004 if you need further information or additional time for review.

☒ No comment on this project ☐ Proposal is supported as written ☐ Comments as indicated below

1. Is project consistent with your agency goals and objectives? ☐ Yes ☐ No ☐ Not Relative to this agency
2. Does project contribute to statewide and/or areawide goals and objectives of which you are familiar? ☐ Yes ☐ No
3. Is there overlap or duplication with other state agency or local responsibilities and/or goals and objectives? ☐ Yes ☐ No
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6. Does project adequately address the intended effects on target population? ☐ Yes ☐ No
7. Is project in accord with existing applicable laws, rules or regulations with which you are familiar? ☐ Yes ☐ No

Additional Comments (Use back of sheet, if necessary):

Reviewers Signature *Eva M Hoover* Date *1/21/82*

Title Telephone

):

Christopher J. Bavasi, Ex. Dir.
NACOG, Region III
119 E. Aspen St.
Flagstaff, Arizona 86001

State Application Identifier (SAI)

JAN 13 1982 State AZ No. 82-80-0002

Transportation
Ag. & Hort.
Energy
Power
Health
Parks

6 Regions

NACOG
JAN 13 '82
REC_IVED

ROM: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

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Additional Comments (Use back of sheet, if necessary):

wers Signature *Jacqueline J. Prine, for* Date 1-20-82 774-1894
ristopher J. Bavasi, Executive Director, NACOG

Telephone

TO:

State Application Identifier (SAI)

JAN 13 1982 State AZ No. 82-80-0002

Mr. David Landrith
Executive Director, SEAGO
118 Arizona St.
Bisbee, AZ 85603

Transportation
Ag. & Hort.
Energy
Power
Health
Parks

6 Regions

820003

FROM: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

JAN 18 1982

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Additional Comments (Use back of sheet, if necessary):

Reviewers Signature Richard V. Francaviglia Date 1/17/82

Title Environmental + Community Development Planning Program Manager Telephone 602-432-5301

TO:

State Application Identifier (SAI)

JAN 13 1982 State AZ No. 82-80-0002

Mr. Les Ormsby, Admin.
Arizona Power Authority
1810 West Adams Street
Phoenix, Arizona 85005

Transportation
Ag. & Hort.
Energy
Power
Health
Parks

6 Regions

FROM: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

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Additional Comments (Use back of sheet, if necessary):

Reviewers Signature L. D. Ormsby Date 1/18/82

Title

Telephone

TO:

[illegible]
[illegible] Health Services
[illegible] of Health Planning
1740 W. Adams, Rm. [illegible]
Phoenix, AZ 85007

XRM: F782-009

State Application Identifier (SAI)

JAN 13 1982 State AZ No. 82-80-0002

Transportation
Ag. & Hort.
Energy
Power
Health
Parks

6 Regions

FROM: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

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Additional Comments (Use back of sheet, if necessary):

18 19 20 21
JAN 1982
Bureau of
Health Economics
ADHS

Reviewers Signature [illegible signature]

Date 1/[illegible]/82

Title [illegible]

Telephone [illegible]

TO:

Director
Agriculture & Horticulture Dept.
421 Capitol Annex West
Phoenix, AZ 85007

State Application Identifier (SAI)

JAN 13 1982 State AZ No. 82-80-0002

Transportation
Ag. & Hort.
Energy
Power
Health
Parks

6 Regions

FROM: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

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Additional Comments (Use back of sheet, if necessary):

Reviewers Signature [illegible signature]

Date 1-22-82

Title Director Division of Compliance

Telephone 255-4373

TO:

Art Auerbach, Supervisor
Socio Economic Analysis Section
Dept. of Transportation
206 So. 17th Ave., Rm. 310 B
Phoenix, AZ 85007

FROM: Arizona State Clearinghouse
1700 West Washington Street, Room 505
Phoenix, Arizona 85007

State Application Identifier (SAI)
JAN 13 1982 State AZ No. 82-80-0002

✓ Transportation
Ag. & Hort.
Energy
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Health
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6 Regions

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Additional Comments (Use back of sheet, if necessary):

ABS 2/4/82

Reviewers Signature Dale Buskirk
Title Senior Planner
Date 22 Jan. 1982
Telephone 261-7251

LAMAR ALEXANDER
Governor

Stephen H. Norris
Executive Director

TENNESSEE STATE PLANNING OFFICE
1800 JAMES K. POLK STATE OFFICE BUILDING
505 DEADERICK STREET
NASHVILLE, TENNESSEE 37219

Executive Director
741-1676
State Planning Division
741-1676
Local Planning Division
741-2211

February 2, 1982

William A. Vaughn
Assistant Secretary
Enviromental Protection,
Safety, and Emergency Prepardness
U.S Department of Energy
Washington, D.C. 20585

RE: CH#TN020282-019 Draft E.I.S.-Liquid Metal Fast Breeder Reactor Program

Dear Mr. Vaughn:

In accordance with OMB Circular A-95 and as the designated State Clearinghouse for federal grant programs. We have reviewed your proposal and have assigned this project the State Clearinghouse number indicated.

Our evaluation of submitted materials identified no conflicts with existing or planned state activities. We hereby are notifying you that your proposal is deemed acceptable on the basis of the descriptive information you have made available to this office. We, or other reviewing authorities, may wish to comment further at a later time.

If our office, as the State Clearignhouse, can be of further assistance, please do not hesitate to contact me.

Sincerely,

Thomas M. Webb

Thomas M. Webb
Manager, Environmental Services

TMW:mcp

STATE OF NEVADA
GOVERNOR'S OFFICE OF PLANNING COORDINATION
CAPITOL COMPLEX
CARSON CITY, NEVADA 89710
(702) 885-4865

February 3, 1982

Mr. Wallace R. Kornack, NE-6 GTN
Office of Nuclear Reactor Programs
Office of the Assistant Secretary
for Nuclear Energy
U.S. Department of Energy
Washington, D.C. 20545

RE: SAI NV# 82300037 Project: Draft - EIS Supplement to ERDA-1535

Dear Mr. Kornack:

Thank you for the opportunity to review the above mentioned project.

The State Clearinghouse has processed the proposal and has no comment. Based on the information contained therein and the responses of interested parties, the proposed project is, as of this date, found not to be in conflict with the State's plans, goals and objectives.

Sincerely,

John Wm. Sparbel
State Planning Coordinator

JWS/sl

82-3311-B161

etdd east tennessee development district

counties
anderson
blount
campbell
claiborne
cocke
grainger
hamblen
jefferson
knox
loudon
monroe
morgan
roane
scott
sevier
union

cities
alcoa
blaine
caryville
clinton
cumberland gap
dandridge
farragut
friendsville
gatlinburg
greenback
harriman
huntsville
jacksboro
jefferson city
jellico
kingston
knoxville
lafollette
lake city
lenior city
loudon
luttrell
madisonville
maryville
maynardville
morristown
new market
new tazewell
newport
norris
oak ridge
oakdale
oliver springs
oneida
parrottsville
philadelphia
pigeon forge
pittman center
rockford
rockwood
rutledge
sevierville
sweetwater
tazewell
tellico plains
townsend
vonore
wartburg
white pine

February 2, 1982

Mr. Wallace R. Kornack, NE-6 GTN
Office of Nuclear Reactor Programs
Office of the Assistant Secretary for
Nuclear Energy
U. S. Department of Energy
Washington, DC 20545

Dear Mr. Kornack:

SUBJECT: Result of Regional Review
U. S. Department of Energy - Draft Supplemental Environmental Impact Statement on the Liquid Metal Fast Breeder Program

The East Tennessee Development District has completed its review of the above-mentioned statement, in its role as a regional clearinghouse to review federally-assisted projects.

ETDD has no comment on this statement at this time. However, ETDD or other reviewing agencies may wish to comment at a later time.

We appreciate the opportunity to work with you in coordinating projects in the region.

Sincerely,

Allen W. Neel
Executive Director

AWN/tg

cc Mr. Mike Jones, Tennessee State Clearinghouse

post office box 19806 • knoxville, tennessee 37919 • telephone (615) 584-8553

MARYLAND
DEPARTMENT OF STATE PLANNING
301 W. PRESTON STREET
BALTIMORE, MARYLAND 21201

HARRY HUGHES
GOVERNOR

CONSTANCE LIEDER
SECRETARY

February 4, 1982

Mr. Wallace R. Kornack
Office of Nuclear Reactor Programs
Office of Assistant Secretary for Nuclear Energy
U.S. Department of Energy
NE-6, Room H0404
Germantown, Maryland 20545

SUBJECT: ENVIRONMENTAL IMPACT STATEMENT (EIS) REVIEW

Applicant. U.S. Department of Energy

Project: Draft EIS - Liquid Metal Fast Breeder Reactor Program
ERDA - 1535

State Clearinghouse Control Number: 81-1-142

State Clearinghouse Contact: James W. McConnaughhay (383-7875)

Dear Mr. Kornack:

The State Clearinghouse has reviewed the above statement. In accordance with the procedures established by the Office of Management and Budget Circular A-95, the State Clearinghouse received comments from the Department of Natural Resources, Department of Public Safety and Correctional Services, Office of Environmental Programs, and our staff noting that the statement appears to adequately cover those areas of interest ot their agencies.

Maryland appreciates your attention to the A-95 review process and anticipates continued cooperation with your agency in the future.

Sincerely,

J. W. McConnaughhay

James W. McConnaughhay
Director, State Clearinghouse

cc: Thomas Schmidt/Herbert Sachs/Max Eisenberg/Dennis Taylor

JMc:BG:pm

TELEPHONE: 301-383-7875
OFFICE OF STATE CLEARINGHOUSE

Burns and Roe, Inc.

700 Kinderkamack Road ■ Oradell, New Jersey 07649 ■ Tel. N.J. (201) 265-2000—N. Y. (212) 563-7700

TWX 710-990-6637 ■ Cable BUROE ORADELLNJ

Main Office
550 Kinderkamack Road
Oradell, New Jersey 07649
(201) 265-2000

February 8, 1982

Mr. Wallace R. Kornack
Office of Nuclear Reactor Programs
Office of Assistant Secretary for
Nuclear Energy
U. S. Department of Energy
Washington, D. C. 20545

Dear Mr. Kornack:

On December 17, 1981, the Department of Energy published the draft supplemental Environmental Impact Statement (EIS) DOE/EIS-0085-DC as a supplement to the final EIS on the Liquid Metal Fast Breeder Program (ERDA-1535) and invited comments thereon. Burns and Roe, Inc. has reviewed the draft supplement and welcomes the opportunity to provide comments in relation to this environmental statement.

Burns and Roe, an architect-engineering firm, has participated in the design of many fossil as well as nuclear power plants and is currently the A-E for the Clinch River Breeder Reactor Plant which will be used as the demonstration plant for the LMFBR Program.

Burns and Roe concurs that the Clinch River Breeder Reactor Plant should be completed as expeditiously as possible as an initial step in an LMFBR development program geared toward potential deployment early in the next century. Our analyses of future economic and electricity growth rates, additions and replacements of various types of electrical generating capacity, and use of nuclear power and uranium indicate the potential need for first commercial LMFBR plant orders as early as the year 2000, leading to first deployment sometime after the year 2010. This is based on maximum use of both renewable resources and coal as well as on expanded use of nuclear power in the interim period, which we believe is essential to the achievement of U.S. Government goals for future national economic and employment growth and stability.

Because of the long lead times inherent in LMFBR development, significant operating experience will not be available from Clinch River until the 1990's. Successful long-term experience will be needed from Clinch River if the private sector is to consider first commercial plant orders around the year 2000. Thus, Clinch River is a timely and necessary step at this time.

Burns and Roe considers that completion of Clinch River is a prudent step in a proper national long-range electrical energy strategy in an age of uncertainty of energy supply. Clinch River will provide a national insurance policy for an unpredictable future as well as confirm the value of the LMFBR concept for conserving nonrenewable natural resources.

Very truly yours,

W. H. Young
Vice President

WHY:sv

COMMONWEALTH of VIRGINIA

Council on the Environment

J.B. JACKSON, JR
ADMINISTRATOR

903 NINTH STREET OFFICE BUILDING
RICHMOND 23219
804 786 4500

February 8, 1982

Mr. Wallace R. Kornack
Office of Nuclear Reactor Programs
Office of Assistant Secretary for Nuclear Energy
U.S. Department of Energy
NE-6, Room H-404
Germantown, Maryland 20545

Dear Mr. Kornack:

The Commonwealth of Virginia has completed its review of the Draft Environmental Impact Statement (Supplemental to ERDA-1535, December 1975) on the Liquid Metal Fast Breeder Reactor Program. The Council on the Environment is responsible for coordinating the State's review of federal environmental documents and responding to appropriate federal officials on behalf of the Commonwealth. The Office of Emergency and Energy Services and the State Water Control Board joined in this review.

We hope that the Final EIS will address the question of impacts on Virginia's water quality, if any, stemming from a possible accident at the Clinch River breeder reactor plant once that project is put into operation. Apart from this, the Commonwealth favors the implementation of the reference alternative, which is the Clinch River Plant and the Large Scale Development Program.

Thank you for the opportunity to review this document.

Sincerely,

J. B. Jackson, Jr.

Enclosure

cc: The Honorable Betty J. Diener, Secretary of Commerce and Resources
Mr. A.E. Slayton, Jr., Office of Emergency and Energy Services
Mr. Brian Harrison, State Water Control Board

JBJ/CHE/all

8. REVIEW INSTRUCTIONS:

A) Please review the document carefully. If the proposal has been reviewed earlier (e.g., if the current document is a FINAL EIS), please consider previous comments.

B) Prepare your agency's comments in a form which would be acceptable for responding directly to a project sponsoring agency.

C) Use the space below for your comments. If additional space is needed, please attach extra sheets.

Return your comments to:

Charles H. Ellis III
Environmental Impact Statement Coordinator
Council on the Environment
903 Ninth Street Office Building
Richmond, Virginia 23219

CHARLES H. ELLIS III
ENVIRONMENTAL IMPACT STATEMENT COORDINATOR

COMMENTS

Based on our review of this supplemental Environmental Impact Statement, we believe that both the Clinch River Breeder Reactor Plant (CRBRP) and the Large-Scale Development Plant (LDP) should be completed to support Liquid Metal Fast Breeder Reactor power plant design and to validate commercial viability of the LMFBR

(SIGNED) ______ (DATE) January 12, 1982

(TITLE) Deputy Coordinator

(AGENCY) State Office of Emergency and Energy Services

COMMONWEALTH of VIRGINIA

Council on the Environment

J B JACKSON JR
ADMINISTRATOR

903 NINTH STREET OFFICE BUILDING
RICHMOND 23219
804-786-4500

February 5, 1982

MEMORANDUM

TO: File

FROM: Charles H. Ellis III

SUBJECT: Department of Energy Draft EIS (Supplement to ERDA-1535) on Liquid Metal Fast Breeder Reactor Program

State Water Control Board comments on the subject document, given over the phone today by Brian Harrison, are that the question of impacts upon water quality in Virginia stemming from a possible disaster at the Clinch River plant in Tennessee should be addressed in the Final EIS.

CHE/all

STATE OF NORTH CAROLINA

OFFICE OF STATE BUDGET AND MANAGEMENT

JAMES B. HUNT, JR., GOVERNOR
AND DIRECTOR OF THE BUDGET

JOHN A. WILLIAMS, JR.
EXECUTIVE ASSISTANT TO THE GOVERNOR
AND STATE BUDGET OFFICER

February 3, 1982

Mr. Wallace R. Kornack
Office of Nuclear Reactor Programs
Office of Assistant Secretary for Nuclear Energy
U.S. Department of Energy
NE-6, Room H-0404
Germantown, Maryland 20545

Dear Mr. Kornack:

RE: SCH File #82-E-0000-5098; Draft Supplemental Environmental Impact Statement - Liquid Metal Fast Breeder Program

The State Clearinghouse has received and reviewed the above referenced project. As a result of this review, the State Clearinghouse finds that no comment is necessary on this project at this time.

Sincerely,

Chrys Baggett (Mrs.)
Clearinghouse Director

CB/njh

116 WEST JONES STREET—RALEIGH 27611 (919) 733-7061

State of California
GOVERNOR'S OFFICE
SACRAMENTO 95814

EDMUND G. BROWN JR.
GOVERNOR

916/323-6237

February 8, 1982

Mr. Wallace R. Kormack, NE-6 GTN
Office of Nuclear Reactor Programs
Office of the Assistant Secretary
for Nuclear Energy
U.S. Department of Energy
Washington, D.C. 20545

Dear Mr. Kormack:

Please find enclosed the comments of the State of California on the draft environmental impact statement (DEIS) for the Liquid Metal Fast Breeder Reactor (DOE/EIS-0085-D). Our review finds that the DEIS is not in compliance with the requirements of the National Environmental Policy Act (NEPA) and is therefore inadequate and should be withdrawn pending further revisions and comments. Due to the short period of time permitted for comments, we were unable to comment fully on all the sections of the DEIS.

Please find enclosed comments from the following State agencies:

1) Governor's Office - Energy and Environment
   - Office of Planning and Research

2) Department of Conservation, Division of Mines and Geology

3) California Energy Commission (with appendices attached).

If you have any questions concerning our comments, please do not hesitate to contact us.

Sincerely,

Phillip A. Greenberg
Assistant to the Governor
for Energy & Environment

Enclosures

State of California
GOVERNOR'S OFFICE
SACRAMENTO 95814

EDMUND G. BROWN JR.
GOVERNOR

ATTACHMENT 1:

COMMENTS OF THE GOVERNOR'S OFFICE--STATE OF CALIFORNIA--ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE LIQUID METAL FAST BREEDER REACTOR

COMMENTS OF THE STATE OF CALIFORNIA -
GOVERNOR'S OFFICE
ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT
FOR THE
LIQUID METAL FAST BREEDER REACTOR

INTRODUCTION

The Draft Environmental Impact Statement for the Liquid Metal Fast Breeder Reactor Program is grossly inadequate and should be withdrawn and substantially revised to incorporate those aspects that are missing, incomplete, or substantially incorrect.

Major flaws exist in every section of the DEIS, including a widespread failure to comply with specific provisions of the National Environmental Policy Act (NEPA), which outlines the requirements for Environmental Impact Statements. In light of past experience with the U.S. light water reactor program, full compliance with NEPA is essential. In particular, the present problems in the LWR program related to basic health and safety, design, economic, and environmental problems result, in part, from our headlong rush into a nuclear program without adequately addressing these issues. Unless these same issues are resolved for the LMFBR prior to extensive development, the breeder program is likely to run into the same difficulties.

We comment here on the deficiencies in the following areas, and note that the short time available for comments prevented us from commenting on other areas in the DEIS that also were inadequate.

The section on the purpose and need for the LMFBR is wholly inadequate. The apparent projected demand for electricity, particularly nuclear electricity, is founded on outdated estimates of electricity demand, and on inaccurate assessments of the ability of alternatives to meet parts of that demand.

The accompanying rationales for LMFBR development are also unsatisfactory. Each of the four rationales presented, that nuclear energy is required to supply a significant fraction of future electrical requirements, that uranium resources are so limited as to constrain the LWR program without the breeder, that LMFBR costs will be low, and that the LMFBR is advanced compared to other long-term alternatives, is misleading or incorrect. The net result is to leave no adequate rationale for LMFBR development at all.

Finally, the section on the timing for the breeder suggests that there would be significant negative effects arising from any delay in breeder development. We find this conclusion to be unsupportable and present evidence suggesting that delay would not only be beneficial to the national interest, but potentially beneficial to the breeder itself, if later development is required.

Another major deficiency is in the treatment of alternative technologies and the environmental impacts of the LMFBR and its alternatives. Considerable research has been done over the last six years on the comparative environmental effects of energy technologies, yet the DEIS states that insufficient information exists on which comparisons can be based. We reject this argument as unfounded. Until such information is incorporated into the DEIS, it will remain inadequate and incomplete.

The last major deficiency that we addressed in our comments is a wholly unsatisfactory treatment of the serious safeguards and proliferation risks that will accompany the development of the LMFBR and its associated fuel cycle. Perhaps more than any of the previous deficiencies, we are deeply concerned about the plutonium fuel cycle and the ramifications of the widespread use of the breeder reactor. Present safeguards are acknowledged to be inadequate and whether or not adequate safeguards can ever be designed and implemented within our framework of freedom and constitutional liberties remains highly doubtful. Similarly, the proliferation of the plutonium fuel cycle to other countries will greatly increase the spectre of the proliferation of nuclear weapons. The LMFBR fuel cycle would greatly increase the availability of weapons-grade materials -- which we deem an unacceptable risk unavoidably associated with the development of the breeder reactor.

For these reasons, the DEIS is inadequate, not in compliance with the requirements of the NEPA, and should be withdrawn pending revision and additional comments. Our detailed comments are presented in the following sections.

COMMENTS OF THE STATE OF CALIFORNIA ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE LIQUID METAL FAST BREEDER REACTOR

The Department of Energy (DOE) Draft Environmental Impact Statement (DEIS) for the Liquid Metal Fast Breeder Reactor (LMFBR) is inadequate and fails to address several issues required by the National Environmental Policy Act (NEPA). For this reason, it should be withdrawn pending further revision and comment.

In particular, the Department of Energy has failed to adequately evaluate the complete range of alternatives to the LMFBR, the comparative environmental impacts of those alternatives, the effects of funding the breeder program at the expense of alternative long-term electricity generating options, and other issues, including the health, safety, and environmental consequences of reactor accidents. In addition, we disagree with DOE assessments of the rationales for future nuclear electricity needs (specifically breeder electricity), the adequacy of safeguards against plutonium diversion, the adequacy of proliferation safeguards, and the status, development, and timing of high-level waste storage facilities.

Full compliance with the provisions of NEPA is required before embarking on a significant commitment to LMFBRs. Although we believe that there is no need, and will be no need, for breeder reactors, there are compelling reasons for a complete, clear, and concise environmental impact statement on the proposed program. Moreover, because it is the NRC's position that the Clinch River breeder reactor program and alternatives to it can only be addressed in the DEIS on the entire breeder program,[1/] it is crucial that the DEIS adequately address these issues. The current version does not do so.

The lessons of the light-water reactor program suggest that it may be better to have no program at all than to have a program at all costs. Forcing through an incomplete, inappropriate, and expensive breeder reactor program is not in the national interest. For these reasons, we concur with the Department of Energy's Energy Research Advisory Board:

> "...construction of a demonstration plant in the early 1980s is not an urgent national priority. Sufficient coal and uranium supplies exist to satisfy project levels of electrical demand for at least 40 years and possibly well beyond. For these reasons, the panel recommends continued research and development on the liquid metal breeder reactor, as well as other breeder concepts, but that demonstration of breeder technology be delayed until a future time."[2/]

PURPOSE AND NEED

Role of Nuclear Energy. The typical justification for large-scale electricity generating facilities has been, and continues to be, anticipated large increases in electricity demand and the urgent

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1/ Clinch River Breeder Reactor Plant (Docket No. 50-537), CCH Nuclear Regulatory Reporter Para 30,094 (1976).

2/ "Federal Energy R&D Priorities", Report of the Research and Development Panel: Energy Research Advisory Board, Nov. 1981.

need to replace increasingly scarce and costly imported oil. We find neither of these rationales sufficient to justify the greatly expanded role of nuclear energy suggested by the DEIS.

Present demand for electricity is well below the levels anticipated in the early 1970s. As energy prices have risen, the rate of increase in demand has fallen. In California alone, the need for 42 large electricity generating facilities anticipated in the 1970s has been eliminated, at great savings to both utilities and ratepayers. We find no reason to expect the rate of demand to increase significantly.

The ability of electricity to displace significant quantities of oil has been greatly discredited, short of a radical and rapid change in national transportation use patterns. Oil presently produced less than 10 percent of total U.S. electricity -- and this share is decreasing annually. If the U.S. totally eliminated using oil to produce electricity, the national oil savings would not be substantial.

There is no prior rationale for the use of nuclear energy. The production and use of energy occurs to provide society with certain benefits. If those same benefits can be obtained by alternate means, with less social, economic, environmental, or political costs, then society may choose that alternative. To attempt to justify nuclear simply on the basis of its ability to provide energy is neither appropriate nor proper in an EIS.

Energy and the Economy. The old argument that GNP and energy use trends will continue in lockstep is a myth with no place in federal documents written later than 1974.[3/] There is a link between economic growth and electricity demand, but there is clearly tremendous flexibility in the nature of the linkage.[4/] The California Energy Commission has examined this link and considers low electricity growth rates to be "entirely consistent" with a strong and growing California economy".[5/] The statement that "the recent rate of efficiency improvements, about 1.5 percent per year in response to greatly increasing costs" (DEIS p. 32), will not be exceeded is unsupported by fact or historical evidence.

The final argument in the DEIS, that electricity can help in the "very large energy substitution problem faced by the U.S. as fossil fuels, especially oil and natural gas, become increasingly scarce and costly", (DEIS p. 32) is also a fallacy as noted above. Although there is indeed a large substitution problem, greater use of electricity will not permit significant reductions in U.S. oil and gas use.

3/ Committee on Nuclear & Alternative Energy Systems (CONAES), Energy in Transition 1985-2010 (1981).

4/ Darmstadter, J., J. Dunkerley, J. Alterman, "International Variations in Energy Use: Findings From a Comparative Study," Ann. Rev. Energy (1978) 3:201-24.

5/ California Energy Commission, "Electricity Tomorrow," p. 29.

The Rationale for LMFBR Development. Research, development, and deployment for the LMFBR should continue only if reasonable rationales can be given for the high cost of that research. In fact, the rationales given in the Draft EIS are neither reasonable nor sufficient to support continued funding for the breeder.

The first rationale, that nuclear power is necessary to meet a significant fraction of future electrical energy requirements, is incorrect. Despite the most sincere wishes of nuclear proponents, by the year 2000 it appears likely that nuclear power will not supply significantly more than the same fraction of the U.S. electrical requirements than it supplies today -- approximately 12 percent. Furthermore, even if nuclear were able to supply a significantly larger fraction of U.S. electricity requirements, that rationale alone does not imply that breeder reactors will or should be a necessary component of the nuclear supply system.

The second rationale given is that limits to economically recoverable uranium resources can be extended by shifting to the breeder reactor. Although this may ultimately be true, it has no validity as a rationale for the immediate development of the LMFBR for three reasons: (1) uranium resources are considerably larger than previously anticipated; (2) estimates of the need for uranium are significantly lower now than they were during early breeder development; and (3) there exist several reactor technologies that could greatly extend the availability of uranium resources beyond that achievable with the current generation of inefficient light-water reactors.

Examination of the literature on the subject of uranium resources and the breeder reactor leaves little doubt that the principal rationale for an early commitment to the LMFBR was the prospect that uranium resources were short and that the United States light-water reactor program might be squeezed as a result.[6/] Recently, however, the extensive exploratory work done under the NURE program yielded discoveries of significantly greater quantities of uranium than were previously known. As resource constraints have been greatly reduced, so has the need for early development of the breeder reactor.

Uranium resource pressures have also been removed by the tremendous reductions in the actual number of light-water reactors and hence in estimated uranium demand for the LWR program. As economic, environmental, and social forces have reduced the number of reactors expected to be operating in the next few decades, the need for an assured source of fissile fuel has simultaneously been reduced.

Finally, the current PWR/BWRs in use in the United States are very inefficient in their use of uranium. If the need arises, there exist alternative commercial reactor technologies with considerably higher uranium burn-up efficiencies. These include the CANDU reactor and modified light-water reactor systems.

6/ Holdren, J. P., "Uranium Availability and the Breeder Decision", Energy Systems and Policy, Vol. 1, No. 3, (Crane, Russak & Co., 1975).

The third rationale given in the DEIS for breeder-development is "forecasts for LMFBR electrical generation costs." Although it is not stated in the DEIS, presumably these costs are projected to be favorable for LMFBR's development. The DEIS fails to provide supporting data for its conclusion that such costs will be competitive. We find this conclusion to be extremely unlikely. Even if LMFBR costs are competitive with the costs of light-water reactors, electricity costs are likely to be too high for utility purchases. There are reasons to believe that the actual costs will be considerably above current LWR costs. Further, the additional costs associated with the uncertainty of a new technology can only exacerbate the cost problems of LMFBRs.

It is inappropriate to justify the LMFBR on the basis of estimated costs because of the gross uncertainties in these costs. In fact, the DEIS itself abandons its justification based on costs when it states:

> "Regardless of whether a particular economic model predicts 2010 or 2030 or some other date of economic competitiveness between LMFBRs and other technologies, responsible national energy policies dictate that the pace of the LMFBR development program be structured to accommodate significant uncertainties." (DEIS p. 38)

Thus, if the costs of electricity from the LMFBR turn out to be unacceptably high, the DEIS argues that some undefined "national energy policy" still dictates that the LMFBR is needed. We reject this argument as self-serving and a clear violation of the NEPA process and guidelines calling for a "full and fair discussion."[7/]

The fourth rationale given for breeder development is that the breeder is in a "relatively advanced" state compared to alternative inexhaustible technologies. We believe this to be untrue. The technology for wind turbines and photovoltaics is considerably more advanced toward commercial deployment than is the technology for the LMFBR. In fact, commercial-scale wind turbines are being deployed throughout the United States, particularly in California. It now appears that a 350 MWe windfarm, scheduled to begin full operation in the mid-1980s, will be operating in California decades before commercial LMFBRs are operating.

> "Even with a relatively vigorous LMFBR development program, a commercially viable LMFBR cannot be available for several decades." (DEIS p. 39)

Similarly, photovoltaics are technically ready for deployment. If they appear to be expensive, we note that their present costs are comparable to the 350 MWe LMFBR costs, which are projected at $3.3 billion so far ($9,500 kW). Moreover, the possibilities for tremendous cost reductions in photovoltaic manufacturing lead us to conclude that among the alternative inexhaustible technologies, photovoltaics and wind offer significant advantages over the breeder reactor.

7/ 40 Code of Federal Regulations 1502.1

The complete discussion of costs in the DEIS in inadequate for both the LMFBR and the alternative long-range technologies. Such a discussion would be informative and enlightening. It is also required by NEPA.

One-sided Risk of Delay. The DEIS claims (p. 39) that the "penalties for developing the breeder too early are small compared to the penalties for developing too late." We reject this claim. Such a claim is based on the assumption that LMFBR electricity costs will be lower than the average cost of electricity. This assumption is unsupportable by fact. Moreover, there is a very strong possibility that the development of the LMFBR will drain significant R&D money away from energy research likely to produce alternatives with significantly lower economic and social costs than the LMFBR.

The failure to discuss the effect of draining funds from other long-term alternatives to fund the breeder program is a violation of the requirement that an environmental impact statement "present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among the options."[8/] When a proposal has the effect of draining funds from the development of these alternatives, such effects should be considered as

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8/ 40 CFR 1502.14

part of the EIS. This conclusion is further supported by the requirement that DEISs offer "meaningful, timely information on the effects of agency action."[9/] The failure to discuss the effect of devoting billions of dollars to breeder development at the expense of R&D for conservation and alternatives violates this requirement.

ALTERNATIVES

40 CFR 1502.14 requires that Environmental Impact Statements:

> "...should present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decision maker and the public. In this section agencies shall:
>
> (a) Rigorously explore and objectively evaluate all reasonable alternatives,...
>
> (b) Devote substantial treatment to each alternative considered in detail..."

The DEIS fails to adequately address the alternatives to the LMFBR. (1) No information is given on the specific advantages, disadvantages, barriers to commercialization, and comparative costs for each technology. (2) No assessment has been made of the comparative risks, reliability, safeguards and proliferation aspects of each technology. (3) No evaluation of the status of commercial development is given even though significant development has occurred since 1975. (4) No discussion of alternative breeder designs is included, even

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9/ Scientists Institute for Public Information, Inc. vs. Atomic Energy Commission 481 F. 2nd. 1079 (DC Cir. 1973).

though there are doubts about the Clinch River LMFBR design. The DEIS is, therefore, inadequate.

ENVIRONMENTAL IMPACTS OF ALTERNATIVE LONG-TERM TECHNOLOGIES

We disagree with the statement at the beginning of the section on the Environmental Impacts of Alternative Long-Term Technologies which states: "Comparative quantitative analyses of alternative long-term technologies are not possible at this time." (DEIS p. 213) In fact, extensive quantitative environmental assessments have been done for both conventional and renewable energy sources.[10-16/] The most advanced work has come from the Energy and Resources Group at the University of California and from Brookhaven National Laboratory in Upton, New York.[10/13/16/] Earlier work was done at the Jet Propulsion Laboratory and the California Institute of Technology.[14/15/]

10/ Holdren, J.P., G. Morris, I. Mintzer, "Environmental Aspects of Renewable Energy Sources", Ann. Rev. Energy (1980) 5:241-291.

11/ Comar, C.L., and L.A. Sagan, "Health Effects of Energy Production and Conversion", Ann. Rev. Energy (1976) 1:581-599.

12/ Committee on Literature Survey of Risks Associated with Nuclear Power, "Risk Associated with Nuclear Power: A Critical Review of the Literature", National Academy of Sciences, Washington DC, 1979.

13/ Holdren, J.P., K. Anderson, P.H. Gleick, I. Mintzer, G. Morris and K. Smith, "Risk of Renewable Energy Sources: A Critique of the Inhaber Report", Energy and Resources Group, ERG 79-3, University of California, Berkeley, 1979.

These works should be reviewed and incorporated into a comparative assessment of environmental impacts. They do not evaluate all environmental risks, nor do they claim to. Nevertheless, they provide useful information on risk assessment methods and drawbacks, actual occupational and public health and safety risks, and they are careful to highlight those risks that cannot presently be included due to lack of data.

The list of impacts in Table 11 is grossly incomplete: "Land use", "Water Use", and two "Construction Materials" estimates. On the basis of this scanty data, the DEIS concludes:

> "It can be inferred from this table that the environmental impacts associated with construction will be less for the LMFBR than for most other long-term technologies." (DEIS p. 213)

In fact, it is not possible to infer this from the table. Even if these measures were complete, which they are not,

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14/ Caputo, R., "An Initial Comparative Assessment of Orbital and Terrestrial Central Power Systems", Jet Propulsion Laboratory Report 900-780, California Institute of Technology, Pasadena, California, 1977.

15/ Herrera, G., ed., "Assessment of RD&D Resources, Health and Environmental Effects, O&M Costs, and Other Social Costs for Conventional and Terrestrial Solar Electric Plants, Jet Propulsion Lab Report 900-782, California Institute of Technology, Pasadena, California, 1977.

16/ Brookhaven National Laboratories, Matrix of Energy-Environmental Residuals Analysis (MEERA) Data Base, Upton, New York, 1979.

the LMFBR is third out of six in land use; fourth out of five on water use; and first out of five on a very limited materials list.

- In the actual descriptions of the specific environmental impact of the alternative long-range technologies, the DEIS states:

> "...the overall impacts of wind energy systems are relatively minor..." (DEIS p. 220)
>
> "Overall, however, photovoltaic technology appears to face only moderate environmental constraints." (DEIS p. 223)
>
> "It is believed that [potential impacts] can be adequately controlled, and that solar thermal technology faces minimal environmental constraints." (DEIS p. 224)

Given these conclusions, we find unacceptable the conclusions in the summary and overview sections that the LMFBR will have fewer environmental impacts than most other long-term technologies. Moreover, given the advances in environmental impact information for both conventional and renewable energy sources, we also reject the statement that "Detailed quantitative comparisons between the LMFBR and alternative long-term technologies are not possible because only the environmental impact information for the LMFBR is complete at this time." (DEIS p. 27) Without this assessment, the DEIS is incomplete and inadequate.

Health Effects. The source term described in the DEIS (p. 192) includes only "routine" releases. However, if it is to be complete, the EIS must examine the consequences of accidents. In fact, we are not convinced that accidents will play such a minor role, either in the total public exposure or exposure to workers. Accident sources should be included in the EIS.

The DEIS contends that it is appropriate to exclude contamination of water supplies because of the "small fraction released to water, the low solubility of most transuranic compounds, and the great dilution volume ultimately provided by the world's oceans." (DEIS p. 192) This contention fails to fulfill the disclosure requirements of NEPA. We are concerned about the potential for transuranics to harm downstream drinking supplies. Analysis of the risk of contamination of drinking water, ground water, evaporation and subsequent rainfall, river and lakebed sediments and soil exposed by indirect means should be discussed in the EIS.

The assumptions made for terrestrial dispersal are very confusing. If it is known that radionuclides migrate downward through the soil, why is it assumed they remain in the root zone? The DEIS states that this assumption makes estimates of exposure higher than expected. While this may be correct, the same assumption ignores possible entry into the hydrologic system via groundwater.

SAFEGUARDS AND PROLIFERATION

Safeguards. The discussion of safeguards in the DEIS is inadequate. One of the most serious risks associated with the

development and use of the fast breeder reactor is its dependence on the plutonium fuel-cycle, which requires the circulation of large quantities of plutonium among various facilities. Plutonium is fissile material suitable for making nuclear bombs. Although the DEIS describes generic safeguards, there is no indication that actual safeguards sufficient to ensure protection of the small quantities of plutonium needed to make nuclear bombs will be available at the necessary time.

It is widely accepted that the most significant barrier to the construction of atomic bombs is not the design and development but the acquisition of weapons materials: highly enriched uranium, or plutonium.[17/] In fact, this "truism" is becoming increasingly less true, as nuclear facilities and material spread throughout the world. There is no fundamental reason why nuclear weapons materials are difficult to obtain, other than the fairly complex technology required. Unless satisfactory controls on this technology are instituted, growing numbers of countries will soon be able to acquire bomb-grade materials. We can only guarantee some degree of protection against this threat if satisfactory safeguards, under international control, are set up. The spread of breeder technology would be accompanied by a concomitant spread of facilities handling special nuclear materials. If LMFBR

17/ Wohlstetter, Albert, et al., "Moving Toward Life in a Nuclear Armed Crowd?", prepared for U.S. Arms Control and Disarmament Agency - ACDA/PAB-263 (April 1976).

safeguards are similar to current LWR safeguards, they are sure to fail with even more dire consequences guaranteeing that large quantities of weapons materials would enter international circulation. It is widely acknowledged that present safeguards are unsatisfactory.

> "Strict accountability of fissile material cannot be achieved practically throughout the entire fuel cycle."[18/]

David Fischer, retired IAEA assistant director general, has pointed out that "a measurement on a certainty of a half a percent could mean an uncertainty of 50 kilograms of plutonium either way" in a large reprocessing plant.[19/] NRC safeguards director Robert Burnett said, "We have not solved the nuclear materials accountability problem" and "the approaches available now are unlikely to be acceptable".[20/]

The safeguards described in the DEIS rely extensively on systems under conceptual development only. Clearly, hypothetical systems can be conceived of that provide foolproof protection, yet we are highly skeptical that adequate systems that are cost-effective and responsive to civil liberties and constitutional guarantees can be developed.

18/ "Report to the APS by the Study Group on Nuclear Fuel Cycles and Waste Management", Review of Modern Physics, Volume 50, American Physical Society (January 1978).

19/ Nucleonics Week, March 9, 1981.

20/ Nucleonics Week, March 13, 1980.

Proliferation. The concern over the proliferation of nuclear materials is that such proliferation poses significant real threats to international peace and stability. As civilian nuclear power systems become more widespread, the possibility increases that they will be used as sources for, or routes to, nuclear weapons materials. The spread of liquid metal fast breeder reactors would contribute significantly to this threat. Plutonium, the principal fuel and product of LMFBRs, is a very attractive nuclear bomb material. The diversion of even a small fraction of reprocessed plutonium would be sufficient for constructing a reliable, high-yield nuclear weapon. Even fresh fuel for the LMFBR is usable for the production of weapons.

> "A bomb made directly even from fresh LMFBR mixed-oxide fuel (15-25% Pu) is theoretically possible, though unwieldy."[21/]

The International Nuclear Fuel Cycle Evaluation (INFCE) concluded that the "relationship between civilian nuclear fuel cycles and the proliferation of nuclear weapons cannot be resolved by technical ingenuity"[22/] and that no conceivable fuel cycle could much reduce the possibility of proliferation. INFCE went on to conclude that the diversion risk

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21/ Lovins, A.B., "Nuclear Weapons and Power Reactor Plutonium", Nature, Vol. 283, p. 817-823 (February 28, 1980). See also: Nonproliferation Alternative Systems Assessment Program, "Nuclear Proliferation and Civilian Nuclear Power", Vol. 2, 2-40, Draft Report DOE/NE-0001 (December 1979).

22/ "INFCE Brings International Agreement on Nuclear Fuel Cycle No Nearer", Nature, Vol. 283, p. 808 (February 28, 1980).

encountered in the various breeder reactor fuel cycle stages presents diversion risks equivalent to those of the light-water reactor with plutonium recycle. The LWR with plutonium recycle is highly vulnerable to materials diversion in the reprocessing and reprocessed fuel-fabrication stages.[23/] The fact that LMFBR fresh fuel itself is attractive to diverters makes the entire LMFBR fuel cycle a more attractive target overall than the LWR with plutonium recycle.

23/ Office of Technology Assessment, Nuclear Proliferation and Safeguards (1977).

State of California
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GOVERNOR

ATTACHMENT 2:

COMMENTS OF THE CALIFORNIA DEPARTMENT OF CONSERVATION ON THE LIQUID METAL FAST BREEDER REACTOR DRAFT ENVIRONMENTAL IMPACT STATEMENT (DOE)

COMMENTS OF THE STATE OF CALIFORNIA
RESOURCES AGENCY - DEPARTMENT OF CONSERVATION
DIVISION OF MINES AND GEOLOGY
ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT
FOR THE
LIQUID METAL FAST BREEDER REACTOR

The California Department of Conservation has reviewed the U.S. Department of Energy's (DOE) Draft EIS addressing the proposed Liquid Metal Fast Breeder Reactor (LMFBR) Program.

While we have reviewed the Draft EIS and prepared the following comments, the extremely short period of time available between receipt of the document in late January 1982 and the deadline for the submittal of comments makes a comprehensive review impossible. We therefore reserve the right to submit additional comments at a later date if we determine it to be necessary. The proposed LMFBR Program is a highly complex and controversial issue, and the State of California, as well as the general public, deserved a reasonable period of time to analyze and weigh the information presented in the document.

The Draft EIS supplements an earlier EIS published in 1975, and only addresses particular subjects identified by the DOE for which there is substantial new information. This includes radioactive waste management and disposal, to which we address the bulk of these comments. However, the DOE has not addressed structural design technology and requirements related to seismic safety, stating that the 1975 discussion remains valid today. Because the state-of-the-art technology is rapidly advancing, the DOE must reassess this aspect of development.

As stated above, our review of the Draft EIS centers on waste management and disposal. The proposed LMFBR Program considers concurrent development of waste management essential to significant development of breeder reactors, and waste management is tied to the availability of a geologically sound disposal facility. If LMFBR development progresses as proposed, this facility will be needed as early as 2005.

The Department of Conservation participated in the U.S. Nuclear Regulatory Commission (NRC) Waste Confidence Rulemaking proceedings on the storage and disposal of high-level waste. We consistently questioned whether the DOE can construct and operate a high-level disposal facility within the anticipated 1997 to 2006 time frame, which complies with NRC regulations and Environmental Protection Agency (EPA) performance standards, neither of which have been developed and approved. There are serious uncertainties surrounding site selection and development of a high-level waste disposal facility which have yet to be answered.

Below is a listing of significant issues which we identified during the Confidence proceedings, and addressed in the documents referenced on the attached list. We believe that these issues must be resolved before the DOE constructs and operates a geologic repository for high-level wastes.

1. It is questionable that a waste disposal facility will be operational by the period 1997 to 2006, and that it will be in a geologic medium which meets NRC regulations and EPA performance standards.

2. Ten thousand years may not be sufficient time for storing nuclear waste in a mined repository which meets NRC and EPA requirements, unless significant containment integrity is achieved beyond this time period.

3. The potential effects of future climatic change make it difficult to document whether a high-level waste repository can meet NRC and EPA requirements. The DOE must include such consideration in its plans to develop an acceptable facility.

4. The hydrological conditions of potential sites must be well characterized to assure that the sites comply with NRC and EPA requirements. This capability must be developed and implemented before establishment of operational facilities.

5. A fail-safe system of monitoring facility performance must be devised and installed at the time the repository goes into operation. The system must be capable of detecting all malfunctions that might occur in the repository during and after the operational period.

6. Expertise must be available to completely and permanently seal the shafts, boreholes, and exploratory openings used to develop and characterize sites. Decommissioned repositories must be sealed to prevent contamination of the biosphere.

7. Retrievability of wastes is a critical capability that must be built into facility selection, design, construction and operation. The DOE included inadequate discussion of this issue in the report "Earth Science Technical Plan for Disposal of Radioactive Waste in a Mined Repository, DOE/TIC-11033, April 1980".

8. The DOE has not found a potential site without significant geologic problems. What is the certainty that sites will be found which have acceptable geologic conditions?

In summary, we believe that the DOE cannot achieve the LMFBR Program within the proposed time frame, as the Program objectives and scheduling are dependent on the completion of an operating high-level waste disposal facility prior to commercial operation of the reactor. We therefore feel that no LMFB reactor should be licensed for operation prior to this event, and we recommend that the DOE re-evaluate and modify the proposed time frame for the LMFBR Program, to assure that a licensed disposal site is available before the commercial operation of reactors under this program.

References

California Department of Conservation, 1980, Cross-Statement of Position in the Matter of: Generic Proceedings of Confidence in Storage and Disposal of Nuclear Wastes, September 5, 1980.

Department of Conservation, State of California, 1980, Filing of the California Department of Conservation Statement of Position in the Matter of: Generic Proceeding on Confidence in Storage and Disposal of Nuclear Wastes, July 7, 1980.

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ATTACHMENT 3:

COMMENTS OF THE CALIFORNIA ENERGY COMMISSION ON THE DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR THE LIQUID METAL FAST BREEDER REACTOR PROGRAM

(with attachments A and B)

CALIFORNIA ENERGY COMMISSION

COMMENTS

ON THE

ADEQUACY OF THE

DRAFT ENVIRONMENTAL IMPACT STATEMENT

LIQUID METAL FAST BREEDER REACTOR

(DOE/EIS-0085-D)

FEB 1982

NUCLEAR FUEL CYCLE COMMITTEE

STATE OF CALIFORNIA—THE RESOURCES AGENCY EDMUND G. BROWN JR., Governor

CALIFORNIA ENERGY COMMISSION
1111 HOWE AVENUE
SACRAMENTO, CALIFORNIA 95825
(916) 920-6815

February 8, 1982

Mr. Wallace R. Kormack, NE-6 GTN
Office of Nuclear Reactor Programs
Office of the Assistant Secretary for
Nuclear Energy
U.S. Department of Energy
Washington, D.C. 20545

Dear Mr. Kormack:

In response to your request for review of the draft environmental impact statement (DEIS) on the Liquid Metal Fast Breeder Reactor (DOE/EIS-0085-D), we are providing the enclosed comments. The California Energy Commission's review indicates that the draft statement is not in compliance with NEPA requirements; in particular, it fails to provide an adequate assessment of the need for the LMFBR program, alternatives and environmental impacts.

If you or your staff have questions concerning our comments, please do not hesitate to contact us.

Sincerely,

EMILIO E. VARANINI, III
Commissioner and
Presiding Member
Nuclear Fuel Cycle Committee

EEV:tld

Enclosure

COMMENTS OF THE CALIFORNIA ENERGY COMMISSION
ON THE DEPARTMENT OF ENERGY'S DRAFT ENVIRONMENTAL
IMPACT STATEMENT FOR THE LIQUID METAL FAST
BREEDER REACTOR PROGRAM

I. INTRODUCTION

The Department of Energy's (DOE) Draft Environmental Impact Statement (DEIS) on the Liquid Metal Fast Breeder Reactor Program (LMFBR) fails to comply with the requirements of the National Environmental Policy Act (NEPA), does not adequately justify the need for the LMFBR program, fails to provide an adequate discussion of alternatives and their environmental consequences in comparison with impacts of the proposed project, and therefore should be withdrawn and substantially revised.

Of major concern is that the development of the breeder reactor program would divert limited federal research dollars from other energy research and development programs (such as alternative energy technologies, conservation, reactor safety and reliability, nuclear waste management) that offer a more sustainable, least-cost energy future. Shifting federal research emphasis toward the breeder program would move the nation toward reliance on a plutonium economy, requiring extraordinary safeguards against sabotage, fuel diversion, and accidents. Because of the significant hazards and economic uncertainties of a plutonium fuel cycle, especially in view of the increased development of alternative sources of energy since ERDA's 1975 EIS on the breeder reactor, the DEIS should carefully explore the need for this program, i environmental impact, and feasible alternatives. Such an extensive review of the breeder program is particularly needed in view of the Nuclear Regulatory

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Commission's (NRC's) position that review of the need for the Clinch River breeder reactor and alternatives to it are not proper issues for the NRC's Clinch River licensing proceeding but only can be addressed in the DEIS on the entire breeder reactor program. Clinch River Breeder Reactor Plant, (Docket No., 50-537), CCH Nuc. Reg. Rptr. ¶ 30,094 (1976).

The DEIS does not present a forthright discussion of issues confronting the development of the breeder reactor program--safeguards; safety; prospects for commercialization; technical, environmental, and economic problems in existing foreign breeders and United States prototypes; and uranium availability, to name a few. The DEIS fails to provide an objective review of the need for the breeder program, its environmental impact, and the existence of more economical and environmentally benign alternatives. In our detailed comments below, we discuss the failure of the DEIS to meet NEPA requirements (Section II), inadequacies of the DEIS' review of the need for the LMFBR (Section III), the availability of alternatives to the LMFBR (Section IV), and the environmental impacts of the program (Section V), with emphasis on safeguards and proliferation, safety and waste management.

II. FAILURE OF DEIS TO MEET NEPA REQUIREMENTS

The DEIS fails to comply with the following requirements of NEPA:

1. "NEPA documents must concentrate on the issues that are truly significant to the action in question rather than amassing needless detail" (40 CFR 1500.1(b)).

Issues significant to the action in question include:

- o The environmental consequences (in particular, issues related to proliferation, safeguards, safety, waste management, and decommissioning of contaminated facilities and equipment) of the proposed LMFBR program in comparison to the environmental consequences of alternative technologies.
- o The need for the LMFBR program, relative to alternatives, as influenced by decreasing projections of energy demand growth, cancellation of nuclear reactors, surplus uranium inventories and declining uranium prices.
- o The potential for commercialization of the breeder reactor.
- o The opportunity cost of supporting a breeder R&D program at the expense of alternate federal R&D programs (for example, research to improve nuclear safety and plant performance, waste management, conservation and alternatives).

On pp. 152 - 157 (DEIS) efforts to improve safeguards applicable to the LMFBR are briefly overviewed. However, the risks and environmental impact of sabotage and theft of nuclear materials at all stages of the LMFBR fuel cycle (reprocessing, waste management, reactor, transportation) are not discussed. Nuclear weapons proliferation has been considered to be the potentially most serious catastrophic problem posed by nuclear power (CONAES study p. xv). A major deficiency that should be addressed is the environmental impact of the expanded use of plutonium in view of current safeguards uncertainties and limitations and to what extent a delay in the LMFBR to avert further nuclear proliferation and safeguards problems can result in better control institutions being put into place. (See Section V on environmental impacts of the LMFBR program).

The DEIS does not address the reduction in need for the breeder reactor as the result of surplus uranium inventories and the cancellation of reactors. Moreover, the DEIS fails to acknowledge that the diversion of billions of dollars of a very limited federal budget into this program is done at the expense of research to address reactor safety and waste management issues and developing conservation and alternative energy sources. NRC Commissioner Victor Gilinsky stated in 1981:

> "If nuclear power should fail to survive into the twenty-first century, it will be at least in part because 25 years of hard sell for an all-nuclear future got in the way of common-sense consolidation of this new technology. While problems in existing plants cried for attention, industry and government pursued visions of even grander reactors. In my view, the romance with the plutonium-fueled breeder which was supposed to solve all our energy problems diverted attention from the hard business of mastering the commercial reactors we have been building and operating." (Bull. Atom. Scien., January, 1980).

After commenting on problems confronting the nuclear industry, Commissioner Gilinsky stated:

> "The commitment to the Clinch River Breeder Reactor is a distraction from these problems. Not only will it consume money in large quantities, but it will also eat up the government's bureaucratic energies to little effect in the period of time we must talk about. To use an economist's term, the opportunity cost is very high. My own feeling is that even though the breeder reactor is currently funded, it is not going to be built. The country is just not in a mood to fund projects that do not make sense economically. And this one does not make sense at this point because uranium is plentiful and the number of reactors expected to use it is diminishing."[1]

2. The DEIS must offer "meaningful, timely information of the effects of agency action" (Scientists' Institute for Public Information, Inc. v. Atomic Energy Commission, 481 F.2d 1079 (D.C. Cir. 1973).

The DEIS provides no discussion of the effect of devoting billions of federal R&D dollars to the development of the breeder reactor program at the expense of R&D funding for conservation and renewable energy resources and funding for research that addresses major problem areas in nuclear reactors (safety, improving the reliability of nuclear plants, waste management).

3. Environmental impact statements "shall provide full and fair discussion of significant environmental impacts and shall inform decisionmakers and the public of the reasonable alternatives which would avoid or minimize adverse impacts or enhance the quality of the human environment" (40 CFR 1502.1).

The DEIS does not provide a fair and full discussion of the environmental impacts of the LMFBR and alternatives. Only solar electric and fusion are discussed as alternate long term technologies. A major oversight is that it ignores the significant contributions made by conservation in reducing national dependence on imported petroleum, as reported in five major national studies (CONAES[2], the Harvard Business School Study[3], SERI[4], RFF[5], Ford Foundation[6]).

4. "The discussion will include the environmental impacts of the alternatives including the proposed action, any adverse environmental effects which cannot be avoided should the proposal be implemented, the relationship between short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and any irreversible or irretrievable commitments of resources which would be involved in the proposal should it be implemented."

It shall include discussions of:

"(e) Energy requirements and conservation potential of various alternatives and mitigation measures."

"(f) Natural or depletable resources requirements and conservation potential of various alternatives and mitigation measures." (40 CFR 1502.16)

The DEIS fails to identify any adverse environmental effects which cannot be avoided and to discuss the relationship between short-term uses of the environment and the enhancement of long-term productivity and any irreversible commitments of resources which would be involved. In particular, long-term environmental impacts from the decommissioning and disposal of contaminated facilities, equipment, and wastes should be identified and discussed.

5. Agencies shall "devote substantial treatment to each alternative considered in detail including the proposed action so that reviewers may evaluate their comparative merits." (40 CFR 1502.14)

A major inadequacy of the DEIS is its failure to provide an objective assessment of conservation and alternative technologies for comparison with the LMFBR program (see Section IV discussion on

alternatives). An example of the poor quality of the analysis of alternatives is Figure 1 (DEIS, p. 31) which provides a dated (1976) comparison of energy available from renewable energy resources. Such information does not reflect significant recent advances in renewable energy technologies, particularly in photovoltaics, wind, small hydroelectric, etc..

6. Environmental impact statements "shall be concise, clear and to the point, and shall be supported by evidence that the agency has made the necessary environmental analyses" (40 CFR 1502.1).

The DEIS vaguely states that, "None of the new information developed since ERDA-1535 indicates a significant change in the environmental consequences of the LMFBR Program over those analyzed in WASH-1535 and ERDA-1535" (DEIS, p. 112). However, there is no discussion of the nature of the "new information developed since ERDA-1535" nor the extent to which the data and conclusions drawn in ERDA-1535 were subjected to critical analyses in light of new findings.

7. Environmental impacts must be considered early enough in the planning of federal programs to ensure that the EIS process does not become a rationalization of past decisions (see, e.g., Scientists' Institute for Public Information, Inc. v. Atomic Energy Commission, 481 F.2d 1079 (D.C. Cir. 1973).

The DEIS ignores this requirement by supporting the development of the breeder reactor program, not because the environmental impacts of the program are minimal or can be mitigated, but because of past federal support of the project and the resources committed to the project (see, DEIS, pp. 86 -90).

8. The environmental impact statement "should present the environmental impacts of the proposal and the alternatives in comparative form, thus sharply defining the issues and providing a clear basis for choice among options by the decisionmaker and the public" (40 CFR 1502.14).

The DEIS provides only a limited discussion of solar electric systems and fusion (pp. 94 - 106). It does not provide an objective, thorough discussion of the major issues (safeguards, proliferation, economics, waste management, safety) identified with breeder development, nor does it provide a clear assessment of alternative technologies and conservation and their respective environmental impacts.

Consequences of Failure to Comply with NEPA

In summary, the DEIS does not meet NEPA requirements because it:

- o Fails to concentrate on the significant issues.
- o Fails to offer meaningful information on the effects of agency action, e.g., reduction in alternate RD&D programs.
- o Does not provide a full and fair disscussion of significant impacts and reasonable alternatives.
- o Fails to discuss adverse environmental effects which cannot be avoided, irreversible impacts and irretrievable resources.
- o Does not provide a detailed treatment of alternatives and their comparative merit.

- o Is not supported by evidence that the necessary environmental analyses have been made, and
- o Is a rationalization of past actions.

Full compliance with NEPA before embarking upon a major commitment to breeder reactors is not only mandatory but also necessary for informed policymaking as is demonstrated by our experience with the light water nuclear reactor (LWR). In the past, government and industry did not adequately address basic safety, environmental, and economic problems with LWRs and the lowering of projected electrical demand growth, while ever larger LWR's were planned. Failure to sufficiently address these problems has seriously damaged the LWR industry, causing escalating costs and turning nuclear into a highly questionable energy source.* Consequently, no LWR's have been ordered since 1978, private investors are unwilling to finance new nuclear projects, and many utilities are cancelling nuclear reactors

*Poor plant performance is an ongoing problem. Design errors, equipment failures, and the accident at Three Mile Island have led to widespread shutdowns. The 62 licensed reactors in the United States with over 400 MW capacity averaged slightly under 57 percent capacity factor from January 1979 through June 1980. The 39 large plants (over 800 MW) averaged only 51 percent capacity factor during the same 18 months (Bull. Atom. Scien., November 1980, Charles Komanoff, "U.S. Nuclear Plant Performance.") Of the 72 nuclear plants with operating licenses, 25 were shut down as of Feb. 6, 1981 according to an informal Associated Press survey of the units. (Sacramento Bee, Feb. 7, 1981).

under construction.* According to a Congressional Research Service estimate, more than 40,000 megawatts (or 40 million kilowatts) of nuclear or coal-fired generating capacity that had been scheduled to be in service by 1985 has been cancelled or deferred beyond 1990.[7]

Because DOE's DEIS on the liquid metal fast breeder reactor program clearly fails to satisfy NEPA requirements, we urge that it be withdrawn until a complete and realistic assessment of the need for the program, its environmental impacts, and alternatives to it is performed.

*A report by the Securities Research Division of Merrill Lynch (Utility Nuclear Power Plants--The Outlook for the '80's) lists 18 plants as candidates for cancellation to improve the near-term financial situation of some utilities (Nucleonics Week, April 2, 1981). A Wall Street Journal article (November 20, 1980, "Generating Doubt: Some Investors Shun Nuclear Powered Utilities, Jeopardizing Funds to Build New Atomic Plants") similarly reported that some utilities will be hard pressed to finish nuclear projects underway, not to mention any new ones. Peter Bennett, a managing director who works on private debt placements for the Merrill Lynch White, Weld Capital Markets Group, an arm of Merrill Lynch, estimates 25 -30 percent of his firm's 200 clients who do long term lending now "shy away" from nuclear. (Id.) Carleton Burtt, Executive Vice President of Equitable Life Assurance Society states: "We are very concerned about the financial obligations of the utilities that face large unfinished nuclear power facilities..." Equitable is "working out an investment strategy that will avoid utilities with heavy nuclear commitments." (Id.)

III. DEIS INADEQUACIES IN REVIEWING THE NEED FOR THE LMFBR PROGRAM

The need for the LMFBR can be determined by assessing:

- o Projected U.S. energy demand growth,
- o Portion of U.S. energy demand that is provided by electrical energy,
- o Portion of U.S. electricity needs projected as being supplied by nuclear power,
- o Availability and price of uranium and,
- o Prospects for breeder commercialization (i.e., ability of breeder to be made commercially available).

However, the DEIS' discussion of the need for the LMFBR Program does not adequately review these issues . Instead of presenting a detailed need analysis for LMFBR development, the DEIS relies upon vaguely stated and at times erroneous justifications for the breeder reactor--the need for nuclear power to meet future energy requirements, economic growth requirements, limited uranium supplies, breeder electrical generating costs, the relatively advanced state of breeder reactor development, and the unavailability of alternatives. We address below the deficiencies in the DEIS' discussion of each of these factors.

Projections of Growth in U.S. Energy and Electricity Demand

First, the projected national energy needs that are used to justify the DEIS' assessment of the need for the breeder program are unclear. While the DEIS does not forecast future energy growth, it appears that the rationale for the need for the breeder is based upon assuming a 3 percent or higher energy growth rate (DEIS, p. F-7). However, there is considerable uncertainty of future demand. Current projections (see Table 1) range from -1.4 to 5.4 percent annual growth rate. As shown in Table 1, the Exxon, Audubon, and SERI studies predict future demand growth below that assumed by DOE in the DEIS.* Nowhere does the DEIS mention such lower forecasts of demand growth and their implications for the need for the LMFBR program.

Projected electricity growth rates also require careful review. For example, the California Energy Commission's (CEC) forecast for California, adopted after extensive analytical review and public hearings, projects statewide peak demand to grow at 1.65 percent per year and annual sales at 1.44 percent per year through 2000** (ET, p. 92). As we found:

> "In the year since the 1979 Biennial Report was issued, the stunning decline in the electricity demand growth rate has continued, with expected growth rates now below 1-1/2 percent per year versus forecasts of over 5-1/2 percent in 1975. The debate over demand forecasting has eased as utilities have begun to accept that the post-embargo drop in growth rates is permanent" (p.xv)

*See for example, The Solar Energy Research Institute study, A New Prosperity: Building a Sustainable Energy Future, 1981 which showed that through increased energy efficiency, the United States can achieve a full-employment economy and increase worker productivity, while reducing national energy consumption by nearly 25 percent (p. 1). The report of The Energy Project at the Harvard Business School (Energy Future, by Robert Stobaugh and Daniel Yergin, 1979) similarly predicts a decline of 30 - 40 percent in the United States energy consumption given a national commitment to conservation (p. 136). The CONAES report shows that U.S. energy demand (78 quads used in 1978) by 2010 could be as low as 58 quads (CONAES, p. 9, 128).

**The CEC undertakes a thorough review of California's energy situation every two years and issues a "Biennial Report" summarizing its findings. The CEC adopted its Third Biennial Report in December 1980. This report contains two volumes (Energy Tomorrow, referenced as ET in this document (Appendix A) and Electricity Tomorrow (Appendix B) referenced as Elec. T.).

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Table 1

FORECASTS OF ELECTRICITY DEMAND GROWTH

SOURCE	DATE PUBLISHED	PERIOD	ANNUAL GROWTH (%)
EPRI[1]	1978	1977–2000	5.4
EEI[2]	?	1978–2000	2.0 to 5.1 (4.3 in "preferred" scenario)
NERC[3]	1980	1979–1989	4.1
Electrical World[4]	1980	1979–1990	3.9
"	"	1990–2000	3.0
PIRINC[5]	?	1980–1990	3.3
DOE EIA[6]	1980	1978–1995	3.1 to 3.2
DOE EIA[7]	In Draft	1978–1995	3.0 to 3.1
EXXON[8]	1978	1990–2000	1.9
AUDUBON[9]	In Draft	1980–2000	1.3
SERI[10]	1981	1980–2000	−1.4 to 2.0

(1) Electric Power Research Institute. Supply 77. May 1978 (quoted in *The Energy Fact Book*, Congressional Research Service. Committee Print 96-IFC-60. p. 663)

(2) Edison Electric Institute. *Economic Growth In The Future—II*.

(3) National Electricity Reliability Council. *1980 Summary of Projected Peak Demand, etc.*, July 1980.

(4) Electrical World. *31st Annual Electricity Industry Forecast*, September 15, 1980.

(5) PIRINC (quoted in *The Energy Fact Book*, Congressional Research Service. Committee Print 96-IFC-60. p. 659).

(6) U.S. Department of Energy. *Annual Report to Congress*. 1979. Volume 3: Synopsis. DOE/EIA-0173(79) 3(SYN). October 1980.

(7) U.S. Department of Energy. *Annual Report to Congress*. 1980. (Draft).

(8) Exxon (quoted in *The Energy Fact Book*, Congressional Research Service. Committee Print 96-IFC-60. p. 659)

(9) Audubon Energy Plan, to be published by National Audubon Society in May 1981, quoted in: Colin Norman, "Energy Conservation: The Debate Begins," *Science* 212, 24 April 1981).

(10) Solar Energy Research Institute. *Report on Building a Sustainable Future*. Committee on Energy and Commerce. Committee Prints 97-K and 97-L. 97th Congress, April 1981.

(From Future of Electric Power Workshop Summary, The MITRE Corporation, July 1981.)

"The Commission forecasts a continuing moderation in the growth of electricity demand for the rest of this century" (p. 35).

In fact, many of the California utilities' projections are as low or lower than CEC projections.

The DEIS' assertion that a healthy American economy depends upon a high energy growth rate (DEIS, pp. 29 - 31) is a much contested theory. It is the CEC's position that:

> While there is still a link between economic growth and electricity demand, the linkage has changed dramatically since the early 1970s. As a result, the lower electricity growth rates forecasted are entirely consistent with a strong and growing California economy" (Elec. T., p. 29).

This conclusion is supported by the California Building Industry Association:

> "The conventional view that conservation means deprivation, lower productivity, and a lower standard of living is simply incorrect. The past three years have shown that improvements in efficiency will save energy, money, and are consistent with increased productivity. The view that conservation is equated with curtailment is not only erroneous, but dangerous to a healthy state economy" (ET, p. 163).

The CONAES Study also concluded:

> "it appears that the energy-to-economic output ratio in the United States economy can be lessened, over the long term, and the prudent, sustained policies can help the economy continue growing with constrained growth of energy consumption" (CONAES p. 120).

The Harvard Business School Study reported that there has been wide and erratic variation in the relationship between energy and GNP in the United States (Harvard Business School Study, p. 142). Similarly, the

Resources for the Future study noted that rarely has there been a lock-step relationship between energy and the GNP and that a given rate of GNP growth need not signify an equivalent or a near equivalent growth rate in energy demand (RFF, p. 85).

Nonelectricity Oil Usage

The DEIS correctly states that oil currently supplies only a small portion of total electricity usage and that the majority of the nation's oil consumption is in nonelectricity sectors.* The DEIS hypothesizes that substantial nonelectricity oil usage will convert to electricity usage and thus require increased electricity supplies from the breeder reactor (DEIS, pp. 28 - 29). The DEIS presents no facts supporting this conjecture. This assumption mistakingly repeats a similar misconception that LWRs would be instrumental in displacing oil. As a recent study pointed out, LWRs are displacing coal, not oil, and LWRs in 1979 displaced only one-tenth (87 million barrels) the amount of oil that the federal government claimed they would for that year (Barron's, August 24, 1981, p. 5).

The DEIS fails to give any basis for assuming that nonelectric uses of oil will actually convert to breeder-supplied electricity. While the DEIS cites electric cars as a justification for the breeder reactor program (DEIS, p. 28), such cars still face major technological barriers (ET, p. 77) which are not mentioned in the DEIS. Moreover, the current

*The DEIS states that oil provides about 10 percent of U.S. electricity now, and it is projected to produce only about 1 percent in the year 2000 to 2020 timeframe (DEIS, p. 29). While petroleum supplies approximately 61 percent of the primary energy consumed in California (ET, p. 9). oil-fired electric generation supplies less than 4 percent of California's total end-use energy consumption (ET, p. 5). More than half of the petroleum (62 percent) is used for transportation, which is also the largest overall energy end-use sector (ET, p. 9).

CEC electrical forecast assumes that electric vehicles will account for about 2 percent of the total miles driven in California in the year 2000 and still projects an electrical growth rate of only 1.65 percent for peak demand and 1.44 percent for sales (ET., pp. 78, 92), far below levels used in the DEIS.

Furthermore, assuming that the DEIS correctly states that the real need for the breeder reactor program is to reduce oil usage in sectors currently not dependent on electricity (DEIS, p. 29), the DEIS does not examine alternatives to the breeder reactor for displacing oil usage in the nonelectricity sector. The automobile is estimated to account for about one third of total petroleum consumed in the U.S.[8] In the transportation sector, potential alternatives include increasing energy efficiency (through improved automobile efficiency, fuel efficient car maintenance and driving practices, improved traffic control systems, more efficient freight handling methods), alternative transportation systems (mass transit, ridesharing, bicycling, telecommunications), and alternative fuel sources (pure alcohol fuels, gaschol, diesel fuel) (ET., pp. 61 - 76).* These alternatives are not mentioned in the DEIS.

Energy Contributions of the Proposed LMFBR Program

Another crucial omission from the DEIS' need assessment is identification of the capacity and projected energy contributions from the LMFBR program

*The Energy Policy and Conservation Act of 1975 mandated that the fuel economy of new cars rise from an average 18.0 mpg for 1978 model year to at least 27.5 mpg in 1985. A new Volkswagen car is under advanced development that is expected to achieve a fuel economy rating of 60 mpg. Therefore, by 2000, there will be a significant savings in petroleum use simply through the use of more efficient cars. The DEIS does not address this alternative method of decreasing oil usage.

to the nation's electricity grid. The original ERDA EIS projected 80 large LMFBRs (DEIS, p. 11) apparently supplying 80,000 MW. The new DEIS references a "more limited program" but never identifies what is the size of the program. The DEIS' effort to determine the need for the LMFBR program, its environmental impacts and alternatives has limited usefulness without knowledge of program size. In addition, where the DEIS hints at program size, the assumptions of size are contradictory. A program 1/10 the size of the original program (or 8,000 MW) is assumed for reprocessing (DEIS, p. 80), while a reduction to 1/20th the size (or 4,000 MW) is assumed for fuel fabrication (DEIS, p. 84).

Forecasts for LMFBR Electricity Costs

The DEIS identifies "forecasts for LMFBR electrical generating costs" as an "important element in the rationale for United States LMFBR development" (DEIS, p. 33). However, the studies cited compared costs of LMFBRs with only LWRs, did not use cost information from foreign breeder experience, and are highly dependent on uncertain assumptions that cannot be verified until breeders approach commercial availability (DEIS, p. 37). Despite the uncertainty of LMFBR cost estimates, the DEIS concludes that the LMFBR is nevertheless justified because "responsible national energy policy dictates that the pace of the LMFBR development program be structured to accommodate significant uncertainties" (DEIS, p. 38). However, in view of the serious cost overruns and plant cancellations plaguing the LWR industry, significant economic uncertainties regarding breeder development warrant concern. The DEIS should include a more extensive analysis of LMFBR electricity costs, including cost information from foreign breeder programs, since these costs are crucial to the successful commercialization of the breeder.

Uranium Availability

The DEIS asserts that limits on economically recoverable uranium will restrict the use of nuclear powerplants and that breeders, offering an essentially unlimited fuel supply, are therefore required (DEIS, p. 33). However, an analysis of the uranium market does not support this hypothesis. United States production of uranium is more than twice that consumed by utilities; mines and mills are closing, and yellowcake prices have been dropping for over 20 months.[9] Further, the DEIS projections of uranium resource requirements and reserves (DEIS, p. 36) ignore: (a) any reduction in LWR uranium requirements through increased fuel-use efficiency and reduced losses during enrichment with advanced technology (30-50 percent improvements have been projected) and (b) any improvements in uranium mining technology over the next 30 - 60 years.[10] The purported need for rapid deployment of breeders decreases with the continuing decline of uranium prices ($40 per pound in 1979, $28 per pound in December 1980, to $23.50 per pound in December 1981, and still falling). DOE's Energy Research Advisory Board predicts that sufficient uranium supplies exist to satisfy projected levels of electric demand for at least 40 years and possibly well beyond.[11]

Contrary to DOE's beliefs, new LWRs beyond those built or under construction are extremely unlikely. NRC Commissioner Victor Gilinsky, in remarks made before the World Nuclear Fuel Market's International Conference on Nuclear Energy, October 27, 1981, reported that 72 nuclear reactors (having a total generating capacity of 55,000 MW) are currently licensed for commercial operation and 77 large plants (about 1,000 MW each) are in various stages of completion, with some nearly finished, and others barely begun. (This number does not include 12 plants which were under construction and which have been cancelled since 1975). The Commissioner expected that at least another 20 of the 77 plants under construction will also be cancelled. Therefore, no more than about 50 new plants (about 60,000 MW) appear to be headed for completion and operation. It is interesting to note that a study by Merrill Lynch recommended that while nuclear plants above 95 percent completion should be completed, those plants whose construction has not progressed beyond 15-20 percent should be considered candidates for cancellation.[12]

DOE's own figures (DEIS, App. A) on uranium supplies in the United States show sufficient fuel for the entire life-time of up to 215 reactors. United States and worldwide uranium production has exceeded consumption by over two to one. In 1980, United States produced about 42 million pounds of U_3O_8, whereas United States utilities only burned about 18 million pounds to produce electricity. There is little doubt that uranium inventories will increase substantially in the years ahead.[13] Thus, there is little basis for the DEIS' assumption that a greatly increased supply of uranium will be needed for LWRs. More importantly, the DEIS fails to include available uranium supplies outside of the United States. In 1980, worldwide uranium production was 110 million pounds of which 40 million pounds were used for electricity production.[14] In view of the surplus of uranium inventories and the decline in new reactor orders, the need for breeder development at this time is unjustified.

Commercialization of LMFBR

The DEIS states (p. 38), "The LMFBR is in a relatively advanced state of development, both in the U.S. and worldwide." However, the report does not include a discussion of experience with actual breeder reactors nor does it include a complete discussion of the status of other major components of the LMFBR fuel cycle (reprocessing, fuel fabrication, etc.). The DEIS should include a more comprehensive analysis of the performance, status of development and economics of foreign breeders and United States prototypes. The DEIS further states (p. 46) "If the U.S. were to reject current development, of the LMFBR, it would be rejecting or deferring a relatively certain technology capable of producing inexhaustible electrical energy supply." An assessment of the performance and economics of foreign breeders and United States prototypes is clearly warranted to support or refute this claim. Moreover, an inspection of these breeder programs reveals a number of significant technical and economic problems, e.g. cost overruns, which the DEIS ignores.

Past U.S. experience does not provide reassurance of acceptable technical, economic and safety risks of the breeder program[15]:

- o The core of EBR-1 melted down and was reported to have nearly exploded due to an autocatalytic reactivity effect;
- o The Fermi reactor suffered a meltdown of two fuel ducts;
- o EBR-II was to be operated as a power plant but has operated at only about one-half of its design power level;

o West Germany's Kalkar breeder (300 MW) was nearly cancelled due to financial problems.

Although the DEIS (p. 45) refers to the "excellent breeder progress in France", it should be noted that France's breeder development program is decades from making any significant addition to the country's nuclear power supply. One small pilot plant (Phenix, 250 MW) is in operation. Even the Superphenix (1200 MW) is not a prototype for commercial breeder reactors. Yet another still larger plant will be needed to demonstrate commercial power production. A recent report by the France's Groupement de Scientifiques d'Information sur l'Energie Nucleaire (Nucleonics Week, March 12, 1981) noted that the costs of the Superphenix have grown from original estimates of $400 million in the early 1970's to $2.2 billion in 1981. The study concluded that the Superphenix posed serious technical hazards and economic uncertainties and attacked efforts to claim the Superphenix safe by simply extrapolating from operating experience at smaller prototypical breeders such as the 250 MW Phenix. The report further stated that no serious economic analysis of breeders has been done in France and that breeders may be decades from profitability.

The United Kingdom's Atomic Energy Authority has expressed hope that it will achieve a 50 percent plant capacity factor with its 250 MW Prototype Fast Reactor (PFR) at Dounreay, Scotland. If it does, the PFR will produce more electricity in 1981/82 than it has in 6 years (Nucleonics Week, March 9, 1981). In over 73 months the plant produced about one-third less power than the Phenix reactor in France produced in 1980 alone which corresponds to a lifetime plant factor for PFR so far of around 7

percent. Due to technical problems, PFR's potential maximum output has been cut by approximately 20 percent. PFR's poor performance, as explained by the Dounreay director Cliff Blumfield, was due to the fact that the British design "took more technical risks and more closely approximated commercial breeder design". The difference between PFR's performance and the output of France's Phenix was thought to be due to the substantial differences between the Phenix and commercial fast breeder reactors. (Phenix fuel elements are not full size and its modular boilers are very different from a commercial design.)

The DEIS states that concurrent development of other elements of the LMFBR fuel cycle (reprocessing, fuel fabrication, transportation, and waste management) is recognized as essential to any assessment by the nuclear industry of readiness to deploy breeders in significant numbers. Therefore, successful commercialization of the breeder reactor is dependent on the progress of work in other areas of the LFMBR fuel cycle. The DEIS does not provide sufficient information on the status of these other important components of the fuel cycle and fails to adequately note the substantial research, development and demonstration work that is still required to bring them to a state of commercial availability. For example, reprocessing of spent breeder reactor fuel requires extensive engineering development, followed by experience at the pilot-scale plant. The high plutonium content of breeder fuels necessitates additional redesign for criticality control. These modifications should be demonstrated before proceeding to full industrial-scale breeder fuel reprocessing. Other components of the fuel cycle similarly require extensive developmental work.

IV. AVAILABILITY OF ALTERNATIVES TO THE LMFBR

Potential for Conservation

There is a serious failure in the DEIS to make a rigorous and objective evaluation of all reasonably available alternative energy resources. The report concludes that the breeder reactor program is the only alternative for meeting the goals of a healthy economy and decreased oil usage. However, the only alternatives discussed are fusion and solar electric systems on the basis that "other alternatives are either too small in potential (e.g., geothermal or expanded hydroelectric facilities) or too far off with uncertain development schedules (e.g., solar electricity or fusion)" (DEIS, p. F-6). The report further states that the only certain alternatives for electricity production on the scale required are coal and nuclear energy. As mentioned, this statement ignores conclusions by major national studies by the National Academy of Sciences (CONAES), the Solar Energy Research Institute, and the Harvard Business School which stressed the opportunities for reducing national dependence on imported petroleum by both conservation and switching to alternative technologies. The CONAES study concluded that "reducing the growth of energy demand should be accorded the highest priority in national energy policy" (CONAES, p. xiii).

DEIS statements on p. 32 and F-3 which dismiss the important contributions of conservation ignore the substantial impact of improved energy efficiency reported in recent studies. The study by the Solar Energy Research Institute* concluded that through increased energy efficiency, "the United States can achieve a full-employment economy and increase

worker productivity, while reducing national energy consumption by 25 percent." The study estimated about 20 - 30 percent of the reduced demand could be supplied by renewable resources (SERI, p. 1). "A strategy built around energy efficiency and the widespread use of renewable resources could result in virtual elimination of oil imports." (SERI, p. 1)

Conservation and the increased use of alternative energy resources (solar, geothermal, cogeneration, wind, small hydroelectric, biomass) are the focal points for California's long-term energy supply investment strategies. A detailed report on California's projected energy supplies and state-of-the-art energy demand forecasting methods by the California Energy Commission concluded that,

> "A concerted, but reasonable, acceleration of programs to channel public and private investment into conservation and alternative supplies would yield substantial additional benefits. Such an approach would, by the year 2000, more than quadruple the present contribution of alternative and renewable energy supplies in California. By expanding this state's already strong programs to eliminate energy waste, California could shave another 10 percent off its total energy use by the year 2000 equivalent to savings of 400,000 barrels a day of oil." (ET, 1981, p. 165)

California's existing conservation programs for electricity and natural gas are projected to save the equivalent of over 100 million barrels of oil per year by 2000 (ET, p. 187). Energy Tomorrow estimated that these savings and continued efforts to improve transportation efficiency can result in virtually zero growth in end-use energy demand over the coming 20-year period while allowing healthy economic growth. Moreover, when renewable and alternative energy sources, as well as conservation are considered, these supplies can furnish almost 22 percent of California's energy needs in 2000, equivalent to over 700,000 barrels of oil per day (p. 187).

Potential for Alternative Energy Resources

The DEIS' cursory dismissal of wind, geothermal, cogeneration, biomass, and hydroelectric as alternative energy sources to the breeder reactor, is unwarranted and violates NEPA's mandate that the DEIS fully explore alternatives. The DEIS ignores comprehensive studies, including studies done by DOE itself, that these sources are feasible, less environmentally disruptive than nuclear power, and will displace oil more rapidly than breeder reactors (see Appendices A and B). The DEIS' assertion that "other alternatives are too small in potential (e.g., geothermal or expanded hydroelectric facilities)" (DEIS, p. F-6), is simply unfounded. For instance:

1. Cogeneration

The market potential for cogeneration applications is quite large. DOE's own estimate is that cogeneration could provide 40,000 MW of electrical capacity by the year 2000.[16] General Electric Company, the leading manufacturer of cogeneration turbines, estimates 50,000 MW by the year 2000.[17] Resources for the Future, on the other hand, projects a possible total cogeneration electrical capacity of 134,000 MW by the end of the century.[18] The State of California has adopted a goal of installing 6000 MW of cogeneration by 1990.[19]

2. Geothermal

It has been estimated that there are sufficient geothermal resources in the U.S. to supply all of its future energy needs.[20] The State of California has adopted a goal of producing 5,000 MW of geothermal electricity generation by the year 2000.[21] The Energy Department has adopted a nationwide goal of 7,500 to 15,000 MW of anticipated geothermal contribution by 1990.[22] The National Academy of Sciences has estimated that with a national commitment the maximum potential realizable from geothermal energy could be just over 60,000 MW by the year 2010.[23]

3. Wind

As a near-term source of energy, wind energy development has become an increasingly attractive investment area. Based on extensive wind data studies prepared for the state, the California Energy Commission has identified 13,000 MW of wind resource potential, not including potential coastal offshore wind resources.[24] In addition, the state has adopted a goal of building 7,700 MW of installed wind power capacity by the year 2000.[25] Nationwide, DOE itself estimates that wind power could provide the United States with 60,000 MW of installed capacity by the year 2000.[26]

4. Small Hydroelectric

At the national level, DOE's own estimate is that small hydro could provide the United States with an additional 20,000 MW of electricity by the year 2000 increasing to 50,000 MW by the year 2020.[27] An even higher estimate is projected by the U.S. Army Corps of

Engineers. Based on an analysis of the watersheds of existing dams, the Corps estimated that "54,600 MW of additional electrical generating capacity is available for immediate development in existing dams."[28] The California Energy Commission estimates that about 2000 MW of small hydro remain to be developed at existing dams in California.[29]

Additional detailed information on the feasibility and availability of these technologies, as well as biomass, solar, and other sources, can be found in Electricity Tomorrow (Appendix B, pp. 203 - 298; see also, Appendix A). The DEIS should be revised to reflect this information, particularly DOE's own statements on the availability of these alternatives.

Energy R&D Allocations

The DEIS overstates the need for and economic potential of the breeder programs. In its initial evaluation of DOE energy R & D programs, at least two-thirds of the members of DOE's Energy Research Advisory Board (ERAB) agreed that the Clinch River Breeder Reactor has low urgency, low economic potential, low benefit-to-cost ratio and that funding should be reduced. Three-quarters of the ERAB members recommended that the "(breeder reactor) demonstration be delayed until a future time."[30]

The DEIS' understating potential contributions of conservation and alternatives and overstating the potential for nuclear programs, in particular the breeder, is reflected in the Energy Research Advisory Board's evaluation of DOE energy R & D programs. The Board noted imbalances in energy programs such as:

- o There is very heavy stress on electrical technology in FY 81, further accented in FY 82, although it is noted that fluid fuels constitute our principal vulnerability.

- o Similarly, within the electricity sector, federally sponsored nuclear programs are receiving a larger proportion of funding than the expected nuclear share of the United States energy mix during the next few decades.

- o Conservation, a very small fraction of the energy R & D budget in FY 81, is further and drastically reduced in FY 82, although it has so far contributed much more than supply augmentations in reducing our dependence on insecure oil imports.

The DEIS states, "A relatively vigorous path of LMFBR development is therefore prudent for the government to pursue, based on the promise of the LMFBR and the uncertainty over future energy events." (p. 46) However, the DOE's Energy Research Advisory Board concluded "construction of a demonstration plant in the early 1980s is not an urgent national priority. Sufficient coal and uranium supplies exist to satisfy projected levels of electrical demand for at least 40 years and possibly well beyond." The panel, in fact, recommended that demonstration of breeder technology be delayed until a future time.

In addition, although the DEIS argues that the cancellation of CRBR will result in the loss of staff resources and an investment of over $1 billion already incurred, it is necessary to weigh forward benefits of the program against forward costs. Current estimates of the total CRBR costs are approximately $3.2 billion (1981 dollars) making the forward costs $2 billion. (In comparison, the estimate in 1973 for the project was $700 million). The question arises whether the LMFBR program is receiving a larger portion of funding completely out of line with the expected nuclear share of future United States energy supply and to what extent this research investment will contribute to reducing the nation's dependency on foreign oil imports. As the three national studies cited in this report have concluded, improvements in energy efficiency have proven to be a more cost-effective means of meeting the nation's energy needs.

V. ENVIRONMENTAL IMPACTS OF THE LMFBR PROGRAM

There are several key environmental issues that are not adequately addressed in the DEIS:

- Safeguards and proliferation concerns, given the current status of materials accountability methods and institutions to control the use of nuclear materials,
- Uncertainties associated with health and safety risk estimates, (e.g., Class 9 accidents and acts of sabotage), and
- Major unresolved waste management issues.

Comments on specific sections of the DEIS are provided below.

1. Proliferation Concerns Associated with a Plutonium Economy Are Not Adequately Addressed

Proliferation risks would be extreme in a plutoniuim economy. With development of the breeder program large amounts of plutonium would circulate through the LMFBR system (reactor reprocessing, fuel fabrication) in forms requiring extraordinarily tight physical security. It has been estimated that more than 10 million kilograms per year of fissile plutonium would circulate in fresh fuel in a plutonium breeder-based nuclear economy.[31] Widespread access to this material would remove a major barrier to the construction of nuclear weapons. By making plutonium more readily available, these plutonium fuel cycles could cut down or even eliminate the lead time required for a political entity to build or use a nuclear weapon. As a result, decisions involving the deployment of plutonium recycle are intimately connected to the acceptability of safeguards to protect their use. A 1977 report sponsored by the Ford Foundation stated:

> "In our view, the most serious risk associated with nuclear power is the attendant increase in the number of countries that have access to technology, materials, and facilities leading to a nuclear weapons capability... If widespread proliferation actually occurs, it will prove an extremely serious danger to United States security and to world peace and stability in general."[32]

Moreover, a recent study by the American Physical Society stated, "Strict accountability of fissile material cannot be achieved practically throughout the entire fuel cycle."[33] The study recommended an evaluation of "safeguards advantageous" fuel cycles using low-enrichment uranium fuel. Of major concern are large plants in which nuclear materials accountability becomes an even greater problem. David Fischer, recently retired as International Atomic Energy Agency (IAEA) assistant director general and still consultant to the agency, said that IAEA safeguards experts concerned with the diversion of nuclear material must begin to consider the possible creation in the 1990s of large enrichment or reprocessing plants where a measurement of uncertainty of a half of percent could mean an uncertainty of 50 kilograms of plutonium either way (Nucleonics Week, April 9, 1981). He further stated (Nucleonics Week, March 9, 1981) that the accounting of nuclear materials is a slow process. Simply relying on accounting to find out whether a country has or has not made explosives may involve a delay of 30 days for the report to be sent and perhaps an additional 3 months by the time the report is analyzed and inspected. As David Fischer stated, "This is

not an ideal situation if you are dealing with large quantities of plutonium." NRC's safeguards director Robert Burnett (Nucleonics Week, April 13, 1980) similarly expressed concern about the level of attention being paid to safeguards: "We have not solved the nuclear materials accountability problem" --"there are significant materials differences that cannot be explained." He further remarked that if the United States moves to the use of commercial reprocessing and the use of mixed oxide fuels, "then the approaches available now are unlikely to be acceptable." He cited the case at Erwin, Tennessee's fuel fabrication facility of Nuclear Fuel Services as being totally unacceptable in failing to account for over 300 kg of uranium over 15 years.

The DEIS' discussion of international safeguards and institutional measures to address the risks of proliferation (pp. 167 - 169) fails to recognize these safeguards problems and fails to provide assurances that adequate control measures can be put in place. The DEIS refers to the President's Nuclear Nonproliferation Policy Statement of July 16, 1981, proposing to improve nonproliferation objectives by strongly supporting and continuing to work with the International Atomic Energy Agency. However, the report does not recognize that United States officials have recently expressed concern about the IAEA and have discussed the possibility of United States withdrawal from the agency and possible agency collapse (Nucleonics Week, November 5, 1981). The DEIS' failure to adequately address concerns regarding existing nonproliferation institutions and control measures is a major inadequacy of the report.

2. <u>The DEIS' Discussion of LMFBR Health and Safety Issues Is Seriously Inadequate</u>

The discussion on LMFBR safety technology relies heavily on information presented six years ago (WASH-1535 and ERDA-1535). It does not provide a complete up-to-date discussion of safety issues associated with the breeder raised, for example, by the National Research Council, the Nuclear Regulatory Commission, and the Council on Environmental Quality. The National Research Council (1979) summarized the unanswered questions remaining for LMFBR safety: whether inherent or engineered safety features eliminate or greatly reduce the probability of core melting; whether, if this probability cannot be reduced to desirable unlikelihood, engineered features can contain the consequences, and by what mechanisms a reasonable consensus can be reached that these objectives have or have not been met.[34]

In addition, the President's Council on Environmental Quality advised former NRC Chairman John Ahearne (March 1980) that Class 9 accidents should be fully discussed in future EIS' on NRC licensing actions. Since the NRC staff classified TMI as a Class 9 event, it is no longer possible to avoid full discussion of such accidents. The DEIS needs to address current information on Class 9 accidents and their implications for safety impacts related to breeder development. The consequences of Class-9 accidents in a breeder reactor could exceed the consequences calculated for the worst accidents in light water reactors.[35]

In addition, the DEIS fails to discuss the potential impacts of sabotage even though such large consequences may be the major contributors to public risk. An assessment of the true risks of the proposed project, as required by NEPA, is therefore not presented.

The CRBR risk assessment, patterned after the Reactor Safety Study (WASH-1400), concluded that CRBR risks are comparable to those from LWRs as characterized in WASH-1400 (DEIS, p. C-1). However, the CRBR risk assessment fails to acknowledge major weaknesses of the WASH-1400 study reported by the Risk Assessment Review Group to the Nuclear Regulatory Commission.[36] This review group was organized by NRC to clarify the achievements and limitations of WASH-1400, assess the peer comments and responses, and study the present state of risk analysis methodology.

The Review Group concluded that:[37]

- o Statistical analyses in WASH-1400 suffer from a spectrum of problems, ranging from lack of data on which to base input distributions to the invention and use of wrong statisical methods;
- o The peer review process of WASH-1400 was defective in many ways and the review was inadequate;
- o The lack of scrutability is a major failing of the report impairing both its usefulness and the quality of possible peer review;

- o The Review Group was unconvinced of the correctness of the WASH-1400 conclusion that initiating events (e.g., fires, earthquakes, human accident) contribute negligibly to overall risk; and
- o Error bounds in estimates of the probabilities of accident sequences are greatly understated due to an inadequate data base, questionable methodological and statistical procedures and inability to quantify common cause failures.

The Ford/Mitre study also found that "the WASH-1400 probability estimate could be low, under extremely pessimistic assumptions, by a factor of as much as 500" and that the expected number of cancers for a given accident "could be several times higher" than in WASH-1400.[38] This implies an upper limit risk 1500 - 3000 times the WASH-1400 median value, or 36 - 72 cancer deaths per reactor year. In addition, to perform an adequate risk assessment, the physical processes must be understood and correctly modeled and uncertainties properly taken into account. Such a complete assessment of the risk associated with the CRBR and other components of the breeder fuel cycle is not provided in the DEIS.

3. The DEIS Fails to Address Unresolved Waste Management Issues

The DEIS' discussion of waste management, one of the four environmental impacts of the breeder program addressed in the document, is inadequate. The DEIS' very framing of the waste disposal issue--the availability of a "generally accepted method" for handling radioactive waste (p. 173) is improper. By characterizing the issue this

way, the DEIS implies that there is an acceptable method for handling wastes. No method for the permanent disposal of waste exists, as DOE has admitted in its filings with the NRC in the waste confidence proceeding. (NRC Docket PR-50, 51.) Thus, from the outset, the DEIS' discussion of waste management is structured to minimize the significance of the issue.

The DEIS consistently understates the obstacles to developing an adequate waste management program. While the DEIS summarizes at length DOE's program, it fails to acknowledge the sharp dispute over the adequacy of the program and the conclusion of many that DOE's program is insufficient to assure that permanent, safe disposal of radioactive wastes will be developed in the foreseeable future. The inadequacies of DOE's waste management program are summarized in a recent consolidated filing submitted by the California Energy Commission; California Department of Conservation; the Attorney General of the State of New York; Illinois; Massachusetts; Minnesota; Ohio; Wisconsin; Delaware; and Ocean County and Lower Alloways Creek Township, New Jersey, in the NRC's waste confidence proceeding.* We have included this filing as Appendix C.

*The DEIS fails to discuss the ongoing modifications to its waste management program, President Reagan's plan to abolish DOE, and the impacts of these changes on developing a waste management program for the breeder reactor. As we and other states have pointed out in our filings, the inevitable results of these changes will be further delay in any resolution of the radioactive waste disposal problem. ("Statement of the California Department of Conservation and California Energy Commission Concerning the Impact of Recent Developments on a Commission Decision in This Proceeding", NRC Waste Confidence Proceeding, Docket No. PR-50, 51, December 18, 1981.)

Neither the technical nor the institutional deficiencies in DOE's waste management program, summarized in Appendix C, are addressed in the DEIS. For instance, while DOE's program is based on "the mined geologic repository strategy for disposal of commercially-generated high-level and transuranic radioactive wastes" (DEIS, p. 178), the scientific feasibility of isolating radioactive wastes from the biosphere for the extensive periods required to assure human safety has not been validated. (Appendix C, p. 5). The DEIS fails to acknowledge this lack of scientific verification.

The DEIS relies in large part upon DOE's "system approach" in concluding that problems with waste disposal are insignificant. (DEIS, p. 180.) However, as Appendix C points out:

> "DOE (and the industry) have adopted a systems approach to waste disposal--use of a series of natural and engineered barriers that supposedly provide a degree of isolation not possible for the natural systems alone. DOE fails to recognize that this approach is still hypothetical and needs to be scientifically verified with respect to the redundancy, effectiveness, and independence of a series of barriers that are still being conceptualized." (Appendix C, p. 6, f.n. 4).

The DEIS also fails to acknowledge the numerous gaps in present technical knowledge concerning permanent waste disposal. These technical gaps include:

a. Waste Rock interaction--There is no real understanding of the interaction of waste with host rock and therefore no assurance that the physical, chemical, and thermal effects induced by the presence of the waste will not cause unmanageable disruptions. (Appendix C, p. 7).

b. Hydrology--Little is known about water transport of radionuclides to the biosphere. (Appendix C, p. 7).

c. Selection of geological mediums--The DEIS asserts that "any of (the potential host rocks) can prove to be acceptable for the mined geologic repository" (DEIS, p. 185). Contrary to this assertion, none of the geological mediums under study have been shown to be technically capable of assuring safe isolation. Each medium under consideration is known to present serious, time-consuming, and possibly insurmountable problems. (Appendix C, p. 8).

d. Future climatic changes, shaft sealing and borehole plugging, monitoring, cannister degradation, waste form dissolution, reaction in the overpack region, rock mechanics, retrievability, seismic and tectonic activity, and waste packaging. (Appendix C). The DEIS addresses none of these problems.

The states' comments on DOE's presentation of its waste program in the NRC waste confidence proceeding are equally true for the DEIS' discussion of DOE's plans for handling wastes from the breeder reactor:

> "Given its lack of knowledge, DOE basically contends that the mere existence of its waste program is grounds for assurance. DOE resorts to speculation that it will successfully overcome all of these technical barriers in the near future, despite the lack of scientific knowledge after 25 years of study.
>
> Such statements do not disguise that these are important, existing data gaps, and that there is no assurance at this time that these gaps will be successfully filled in the future". (Appendix C, p. 9).

A third technical problem that the DEIS fails to adequately address is the state of DOE's mathematical models. (DEIS, p. 182). The models are used to compensate for uncertainties in technical knowledge. (DEIS, p. 182). However, the DEIS fails to acknowledge that the modelling is currently undeveloped, that there is no indication that it will be successfully developed, and that USGS has rejected reliance on models. (Appendix C, p. 10).

Other technical deficiencies in the DEIS include the failure to analyze how many sites would be needed for disposal of wastes and the failure to discuss the lack of evidence that sufficient sites for handling wastes will be found. (Appendix C, pp. 10-11). There is also a failure to provide information on how long the wastes will be stored or that they can be stored safely for the requisite period. Finally, the DEIS alludes to "predetermined criteria" for the waste disposal repository. (DEIS, p. 181). However, environmental, site selection, and performance criteria for a repository are still speculative, as is a demonstration that the criteria can be met. (Appendix C, pp. 12-13).

One of the most important studies on waste management, the Interagency Review Group* report, concluded that the resolution of social, political, and institutional concerns is necessary to permit the orderly implementation of a nuclear waste program and that "resolution of institutional issues may well be more difficult than

*The Interagency Review Group on Nuclear Waste Management was established in March 1978 by President Carter to make recommendations for the establishment of an integrated and credible nuclear waste management policy.

finding solutions to remaining technical problems". (Appendix C, pp. 13-14). Nevertheless, the DEIS' discussion of institutional obstacles to DOE's waste management program is almost nonexistent. (DEIS, pp. 180, B-3).

There is no mention whatsoever of the numerous problems on the federal level which have prevented a satisfactory waste disposal program--DOE's failure to maintain a consistent program, the substantial changes in program goals with each successive administration, the proliferation of decision-makers in the federal government, and the division of jurisdiction in Congress over waste disposal. (Appendix C, pp. 14-16).

State and local concerns over waste disposal are an equally important issue. In this area, the DEIS fails to analyze the problems at all, and simply asserts that DOE is "committed to providing an effective role" for states and local governments and Indian tribes (DEIS, p. 180). Clearly, this cursory statement does not present the analysis required by NEPA. The states' review of DOE's presentation of this issue in the NRC waste confidence proceeding applies equally well to the DEIS:

> "As DOE itself acknowledges, the public is very concerned about the consequences of building repositories, and many state and local governments, through legislation or otherwise, have expressed opposition to accepting repositories. Every government effort to date to select particular sites has been opposed. Since dozens of candidate sites must be selected for testing and evaluation, the acknowledged public opposition creates doubt that repositories actually will be established".

"DOE's response is that it will engage in consultation with affected state and local governments and that objections therefore will disappear. This approach, however, is naive, because discussions are not likely to override strong local objections to the siting of the repository. Moreover, DOE has consistently failed to adhere to its purported policy of 'consultation and concurrence'. DOE's promise in its filings to deal with states is suspect, given its failure to even inform Wisconsin of its disposal plans for that state during this proceeding. As Wisconsin says, DOE deliberately concealed from the state a report showing that the state was the primary candidate for exploration of granite formations."

"On an equally fundamental level is DOE's pervasive inability to deal with the concept of public trust and participation. DOE (and the NRC Working Group) continues to view the public as a special interest group whose support is desirable but unnecessary. DOE has no meaningful internal mechanism for instilling public confidence and this limitation will most likely effectively frustrate site selection and development. DOE fails even to acknowledge the existence of a credibility problem, let alone begin the arduous task of dealing with it. Instead, DOE simplistically argues that the public should just accept whatever risks DOE determines should be accepted from radioactive wastes. Such an approach clearly does not present a factual basis for concluding that institutional barriers will be overcome." (Appendix C, pp. 16-17; cites omitted).

In sum, the DEIS fails to address the many technical and institutional issues associated with waste disposal for the breeder reactor program. Had these issues been adequately addressed, the DEIS could not have concluded, as it does, that "[t]here does not appear to be any constraint on the LMFBR Program imposed by disposal requirements for high-level or transuranic radioactive wastes" (DEIS, p. 174) and that waste management will not have a significant environmental impact. (DEIS, p. 7) We therefore recommend that the DEIS be withdrawn until a complete analysis of this crucial issue is performed and that the federal government not add, through the breeder reactor

program, to the existing waste disposal problem until the technical, institutional, social, and political barriers to waste disposal are significantly diminished.

REFERENCES

1. Remarks of Victor Gilinsky, Commissioner, U.S. Nuclear Regulatory Commission before the World Nuclear Fuel Market's International Conference on Nuclear Energy, October 27, 1981, Washington, D.C., "The New Policy for Nuclear Power."

2. Final Report to the Committee on Nuclear and Alternative Energy Systems, Energy in Transition 1985 - 2010, 1981; Cited herein as CONAES.

3. Energy Future, Report of the Energy Project at the Harvard Business School, edited by Robert Stoubaugh and Daniel Yergin, 1979; Cited herein as Harvard Business School Study.

4. The Solar Energy Research Institute study, A New Prosperity: Building a Sustainable Energy Future, 1981; Cited herein as SERI.

5. S. Schurr, J. Darmstadter et al., Energy in America's Future: The Choices Before Us, prepared by the Resources for the Future National Energy Strategies Project; John Hopkins University, Press, 1979; Cited herein as RFF.

6. A Study Group, Hans Landberg, Chairman, Energy: The Next Twenty Years, sponsored by the Ford Foundation, Dallinger Publishing Co., 1979.

7. National Journal, "Utilities Paying Price for Counting on Demand Growth that Never Came," October 17, 1981.

8. M. Ross and R. Williams, Our Energy Regaining Control, 1981, McGraw - Hill Book Co., p. 135

9. NUEXO, Monthly Report on the Uranium Market, October 1981.

10. DOE, NASAP Report, DOE/NE-0001, Executive Summary, June 1980, p. 11.

11. Report of the Research and Development Panel, Energy Research Advisory Board, "Federal Energy R&D Priorities", November 1981, p. 56.

12. Energy Daily, "Duke Power Hesitate on Cherokee Units," March 2, 1981.

13. NUEXO Special Report, Uranium: A Market in Transition, June 1981

14. NUEXO Special Report, Uranium: A Market in Transition, June 1981.

15. R. Webb, The Accident Hazards of Nuclear Power Plants, The University of Massachusetts Press, Amherst, 1976.

16. Colin Norman, "Renewable Power Strikes Financial Interest," Science, June 26, 1981, p. 1480.

17. "Energy Conservation Spawning A Billion Dollar Business," Business Week, April 6, 1981, p. 60.

18. RFF, p. 176.

19. Governor Edmund G. Brown, Jr., Cogeneration: Energy for the 80's and Beyond, Conference Proceedings, June 1981, p. 10.

20. Richard T. Sheahan, Alternative Energy Sources, An Aspen Publication, Aspen Systems Corporation, Rockville, Maryland, London, 1981, p. 188.

21. California Energy Commission, Geothermal Energy: Opportunities for California Business, September 1981, p. 3.

22. U.S. Department of Energy, Geothermal Energy, Government Printing Office, Washington, D.C., 1980, p. 15.

23. CONAES, pp. 417-418.

24. California Energy Commission, Energy Tomorrow: Challenges and Opportunities for California, p. 102; California Energy Commission, Electricity Tomorrow: 1981 Final Report, January 1981. p. 258; California Energy Commission, Nontraditional Energy Technologies: Issues and Actions, Dec. 1980, p. 8.

25. California Energy Commission, Wind Energy Program Progress Report, P500-80-001, Jan. 1, 1980, p. 1; CEC, Wind Energy, Investing in Our Energy Future, April 1981, p. 7; CEC, A Guide to Financial Assistance for Wind Energy, P500-81-014, March 1981, p. 4.

26. Id.

27. DOE, Environmental Readiness Document: Small-Scale Low Head Hydro, Sept. 1978, p. 5; John Huetler, Jr., "Small-Scale Hydroelectric Power: The Community-Size Renewable Energy Source," Community Energy Self-Reliance Proceedings of the First Conference on Community Renewable Energy Systems, SERI/CD-354-421, Aug. 1979, p. 149; Richard Corrigan, "With an Off-Handed Push from Congress, Speculators Plunge Into Small Hydro," National Journal, May 30, 1981, p. 977.

28. Norman M. Clapp, former administrator, Rural Electrical Administration, "Take A New Look At Small Hydro," Public Power, May-June 1979, p. 30.

29. California Energy Commission, Energy Futures For California: Two Scenarios, 1978 - 2000, P300-81-005, Sept. 1980, p. 31.

30. Report of the Research and Development Panel, Energy Research Advisory Board, "Federal Energy R&D Priorities," November 1981, Appendix D., p. 6.

31. M. Ross and R. H. Williams, Our Energy Regaining Control, McGraw Hill Co., 1981.

32. The Ford/Mitre Study Nuclear Power: Issues and Choices, Cambridge, MA, Ballinger Publishing Co.

30. Report of the Research and Development Panel, Energy Research Advisory Board, "Federal Energy R&D Priorities," November 1981, Appendix D., p. 6.

31. M. Ross and R. H. Williams, Our Energy Regaining Control, McGraw Hill Co., 1981.

32. The Ford/Mitre Study Nuclear Power: Issues and Choices, Cambridge, MA, Ballinger Publishing Co.

33. American Physical Society, "Report to the APS by the Study Group on Nuclear Fuel Cycles and Waste Management," Reviews of Modern Physics, Vol. 50, January 1978, p. 293.

34. CONAES, p. 292.

35. CONAES, p. 291.

36. H. W. Lewis, Chairman, Risk Assessment Review Group Report to the U.S. Nuclear Regulatory Commission, NUREG/CR-0400.

37. Id., p. viii, ix.

38. CONAES, p. 627.

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APPENDIX A

ENERGY TOMORROW
CHALLENGES AND OPPORTUNITIES FOR CALIFORNIA

1981 BIENNIAL REPORT TO THE GOVERNOR AND THE LEGISLATURE

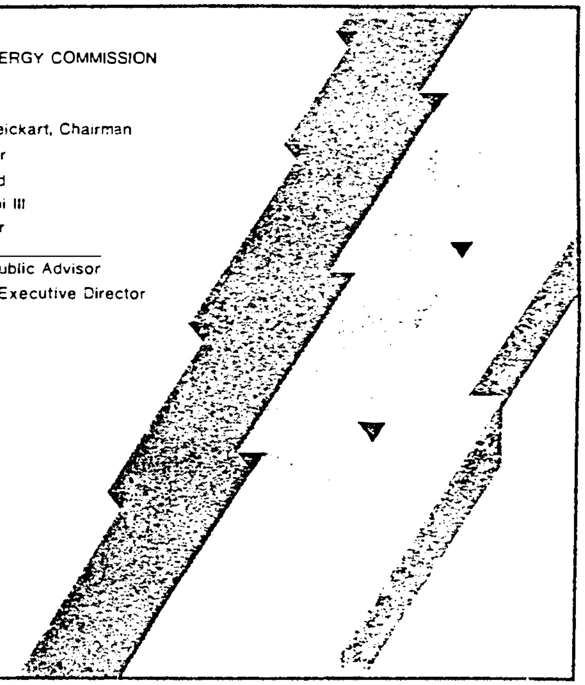
APPENDIX B

Electricity Tomorrow

1981 Final Report to the Governor and the Legislature

January 1981

CALIFORNIA ENERGY COMMISSION



Appendix C

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of: Proposed Rulemaking on Storage Disposal of Nuclear Waste, 10 CFR Parts 50 and 51 (Waste Confidence Rulemaking)	)	PR-50, 51 (44 FR 61372)

CONSOLIDATED STATEMENT OF THE STATE GROUP

I. INTRODUCTION

This consolidated Statement is submitted on behalf of the California Department of Conservation ("CDC"), California Energy Commission ("CEC"), Illinois, Massachusetts, Minnesota ("Minn."), Attorney General of the State of New York ("NYAG"), Ocean County and Lower Alloways Creek Township (New Jersey), Ohio, Wisconsin and Delaware, pursuant to the Commissions' Second Prehearing Memorandum and Order, dated November 6, 1981. The remaining participants consolidated in Group 3, listed on p. 7 of the Memorandum and Order, have not joined in this Statement.

There is no factual basis today for confidence either that nuclear waste will be safely disposed of by the necessary time frame or that it will be safely stored until it is disposed of safely. Furthermore, because a permanent, safe solution to the waste management problem will not be available when needed, both the California Energy Commission and the Attorney General of the State of New York support a policy of ceasing to issue new construction permits for nuclear power plants until the technical, institutional, social and political barriers are significantly diminished.

II. THE COMMISSION MUST DETERMINE WHETHER OR NOT IT IS NOW CONFIDENT, ON THE BASIS OF EXISTING FACTS, THAT THERE WILL BE SAFE DISPOSAL OF NUCLEAR WASTE.

At issue is not whether radioactive wastes produced by nuclear facilities "can" be disposed of safely but whether they "will be" safely disposed by a specified date. 44 Fed. Reg. 61372-73 (October 25, 1979) (emphasis added).[1] The mere conclusory statements by DOE that there can be safe waste disposal are an insufficient basis for the NRC to conclude that it has assurance that wastes will be disposed of safely.

DOE has not met its burden of proving that a factual basis exists. Its filings consistently ignore past events, do not show reasonable facts existing today for assurance that waste disposal will occur, and instead speculate that disposal can, may, or should occur. The decision to abolish DOE makes DOE's position even more illusory.

In order to make a finding of confidence at this time, the Commission, among other things, would have to conclude,

1. At a minimum, the legal standard for the NRC to use is whether it has "reasonable assurance" that wastes will be disposed of safely. While participants have used differing phrases to describe this burden, all states joining in this filing agree that DOE's filings do not satisfy the "reasonable assurance" standard.

from facts existing today, that all technical and political-social ("Institutional") problems will truly be resolved by a specified date. However, there is no basis for reaching that conclusion. Indeed, even if safe disposal is technically feasible, in the sense that no known scientific principle would prevent its being achieved, nonetheless, the Commission could not find confidence because (i) many repository sites are needed but no site has been found which would be suitable, and questions are known to exist about the suitability of all the various regions and media under consideration; (ii) it is possible that technical solutions to outstanding problems will not be found by the specified date; and (iii) institutional problems could prevent the establishment of any repositories by the specified date.

Instead of discussing long-term safety, DOE frames its case in terms of whether it will succeed in getting one repository licensed by the NRC by the year 2007. But that question misses the point. First of all, many repositories will be needed, not only one. Secondly, even if a license is obtained, that does not assure establishment of a repository because public opposition could prevent it. Further, the mere existence of a license does not establish that the repository will function without accident for the necessary time period. Events at Three Mile Island, Brown's Ferry and Diablo Canyon demonstrate this point.

Actual facts, rather than beliefs, are required in determining confidence, particularly in view of the past history of waste disposal efforts ("an unbroken history of failure"). (CEC SP 30; see also Illinois SP 4-5; Minn. SP, Dr. Abrahamson's comments 13-20.) Additionally, the nature of the problem--extremely long-term danger to many future generations--calls for the highest care in reaching conclusions in this proceeding.[2]

DOE and the industry groups say erroneously that because research is planned or in process we can be confident today that safe disposal will be achieved. However, for years government officials have misled the public with assurances that the technical solutions were at hand. The truth is that we do not know today whether the ongoing research will remove all obstacles; instead, it may fail to

2. Disposal of nuclear waste presents unique problems because never before has any society had to devise plans to assure safety so far in the future, and never before have government agencies had to devise regulations to assure such safety. Thus, it is more than natural to expect that errors will occur in the technology, and that the regulations themselves will be less than perfect. Indeed, the U.S. Geological Survey ("USGS") has noted that waste disposal "requires new and hitherto untried technology" which "typically" involves "initial failure of some components to perform as originally conceived, discovery of new problems to be resolved, and reconsideration of design concepts." USGS SP 5.* This view is in accord with that taken by the NRC in its draft technical criteria for regulating disposal, that building a repository "is a new human enterprise," and it is therefore "reasonable to expect that, whatever the care exercised and however advanced the techniques, mistakes will occur, improved technologies developed, better designs created, and operational procedures improved." 45 Fed. Reg. 31398, col. 2 (May 13, 1980). (* "SP" refers to the participants' Statements of Position and "CS" references the Cross-Statements of Position.)

do so, or even uncover new uncertainties or problems making the task still more difficult to achieve. Confidence cannot be predicated on hope or blind technological optimism. Until the research has been completed and has successfully resolved all the technical difficulties, it is premature even to talk about confidence.

III. THERE IS NO FACTUAL BASIS TODAY FOR CONFIDENCE THAT TECHNICAL BARRIERS TO THE SAFE DISPOSAL OF WASTE WILL BE SUCCESSFULLY OVERCOME.

A. The scientific feasibility of isolating radioactive wastes from the biosphere for the extensive periods required to assure human safety has not been validated.

A key factor in the states' position that there is no present, reasonable assurance that technical barriers to safe waste disposal will be surmounted is the lack of scientific verification of the geologic repository concept. (CEC SP 6.) Actual assurance that geologic repositories can isolate radioactive wastes requires:

> "[C]omparing the results of field experiments to the model predictions and modifying the models. . . . The experiments must, of course, be carried out under conditions representative of those inside a loaded repository; that is, in-situ. It is only under these circumstances that the isolation hypothesis can be validated and reasonable assurance achieved." (CEC SP 7; see also NYAG SP 60; Wisconsin SP 8; Delaware SP 6.)

None of the waste experiments to date have utilized a vigorous scientific hypothesis testing and model verification method, and certainly no in-situ test experiments have been performed which demonstrate verification of the geologic repository concept (CEC SP 12; Appendix C; see also Wisconsin SP 3-4).

DOE admits that in-situ testing is necessary to assure adequate site characterization and verification and to verify the models used for performance assessment. (DOE CS II-143.) However, in this area as in others, DOE looks to additional "planned in-situ tests to provide sufficient data" (DOE CS II-140). DOE thus admits that concept feasibility has not been proven,[3] and that its optimism that it will be shown is dependent upon successful completion of as-yet unperformed in-situ experiments.[4]

B. The numerous gaps in present technical knowledge concerning permanent waste disposal prevent a finding of confidence at this time.

Every filing in this proceeding identified many generic uncertainties and data gaps in the technology for waste

3. The IRG report recognized that concept feasibility for geologic repositories is unproven:

"The feasibility of safely disposing of high level waste in mined respositories can only be assessed on the basis of specific investigations at and determinations of suitability of particular sites." (Reference 13, CEC SP 8.)

4. DOE (and the industry) have adopted a systems approach to waste disposal--use of a series of natural and engineered barriers that supposedly provide a degree of isolation not possible for the natural systems alone. DOE fails to recognize that this approach is still hypothetical and needs to be scientifically verified with respect to the redundancy, effectiveness, and independence of a series of barriers that are still being conceptualized. (CEC SP 45.)

disposal. These gaps preclude assurance at this time that technical problems with waste disposal will be overcome. (NYAG SP 77-101; CEC SP 6-12; Appendices A, B and C; CDC SP 5-8; CDC CS 36-38.) It is impossible to even list all the existing data gaps in the limited space allowed for this summary. However, some of the most important data gaps and uncertainties are:

1. Waste-rock interactions--USGS has stated that "the uncertainties associated with hot wastes that interact chemically and mechanically with the rock and fluid system appear very high" (NYAG SP 79; CDC CS 3). DOE acknowledges that the effect of the heat emanating from the wastes on the surrounding rock of a repository is "a major unknown geologic factor (presenting) the most difficult engineering uncertainties." (NYAG SP 79.) One participant has described in detail the gaps in knowledge that prevent any understanding of the interaction of waste with host rock and the resulting lack of assurance that the physical, chemical, and thermal effects induced by the presence of the waste will not cause unmanageable disruptions. (NYAG SP 78-84.) It is simply not known if any site will be able to perform its function given the heat and radiation being emitted by the waste. (NYAG SP 78-84; see also CEC SP 10.)

2. Hydrology--DOE admits that "knowledge of groundwater hydrology, is perhaps, the most important requirement for understanding the long-term behavior of a mined geologic

repository." (DOE SP II-76.) Nevertheless, little is known about water transport of radionuclides to the biosphere (CDC SP 15-17; CDC CS 13-15, 18, 20-21; CEC SP 10, 50-55). As USGS has said:

> ". . . The need for such data severely taxes both the available data base and the technology for generating it. Most of the requisite data are presently unavailable; most of the available data have such large error limits that their usefulness in predictive models is limited." Circular 779, pp. 8-9.

3. Selection of geologic medium--While salt, shale, basalt, and granite are all under study as potential repository media, none have been shown to be technically capable of assuring safe isolation. Each medium under consideration is known to present serious, time-consuming, and possibly insurmountable problems which leaves the possibility of achievement within the requisite time frame speculative. (NYAG SP 84-92; CDC SP 9-10, 24-15; CDC CS 3, 6, 33-36; see also Delaware SP 5.)

4. Future climatic changes--It remains to be established that repositories can be located to withstand future climatic changes such as re-glaciation or significant increases in precipitation or surface erosion. (NYAG SP 47; CDC SP 12-13; CDC CS 10-12.)

5. Shaft sealing and borehole plugging--There is no established way to seal a repository so as to prevent radionuclide release to the biosphere for the necessary

period of time. (CEC SP 10; NYAG SP 99; CDC SP 19-23; CDC CS 25-29.) DOE has termed the sealing problem a "key unknown" (NYAG SP 99) but there is no consensus that the technology which is currently anticipated will provide adequate seals for even a few decades. (Id. 99.)

6. Monitoring--While DOE believes that a monitoring system should be developed to operate for a few centuries (NYAG SP 100), DOE's filings ignore the lack of equipment and methodology for monitoring the repository after closure. (Id.; DOE SP II-280; CDC SP 18-19; CDC CS 23-27.)

Given its lack of present knowledge,[5] DOE basically contends that the mere existence of its waste program is grounds for assurance. DOE resorts to speculation that it will successfully overcome all of these technical barriers in the near future, despite the lack of scientific knowledge after 25 years of study. (DOE SP I-5; CEC SP 10-11, 46.) Such statements do not disguise that these are important, existing data gaps, and that there is no assurance at this time that these gaps will be successfully filled in the future. (CEC SP 46.) DOE's abolishment makes its representations regarding the future success of its waste program even emptier.

5. Other identified knowledge gaps include cannister degradation (CEC SP 50), waste form dissolution (CEC SP 52), reaction in the overpack region (CEC SP 53), rock mechanics (CEC SP 54), retrievability (CDC SP 23-24; CDC CS 30-32), seismic and tectonic activity. (NYAG SP 46; CEC SP 10), and waste packaging (Illinois SP 30.)

C. Necessary mathematical modeling of repository performance is undeveloped.

Because geologic and other scientific data are unavailable, DOE wants to use computer modeling to demonstrate the validity of the geologic waste concept and wants to have the Commission find confidence based on these models and on results of future modeling studies. There is no clear indication of whether modeling will be successful or whether it can be succesfully achieved during the necessary time frame. (CDC SP 4.) And, there is no valid basis for assigning numbers to represent the probability of an earthquake, human intrusion, re-glaciation or other repository failure many years in the future. USGS, in its Preliminary Statement of April 15, 1980 (pp. 11-12), rejected reliance on models, and insisted on hard data from site-specific investigations. The models are not based on detailed site-specific information, and therefore, are not subject to verification. (CDC SP 20.) In any event, DOE concedes that even the models already cited will not be available for a number of years. (DOE SP II-203, 219, 222.) Simply having an extensive program for improvement of models is not evidence of confidence now that the far-field predictions will be more accurate. (CDC SP 20.)

D. There is no basis for confidence that sufficient sites will be found.

DOE says that as many as eight repositories would be needed if salt or shale is used as the medium. (DOE SP

II-289.) If ultimately eight sites are needed, dozens of sites meeting all the technical criteria must be located so that in-situ testing can begin. Such testing will likely discover problems with at least some of the sites. For example, the Salt Vault site in Lyons, Kansas was abandoned after a decade of testing, when it was finally found to be unsuitable. (NYAG SP 61.) Also, extra repository sites are needed in case of a need to quickly transfer the nuclear waste from an existing repository which has proven unsatisfactory.

There is simply no basis for confidence that dozens of sites meeting all the technical criteria will be found. The vague assumptions that the expanded National Waste Terminal Storage Program, because it includes a larger area for consideration, provides the confidence necessary to believe that the timetable will be met, is unacceptable. The site selection process has not even been properly started yet, and therefore, cannot possibly demonstrate confidence now that a repository will be available by 1997-2006. (CDC CS 33-36.) Indeed, DOE and USGS acknowledge that unknown deficiencies may exist in many of the regions under consideration and that knowledge about all the regions is insufficient to project the location of multiple suitable sites. (NYAG SP 65-67; NYAG CS 42-45.)[6]

6. Moreover, even if dozens of sites are found initially, many of them may be rendered unsuitable during in situ testing, because non-destructive testing methods have

Footnote continued on next page

E. DOE has not shown, and does not even claim, that disposal will be safe for the necessary period.

Nuclear waste, as DOE admits, must be isolated for up to one million years. (NYAG SP 30.) However, DOE's filing predicts isolation for only 10,000 years, only 1 percent of the time for which isolation is needed for safety, by DOE's own admission. (NYAG SP 30.) Industry argues that nuclear waste will be truly hazardous for a mere few hundred years, ignoring that some elements have half lives of hundreds of thousands of years. In fact, a chart submitted by the utilities shows that spent fuel will be more toxic than uranium ore for about 40,000 years. (Doc. 3, p. 2-8 of UNWMG-EI SP.) Another source cited by industry says that some of the waste products remain hazardous for millions of years. (NYAG CS 10-11.) DOE has failed to provide any assurance that its program will provide protection for that period of time and, in fact, admits that it has no plans to ensure such isolation. (<u>See also</u> CDC SP 5-6.)

F. Environmental, site selection, and performance criteria for a repository are speculative as is a demonstration that the criteria can be met.

Several participants have pointed out that establishment of environmental, site selection, and performance

---

not been demonstrated. (NYAG SP 63-64.) And, sites surviving that hurdle may be breached during excavation, because there too non-destructive technology has not been developed. (NYAG SP 96.) Therefore, sites which are otherwise safe may be rendered unsuitable before a repository can be established.

criteria for a repository and demonstration that these criteria will be satisfied, are necessary for a reasonable assurance that safe waste disposal will be available. (Minn. SP 4; CDC SP 6; Illinois SP 2.) EPA has not yet published even its proposed environmental criteria for disposal of high-level wastes. (<u>Id.</u>) NRC has admitted that there is insufficient earth science knowledge to set forth general site acceptability criteria, and that therefore it may be necessary to determine suitability on an <u>ad hoc</u> basis for each tentative site. (Minn. SP 5.) While NRC has proposed technical criteria (46 Fed. Reg. 35280-96, July 8, 1981), the criteria are not yet final. The absence of final regulations and sites to compare them with precludes confidence at this time. NRC is also responsible for issuing performance standards. While the NRC has identified preliminary technical performance criteria (Minn. SP 6), DOE's filings ignore these requirements and provide no assurance that they will be met. (Minn. SP 7-11.)

IV. INSTITUTIONAL BARRIERS PREVENT A FINDING OF CONFIDENCE THAT THERE WILL BE WASTE DISPOSAL.

A. Unresolved institutional issues are as great a hindrance to a finding of confidence as technical obstacles.

There is no basis for confidence that institutional problems can be resolved. (NYAG SP 68-75; Ohio SP 15; Wisconsin SP 2; Minn. SP 5, and Dr. Abrahamson's comments 23-30.) The IRG report concluded that the resolution of social, political, and institutional concerns is necessary to permit the orderly implementation of a nuclear waste program and that "resolution of institutional issues may well be more difficult than finding solutions to remaining technical problems." (IRG, p. 87; NYAG SP 68-69.) DOE has acknowledged that "less confidence can be placed in assessment of [institutional] impacts on the repository program" than technical issues (DOE SP III-37) and that it is "possible that unanticipated or unresolved issues of concern at the State or local level could cause prolonged perturbations in the schedule." (DOE SP III-31.) The states' submittals (and indeed, almost all non-industry and non-federal government filings) have pointed out that DOE's blithe conclusion that institutional concerns can be resolved ignores reality and presents no factual basis for confidence that they _will_ be resolved.[7]

B. Institutional problems at the federal level are a significant obstacle precluding a finding of confidence.

The federal government's own handling of the waste disposal problem precludes finding assurance that waste disposal will be available. DOE, the lead federal agency

7. Virtually all the institutional factors cited by the states in their filings as precluding confidence that there will be safe storage of waste remain. President Reagan's support for reprocessing shows that, once again, a change in administrations has caused a change in the basic objectives of the nation's waste disposal program. Bitter struggles continue over the form and goals of waste disposal legislation, particularly with regard to state government and local participation in the program.

responsible for the waste disposal program, suffers from disjointed project management. (CEC SP 19-20.) DOE has failed to maintain a consistent program and objectives, due at least in part to the fact that the program is amenable to drastic change with each successive administration and that Congress has yet to take action to provide stability to the program. (Ohio SP 5-11.) The overall federal government management structure is inadequate (Wisconsin SP 4), characterized by a disorganized proliferation of decision-makers (at least six other agencies in the Executive Branch alone compete with DOE for jurisdiction over waste disposal) (CEC SP 20); disagreement among these decision-makers (CEC SP 21-22); and inefficient coordination of the decision-makers' activities. (Ohio SP 10; CEC SP 20.)[8]

In addition, there is the continuing institutional uncertainty in presidential input, as illustrated by the succession of presidents with differing waste management policies. (Ohio SP 6.) Congress, through its budgetary and statutory authority, is obviously also essential to timely implementation of an effective waste disposal solution. Jurisdiction in Congress over waste is split among numerous committees (Wisconsin SP 5) and no bill establishing a national program has passed. (Ohio SP 8-9.) Most importantly, significant changes in congressional

8. Participants have also pointed to the repeated failure of the AEC, ERDA, and now EPA and DOE to meet their own timetables. (Ohio SP 10; Vermont SP 2.)

membership occur regularly, causing an ever-changing set of goals (and legislation). DOE filings ignore these political obstacles. (Ohio SP 9.)

C. State and local concerns over waste disposal and the federal government's consistent failure to deal with them prevent a finding of confidence.

As DOE itself acknowledges, the public is very concerned about the consequences of building repositories, and many state and local governments, through legislation[9] or otherwise, have expressed opposition to accepting repositories. Every government effort to date to select particular sites has been opposed. Since dozens of candidate sites must be selected for testing and evaluation, the acknowledged public opposition creates doubt that repositories actually will be established. (NYAG SP 69-75; CEC SP 26-28; Ohio SP 13; Minn. SP 5.)

DOE's response is that it will engage in consultation with affected state and local governments and that objections therefore will disappear. (DOE SP V-19.) This approach, however, is naive, because discussions are not likely to override strong local objections to the siting of a repository. (NYAG SP 74; Ohio SP 15-16; Minn. SP, Dr. Abrahamson's comments, p. 30.) Moreover, DOE has

9. By October 1979, some 19 states had enacted bans or moratoria on the siting of a nuclear waste repository. (CEC SP 26.) Almost 40 states have either considered or taken some action concerning nuclear waste disposal. (Ohio SP 13.)

consistently failed to adhere to its purported policy of "consultation and concurrence." DOE's promise in its filings to deal with states is suspect, given its failure to even inform Wisconsin of its disposal plans for that state during this proceeding. (Wisconsin Supplemental Statement, dated October 10, 1980.) As Wisconsin says, DOE deliberately concealed from the state a report showing that the state was the primary candidate for exploration of granite formations. (Id.)

On an equally fundamental level is DOE's pervasive inability to deal with the concept of public trust and participation. DOE (and the NRC Working Group) continues to view the public as a special interest group whose support is desirable but unnecessary. DOE has no meaningful internal mechanism for instilling public confidence and this limitation will most likely effectively frustrate site selection and development. (Vermont SP 3.) DOE fails even to acknowledge the existence of a credibility problem, let alone begin the arduous task of dealing with it. (CEC SP 30.) Instead, DOE simplistically argues that the public should just accept whatever risks DOE determines should be accepted from radioactive wastes. (DOE SP II-14; NYAG SP 73.) Such an approach clearly does not present a factual basis for concluding that institutional barriers will be overcome. (Minn. SP 5-6.)

V. THERE IS NO BASIS FOR CONFIDENCE THAT SAFE DISPOSAL WILL BE IMPLEMENTED BY A GIVEN DATE.

Even if it could be said with confidence that safe disposal will be achieved ultimately, there is no basis for confidence that it will be achieved by any given date. This is because there is no way of knowing when, if at all, the required number of repository sites meeting all the technical requirements will be found, verified through in-situ testing, and accepted by state and local governments. It also cannot be known when, if at all, ongoing research will furnish satisfactory answers with respect to the existing data gaps or known technical problems. DOE itself, in commenting on a report issued by the General Accounting Office in June 1979 on the need for spent fuel storage facilities, said that it was not then possible to develop specific time frames for the final disposal of spent fuel. (NYAG SP 36.) The American Nuclear Society says that the timing of waste disposal is a "political question" and that under certain political assumptions--such as "reductions in funding, and policy changes"--the date of implementation would be later than is projected by DOE in this proceeding. (ANS SP, p. 3 and fn.)

USGS also recognizes that no date can be estimated. In its Statement of Position, as in its Preliminary Statement of April 15, 1980, USGS points to all the research that must still be done in so many areas, and says it is "unable to estimate when [waste] disposal will be available" because

such prediction "will be imprecise and premature until many of the key issues identified in this Statement have been addressed." (USGS SP 4, 29.) "From a technical standpoint," adds USGS, estimating a date for waste disposal is impossible because "new and hitherto untried technology" will be needed, and initial failures are therefore likely. (Id. at 5.) "How much time should be allowed for such contingencies is not clear." (Id.) Estimating a date is also impossible, says USGS, because of institutional unknowns. (Id.)

VI. THERE IS NO BASIS FOR CONFIDENCE THAT NUCLEAR WASTE CAN BE SAFELY STORED FOR THE NECESSARY PERIOD.

Long-term storage, for the indefinite period until and if safe disposal becomes available, is no answer.[10] It could be decades, or even centuries or more, before safe disposal is achieved, and there is no basis for confidence that nuclear waste can be safely stored for that period of time. To the contrary, a report prepared for the Tennessee Valley Authority ("TVA") has said about techniques for storing spent fuel:

> "[S]ince operating experience for more than 20 years is not available, a very long passage of time (i.e., several decades or longer) also may make the fuel assemblies less reliable by weakening the cladding, which means that the current methods for storing these assemblies are interim measures."

10. Ohio has pointed out cost, safety, and institutional concerns raised by storage at AFR facilities. (Ohio SP III.)

(Appendix to the TVA SP 10.) Therefore, until it is known when disposal will be available it cannot be said that nuclear waste will be safely stored until that date.

While storage in this country has not so far resulted in any calamitous accident, NRC records demonstrate that there have been many mishaps already, some of which led to releases of radioactivity. These are discussed at NYAG SP 105-107 and demonstrate the frequency of mechanical failure and human error at storage facilities. On at least one occasion, storage of nuclear waste did result in a major release of radioactivity. An Oak Ridge study concluded that this occurred in the Soviet Union and required the removal of the population from an area of from 38 to 380 square miles. (Id. 107-108.) Therefore, the fact that no major accident has yet occurred in the United States is reason to be thankful, but not reason to be confident that storage will be safe for an indefinite period of time.

VIII. CONCLUSION

The Commission should rule that it does not have confidence at this time that nuclear waste will be safely disposed of by a specific date, and that it also does not have confidence that such waste will be safely stored until safely disposed of. Any other conclusion would be based on hope or speculation rather than fact, and would be unjustified, arbitrary and capricious.

Dated: December 18, 1981

CALIFORNIA ENERGY COMMISSION
By

Dian Grueneich

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Deputy General Counsel
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ROBERT ABRAMS
Attorney General of the State of New York
By

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STATE PLANNING BUREAU
State Capitol
Pierre, South Dakota 57501
605/773-3661
South Dakota Office of Executive Management

February 4, 1982

Mr. Wallace R. Kornack, NE-6GTN
U.S. DOE, Assistant Secretary for Nuclear Energy
Office of Nuclear Reactor Programs
Washington, D.C.

RE: SD820107-E26
DRAFT EIS Liquid Metal Fast Breeder Reactor Program

Dear Mr. Kornack:

The State Clearinghouse has distributed for review the above stated environmental impact analysis. No comments were received in regard to this document, but thank you for the opportunity to review and comment.

Sincerely,

Tony C. Merry
Commissioner
STATE PLANNING BUREAU

TCM:jrr

STATE CLEARINGHOUSE
30 EAST BROAD STREET • 39TH FLOOR • COLUMBUS, OHIO 43215 • 614 / 466-7461

82-02-10 P
09

Mr. Wallace R. Kornack
Office of Nuclear Reactor Programs
Office of Ass't Secretary for Nuclear Energy
U.S. Department of Energy
NE-6, Room H-404
Germantown, Maryland 20545

RE: Review of Environmental Impact Statement/Assessment
Title: Draft Supplement Environmental Impact Statement on the Liquid Metal Fast Breeder Reactor Program.
SAI Number: 36-471-0016

Dear Mr. Kornack:

The State Clearinghouse coordinated the review of the above referenced environmental impact statement/assessment.

This environmental report was reviewed by all interested State agencies. No reviewer has stated concerns relating to this report.

Thank you for the opportunity to review this statement/assessment.

Sincerely,

Judith Y. Brachman
Administering Officer

JYB:lr

cc: DNR, Mike Colvin
EPA, Anthony Sasson

The Secretary

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
P.O. Box 2063
Harrisburg, PA 17120
(717) 787-2814

February 5, 1982

William A. Vaughan
Assistant Secretary
Environmental Protection, Safety
and Emergency Preparedness
Department of Energy
Washington, DC 20585

Dear Mr. Vaughan:

The Commonwealth has reviewed the Draft Supplemental Environmental Impact Statement (EIS) to the Final EIS on the Liquid Metal Fast Breeder Program and has no comment to make at this time.

Thank you for the opportunity to review the Impact Statement.

Sincerely,

PETER S. DUNCAN

The State of North Dakota
FEDERAL AID COORDINATOR OFFICE
State Capitol
Bismarck, North Dakota 58505
224-2094

Dale E. Moug
FEDERAL AID COORDINATOR

Allen I. Olson
GOVERNOR

February 5, 1982

"LETTER OF CLEARANCE" IN CONFORMANCE WITH OMB CIRCULAR NO. A-95

To: US Department of Energy

STATE APPLICATION IDENTIFIER: ND8201070007

Mr. Shelby T. Brewer
Assist. Secretary for Nuclear Energy
US Department of Energy
Washington, DC 20585

Dear Mr. Brewer:

Subject: Draft Environmental Impact Statement for the Liquid Metal Fast Breeder Reactor Program.

This Draft EIS was received in this office on January 7, 1982.

T ank you for submitting your draft environmental impact statement for review and comment through the North Dakota State Intergovernmental Clearinghouse.

Your draft was referred to the appropriate agencies, and no comments were received to this date.

Please send copies of the final environmental impact statement and any supplemental impact statements to the North Dakota agencies that have commented on the draft and to this office. The opportunity to review your draft is appreciated, and if this office as Clearinghouse can be of further assistance with this project, please let me know.

Sincerely yours,

Mrs. Leonard B. Banks
Coordinator
State Intergovernmental Clearinghouse

BAB/gd

VICTOR ATIYEH
GOVERNOR

Executive Department

155 COTTAGE STREET N.E., SALEM, OREGON 97310

February 9, 1982

Shelby T. Brewer
Assistant Secretary for
Nuclear Energy
Department of Energy
Washington, D.C. 20585

Dear Ms. Brewer:

Liquid Metal Fast Breeder Reactor Program
OR820111-022-4

Thank you for submitting your draft Environmental Impact Statement for State of Oregon review and comment.

Your draft was referred to the appropriate state agencies for review. The consensus among reviewing agencies was that the draft adequately described the environmental impact of your proposal.

We will expect to receive copies of the final statement as required by Council of Environmental Quality Guidelines.

Sincerely,

INTERGOVERNMENTAL RELATIONS DIVISION

Jack Carter

Jack Carter, Manager
Program Information and
Analysis Section

JC:cb

John V. Evans, *Governor*
Daniel T. Emborg, *Administrator*

State Capitol Building
Boise, Idaho 83720

DIVISION OF ECONOMIC AND COMMUNITY AFFAIRS

February 17, 1982

Mr. Wallace R. Kornack, NE-6 GTN
Office of Nuclear Reactor Program
Office of the Assistant Secretary for
Nuclear Energy
U.S. Department of Energy
Washington, DC 20545

Dear Mr. Kornack:

The Idaho State Clearinghouse has completed its review on the DRAFT ENVIRONMENTAL IMPACT STATEMENT LIQUID METAL FAST BREEDER REACTOR PROGRAM - SAI 00126526. The following agencies were contacted for their review and comment:

Panhandle Area Council
Clearwater Economic Development Association
Ida-Ore Regional Planning and Development Association
Ada Planning Association
Region IV Development Association
Southeast Idaho Council of Governments
East Central Idaho Planning and Development Association
Department of Health and Welfare/Division of Environment
Department of Agriculture
Department of Transportation/Division of Highways
Department of Transportation/Division of Aeronautics and Public Trans.
Idaho Historical Society
Department of Fish and Game
Department of Parks and Recreation

At the time of sign-off, comments have not been received from the reviewing agenices.

Thank you for letting us assist you with the review of this project. If you have any questions, do not hesitate to contact either myself or Lois Wade at (208) 334-4718.

Sincerely,

Gloria Mabbutt

Gloria Mabbutt, Coordinator
Idaho State Clearinghouse

GM:lw

IDAHO
A Land For All Seasons

STATE OF DELAWARE
EXECUTIVE DEPARTMENT
OFFICE OF THE BUDGET
DOVER, DELAWARE 19901

TELEPHONE: (302) 736-4205

February 16, 1982

Office of Nuclear Reactor Programs
Office of Assistant Secretary for Nuclear Energy
U.S. Department of Energy
Attn: Mr. Wallace R. Kornack
NE-6, Room H-404
Germantown, MD 20545

Dear Mr. Kornack:

RE: Liquid Metal Fast Breeder Reactor Program (Supplement to ERDA-1535)

The Office of the Budget, in its function as the State Clearinghouse, has reviewed the above listed supplemental draft EIS and has no negative comments to offer at this time.

Sincerely,

Henry J. Decker

Henry James Decker
State Budget Director

HJD:FB:jm
026ly

XIII. RESPONSES TO COMMENTS

Changes in the text of the Supplement are indicated by a vertical line and the number of the comment letter (see page xviii).

Example: (page 36, line 1)

9 The annual uranium requirement for a LWR varies between 140 and 200 ST

A. General Comments

1. Programmatic and Policy Issues

Comment (Letter #11, pages 13-16):

The reasonably foreseeable consequences of the LMFBR program were not addressed (and should have been).

Response:

As discussed in the Supplement (pages 112 and 113), none of the new information developed since ERDA-1535 indicates a significant change in the environmental consequences of the LMFBR Program over those analyzed in WASH-1535 and ERDA-1535, except for the special case of releases of transuranics, which was addressed in the Supplement (pages 22-26, 189-212, and Appendix D). The reasonably foreseeable consequences of a deployed LMFBR economy were addressed in detail in WASH-1535. The scope of WASH-1535 and ERDA-1535 completely encompasses possible impacts associated with the less extensive program addressed in the Supplement.

Comment (Letter #2, pages 1-5; #9, page 1; #11, pages 4-12):

An updated economic cost/benefit analysis of the LMFBR Program should have been prepared and included in the Draft Supplement, to aid decision making concerning the LMFBR Program.

Response:*

The basic reasons for not providing any cost/benefit analyses in the Supplement were stated on pages 3 and 4.

> "Cost/benefit analyses of the LMFBR program were included in WASH-1535 and ERDA-1535. However, no such further cost/benefit analyses have been performed and none, therefore, are included in this supplement for the following reasons:
>
> 1. Cost/benefit analyses are not required in an EIS (see CEQ regulations, 40 CFR 1502.23),
>
> 2. Cost/benefit information for alternative long-term technologies (fusion and solar electric) has not been developed to a degree that would make cost/benefit analyses of these alternatives meaningful, and
>
> 3. Parameters (e.g., discount rate(s), LMFBR introduction date(s), future nuclear capacity, future cost of coal) used in complex cost/benefit analyses of the LMFBR are so uncertain at present that the value of such analyses would be questionable. It is a goal of the breeder research and development program to reduce such uncertainties."

*See also pages cxxvi to cxxviii.

Uncertainties in electrical demand growth, resource base, uranium and LMFBR plant costs, and other planning assumptions make this type of projection a very poor planning basis for long-range programs. Selection of a breeder commercialization date based upon such a projection would be highly uncertain.

Because of large uncertainties, prudence requires a continuation of the development and demonstration program so that LMFBR commercialization would be possible when needed. The consequences of early development are minor compared to the consequences of possible electricity shortages and the attendant economic penalties resulting from late development. To be able to have breeder deployment capability early in the next century requires an active breeder development and demonstration program. Significant program delays at this time would destroy the continuity that is essential to any high technology development area and push the commercialization potential of the breeder well into the 21st century.

The LMFBR program is a complex undertaking requiring years of intensive work. The program scope is beyond the investment/time horizons of any domestic business group. The federal role for development of breeder reactors is to support necessary research, development, and demonstration to reduce the uncertainties in the potential economic, environmental, and safety areas of the breeder so that private industry can make the commercialization decisions at a venture risk level that is consistent with normal business practices. It is expected that industry would make this decision based on its own cost/benefit analyses, as well as on numerous other considerations.

Comment (Letter #11, pages 19 and 20, #21, attachment 3, pages 5, 6 and 22-24):

Conservation and improved energy efficiency were not discussed (as alternatives).

Response:*

The effects of conservation and improved energy efficiency, as well as factors that would increase future energy demands, are included in projections of future energy demand (see, for example, Appendix F in the Supplement). These effects are incremental relative to the purpose and need of the LMFBR program and therefore are not in and of themselves considered alternatives.

*See also pages xcix to cii.

2. LMFBR Safety (pages xxiii to xxx)

Comment (Letter #11, page 31, second paragraph):

The authors of the DEIS presented the LMFBR safety issue in the most favorable light and have downplayed or excluded data casting doubt on breeder safety.

Response:

DOE has attempted to present a comprehensive and balanced view of LMFBR safety. The Supplement provides information on the status of resolution of key safety issues that were identified in ERDA-1535, as well as other issues that have arisen since ERDA-1535 was published. Taken together, this set of old and new issues covers all major areas of LMFBR reactor safety concern. Further, the Supplement recognizes that, while substantial progress is being made, safety research conducted to date has not eliminated all concerns. This is illustrated on page 122: "The data and codes also indicate that a loss-of-flow event with failure to scram would most likely progress to whole-core disruption . . . ," and on page 124: "However, recriticality events during the whole-core meltdown phase still cannot be completely ruled out . . . ." The Supplement also supports the need for additional safety research. Page 115 of the Supplement makes a general statement on this: "There are certain safety-related areas where the availability of additional information would permit the designers of future large LMFBR plants to provide more cost-effective designs while meeting all safety requirements. Present and future Safety Program efforts will concentrate on providing these elements of improved safety technology." A more specific statement is found on page 126: "The current technology base supports the position that the CRBRP has the core debris accommodation capabilities necessary to meet licensing requirements associated with core disruptive accidents.[39] At the same time, a number of issues in core-debris accommodation technology must be studied further in order to assure that questions on optimal containment designs and licensing concerns for large plants can be adequately resolved.[40] These questions arise for large plant designs due to the much larger fuel inventory and the associated decay heat loads."

The safety questions that remain open arise primarily in connection with postulated core disruptive accidents in future large LMFBRs. Thus, much of the discussion in the Supplement addresses these questions. This emphasis should not lead to the conclusion that such events are considered likely to occur. As stated in the Supplement (page 116):

"It is essential to appreciate the massive efforts that have been devoted to assuring that LMFBRs can be and are designed, constructed, and operated to have an extremely low probability of occurrence of core disruptive accidents. The strategy that has been used to accomplish this objective is to provide a design that is sound, conservative, and intrinsically safe during normal operation, and has sufficient margin to safely accommodate anticipated, unlikely, and extremely unlikely events (the three levels of design safety approach discussed in Section 4.2.7.3 of WASH-1535)."

Further perspective is provided through the realization that significant experience has been gained in the design of systems and features to mitigate the consequences of severe accidents, assuming they occur. This experience provides confidence that such systems and features can readily be provided in future large LMFBRs. The following Supplement passage (page 117) is applicable:

"While some residual uncertainties remain as to how best to design these systems and features for future large plants, sufficient conservatism is employed in the design of present plants to ensure that they can meet safety requirements. This conservatism is provided by requiring that significant margins be provided in the design of these systems and features and by providing redundancy and diversity of systems and structures. Operation of FFTF and CRBRP will provide additional evidence of the adequacy of the design of these plants with respect to safety. As stated earlier, present and future efforts in the Safety Program are aimed at reducing uncertainties and further improving designs so that plant capital and operating costs can be reduced by eliminating excessive conservatisms while still meeting safety requirements."

Comment (Letter #11, page 31, last line):

The DEIS admits to the "explosive potential" of large breeders.

Response:

The term "explosive potential" is not used in the Supplement, or in the LMFBR safety research community in general, because it is considered to be an erroneous term for the HCDA energetics phenomenon. The topic of large breeder HCDA energetics is discussed in one of the four places cited by NRDC, page 135. The key points are: "For LMFBRs larger than CRBRP, such as LDP, it is believed to be prudent to obtain additional confirmation that practical primary system boundary designs provide adequate capability to accommodate HCDA energetics . . . . These [research] programs are expected to provide the necessary confirmation." The intent was to describe the need for additional research on an important safety question, and not to convey the notion that DOE believes this to be so serious a problem as to defy resolution. On the contrary, DOE has high confidence that the comprehensive research program cited in the Supplement will produce affirmative results.

Comment (Letter #11, pages 32 and 33):

With respect to LMFBR and, specifically, CRBR safety, the DEIS does not consider: (1) the disagreements between NRC and DOE on an "adequate energetic consequence envelope" and six other issues; (2) the approximately 100 safety issues compiled by NRC in the 1978 Gammill to Caffey letter; (3) the discussion and conclusions of the 1979 White House Report on CRBR; and (4) the licensing issue of whether a core disruptive accident should be a design basis accident.

Response:

Parts (1), (2), and (4):
Although the Supplement contains some information on CRBRP safety work which has been accomplished as part of the LMFBR program, it is not the purpose of the Supplement to consider specific unresolved CRBR safety issues. Such issues are being addressed in the CRBR licensing process through interaction with NRC.

Regarding part (4), the following quotation from the May 6, 1976 letter from R. P. Denise (NRC) to L. W. Caffey (CRBR Project Office) may be of interest: "It is our current position that the probability of core melt and disruptive accidents can and must be reduced to a sufficiently low level to justify their exclusion from the design basis accident spectrum. We will therefore not consider CDAs as design basis accidents." This position is currently under review by the NRC.

Part (3):

Chapter VI of the White House Report addresses CRBR safety issues only to the extent of referring to the 1978 Gammill to Caffey letter and summarizing, without discussion, some safety issues from that letter. As stated previously, it is not the purpose of the Supplement to consider specific unresolved CRBRP safety issues. It should be noted, however, that the CRBRP Safety Study (see Appendix C of the Supplement) concluded that the CRBRP risks are comparable to LWR risks.

It should also be noted that the General Accounting Office has criticized the treatment of safety issues in the White House Report. Specifically, the White House Report was said to lack proper balance, to be misleading, and to have reduced credibility because of omission of important information (see "Comments on the Administration's White Paper: The Clinch River Breeder Reactor Project -- An End to the Impasse," EMD-79-89, July 10, 1979, pages 25-31).

Comment (Letter #11, pages 33 and 34):

The DEIS fails to discuss a number of important lessons learned from the TMI accident and the effects of post-TMI NRC rules and standards on the licensability of CRBR and other LMFBR's.

Response:

The footnote on page 137 shows that the CRBRP Project recognizes the implications of the Three Mile Island (TMI) accident and is taking appropriate actions. Requirements and regulations resulting from the assessment of the TMI accident are being comprehensively addressed in the CRBRP licensing proceeding. The CRBRP will accommodate all applicable post-TMI requirements. The same will be true for future LMFBRs.

Comment (Letter #11, pages 34 and 35; #21, attachment 3, pages 33 and 34):

The CRBR risk assessment, patterned after WASH-1400, fails to acknowledge major weaknesses of WASH-1400, as stated by the Risk Assessment Review Group and others. The DEIS should provide a complete assessment of risk for CRBR and other components of the breeder fuel cycle.

Response:

In addition to the findings cited in the comments, the Risk Assessment Review Group also concluded: "Despite its shortcomings, WASH-1400 provides at this time the most complete single picture of accident probabilities associated with nuclear reactors. The fault-tree/event tree approach coupled with an adequate data base is the best available tool with which to quantify these probabilities."

The Rasmussen Report was mentioned in the Supplement because it served as a pattern for the 1977 CRBR Safety Study and was referred to in the conclusions of that study. The publication of the CRBR study was an important event in the ongoing development of LMFBR risk assessment and was described in that context in the Supplement. The Supplement also states (page 139) that the CRBR study " . . . is being revised to account for changes in plant design and risk assessment methodology, and to address earlier comments." The revised CRBR study will account for the Lewis Report and other criticisms of WASH-1400 to the extent that they apply to the content of the revised study.

Risks associated with other components of the breeder fuel cycle (fuel fabrication, reprocessing, transportation, etc.) were addressed in WASH-1535 (Volume II).

Comment (Letter #21, attachment 3, page 32, first paragraph):

The DEIS relies heavily on six-year old information and fails to provide complete and up-to-date discussions of safety issues raised by several organizations, or discuss by what mechanisms a reasonable consensus (that safety objectives can be met) can be reached.

Response:

The Supplement summarizes information presented in ERDA-1535 merely as background for discussons of changes that have taken place since ERDA-1535 was issued and of current status. The reliance is on the best available information, some of which was presented in ERDA-1535 and some of which is more recent. The set of issues discussed in the Supplement covers the significant areas of LMFBR reactor safety concern, including the technical questions cited in the comment. DOE does not believe that there is an unanswered question regarding mechanisms for reaching a consensus that safety objectives have been met. The Federal Government's (i.e., NRC's) nuclear reactor licensing process is the mechanism.

Comment (Letter #21, attachment 3, page 32, second paragraph):

The Council on Environmental Quality advised NRC that future NRC licensing-related EIS's should discuss Class 9 accidents. Thus, the DEIS needs to address Class 9 accidents and their implications for breeder development. The consequences of Class 9 accidents in breeders could exceed those of LWR's.

Response:

The CEQ suggestion that EIS's should include discussion of Class 9 accidents applies to EIS's issued by NRC for conventional LWRs. The Supplement does contain considerable discussion of Class 9 accidents (HCDAs); see pages

122-124, 125-126, and 131-135. (HCDAs were discussed at greater length in Section 4.2.7.8 of WASH-1535 and Section III B.2 of ERDA-1535.) As stated in the Supplement (footnote, page 134), such discussion has been provided in NRC's EIS for CRBRP and can be anticipated in EIS's for individual future large breeders. Regarding the consequences of Class 9 accidents in breeders and LWRs, the CRBRP EIS mentioned in the Supplement footnote makes the following statement (NUREG-0139, page 7-11): "The staff believes it is within the state-of-the-art to design, construct and operate the CRBRP in such a manner that the consequences of accidents will not be significantly different from those already assessed for LWRs."

3. Health Effects (pages xxxi to xlvi)*

Comment (Letter #11, page 63; #21, attachment 1, pages 16 and 17):

The source term for releases of transuranics in the EIS is not conservative because accidental releases were not included (and should have been).

Response:

The source term for releases of transuranics includes only routine releases because accidental releases have been estimated to be considerably smaller, as shown in the following material from WASH-1535 (see pp. II.G-5 to II.G-10).

> "Several commenters have questioned the treatment of unscheduled events. NRDC stated that
>
> > There is no justification for the assertion that accidental releases 'would make a negligible contribution to the source term.' . . .
>
> "The last column of Table II.G-2 lists the contribution of the 1000 MWe-year transuranic source term from the tabulated accident types, assuming that fuel fabrication and fuel reprocessing accidents occur at 10-year intervals and that other accidents occur as described in footnotes to the table. The total estimated contribution from accidents is 0.010 mCi, which is small in comparison to the estimated routine release of 0.36 mCi. It is therefore concluded that the 0.36 mCi/1000 MWe-year source term accounts adequately for both routine and accidental transuranic releases."

Comment (Letter #11, pages 60-63):

"...the DEIS....ignores the widely divergent views of experts regarding these uncertainties (sic, in the estimates used in the model) and its

*See also pages cix to cxi and cxvi to cxxv.

conclusions are by no means conservative. This results in a serious underestimation of the potential health effects of the LMFBR program."

Response:

Except for a few items, the commenter does not present evidence as to which estimates it considers to be nonconservative, or why they are considered to be nonconservative. The commenter relies upon lengthy lists of references to articles that propose different estimates from those employed in the Supplement, and does not present reasons why these estimates should be preferred to the ones employed in the Supplement. The views espoused by most of the authors referenced by the commenter in support of its position have been criticized by the majority of workers in the field and this criticism was considered at length in WASH-1535 (1)* and ERDA 1535 (2). DOE does not consider it necessary to repeat, in detail, the discussions previously presented, particularly since little new material has been presented.

This commenter included a list of 15 references to publications that purportedly do not view the values for model parameters employed by DOE as either "most probable" or "conservative." Of the 15 publications, 3 are 5- to 7-year old reports of the NRDC itself, which restate previous contentions that have been considered at length in the past (1,2). Other references cited which were relevant to the transuranic elements appear to offer little beyond opinions previously considered (3,4) and/or have been

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* References are given at end of this health effects section (pages xlii to xlvi).

addressed elsewhere by the scientific community (5,6,7). One reference (8) was to BEIR-III risk coefficients, which are not relevant to the risk coefficients for alpha irradiation employed in the Supplement. The remaining 6 papers are all concerned with a study of mortality among Hanford workers -- a study whose conclusions have been widely criticized by other epidemiologists (9,10,11).

The commenter stated the criticism that use of a combination of "mean" and "conservative" values for model parameters "does not insure that the results are conservative." The Supplement statement that such an approach "...leads to overestimates of transuranic deposition in man..." is characterized by the commenter as not statistically correct and "just plain wrong." To clarify the intent of the statement in the Supplement, the wording has been changed to read, "This approach leads to conservative estimates of transuranic deposition in man...," to avoid any implication of absolute certainty about the direction of uncertainty. (Change occurs in line 10, page 191.)

The final sentence on page 63 of the commenter's letter implied that the contamination of the environs of the Rocky Flats Plant was the result of an accident. This contamination was due, almost entirely, to leakage from barrels of waste stored in a manner considered adequate at that time (12). This was, in retrospect, a very poor way to handle these wastes (and one which is not apt to be repeated).

<u>Comment</u> (Letter #11, page 64):

"The DEIS fails to address a series of German studies which consider the uncertainties in data, models, and assumptions for pathway analyses of routine emissions from light water reactors (LWRs). While these papers concern emissions from LWRs in the Federal Republic of Germany, their analysis is relevant to the LMFBR and associated fuel cycle facilities since the German pathway models and input parameters are based primarily on U.S. data. The final EIS should consider these studies and any reviews of them."

Response:

The Heidelberg Report (13) referred to is an assessment of the radiation doses to critical population groups associated with a specific pressurized water reactor in Germany. As such, it has little direct relevance to the generic assessment of transuranic health effects from an LMFBR technology. The report has received considerable publicity, however, because its estimates of dose are several orders of magnitude higher than those generally calculated for a plant of this type. The Heidelberg group employed generally accepted methods of calculation, based on those of the U.S. Nuclear Regulatory Commission, but incorporated parameter values of their own choice for source terms, for transfer through food chains and for incorporation and retention in man.

The conclusions of this group have been reviewed at some length by the U.S. Nuclear Regulatory Commission (14), and briefly reviewed by the National Radiological Protection Board of the United Kingdom (15). These reviews conclude that unrealistically conservative parameters were chosen throughout the Heidelberg evaluation, and that the resulting predictions are not only scientifically indefensible, but are in sharp conflict with an accumulating body of environmental measurement data from the vicinity of operating reactors in the U.S. Perhaps the chief relevance of this report to the present LMFBR evaluation is the example it provides of how overly conservative assumptions of parameter values can combine in environmental models to produce radiation exposure estimates that are excessive.

Comment (Letter #11, pages 64 and 65):

The book by Gofman and the papers by Morgan and Johnson "...indicate that the assumptions in the DEIS concerning plutonium toxicity are nonconservative by at least two orders of magnitude."

Response:

Although the basis for this statement was not given by the commenter, DOE assumes that the numerical judgement probably derives from Morgan's paper, in which he attempted to demonstrate that the exposure limit for ^{239}Pu was too high by a factor of 240 (4). This contention was considered in some detail during the discussion following presentation of a paper by Charles W. Mays at an IAEA Symposium, where a factor of 9 was concluded to be more reasonable, though still possibly excessive (5). Morgan's contention was also discussed, at length, in the Environmental Impact Statement for the Rocky Flats Plant site, which concludes with the following summary (6):

"Morgan's overall factor of 240 would therefore, more realistically, be re-evaluated as something between one and five. His is, moreover, only a partial approach to the evaluation of plutonium hazards; many other factors might be considered. All such factors are under continual review by national and international bodies charged with the responsibility for such evaluations. While some changes in plutonium exposure standards may be expected to result from the continuing accumulation of better data, there is no present indication that such changes will be large."

Since Morgan's publication, the International Commission on Radiological Protection (ICRP) has made changes in its plutonium exposure limits (16). Changes in the ICRP metabolic models for the transuranic elements were incorporated in the revised dose calculations for the Supplement and are detailed in Table II.G-9 (Replacement), pages D-13 and D-14.

Carl Johnson's claims of increased cancer incidence due to plutonium contamination from the Rocky Flats Plant (17,18) have been refuted (7). A crucial point is the undisputed fact that the concentration of plutonium from weapons test fallout in the Denver area is nearly 10 times as large as the concentration of plutonium originating from Rocky Flats, and the radiation dose to the lungs of Denver residents from natural sources is 100 times that from plutonium. Against such a background of radiation from other sources, any effect from Rocky Flats plutonium could never be demonstrated(7).

The commenter suggests that a purported disparity in radiosensitivity of beagle dogs and humans to radon exposure casts serious doubt on the health risk estimates in the Supplement. The estimates of health risks in the Supplement are based upon human dose-response data, and not upon experimental studies in beagle dogs. Furthermore, the referenced studies (19), as acknowledged by the commenter, deal with radon and radon daughter exposures, not with transuranics. The referenced studies do not address the question of minimum radiation dose levels at which lung tumors can be produced in dogs, since only a single, very high dose level was studied; no dogs survived more than about 6 years following initiation of exposure (scarcely long enough for cancer expression), and much of the total calculated radiation dose was received too late in the survival period to be effective in cancer production. A more relevant comparison of the radiosensitivity of beagle dogs and man is provided by the very extensive data relating radium deposition and bone cancer induction, which show the dog to be more sensitive than man (20).

Comment (Letter #11, page 65):

"The DEIS summarizes risk estimates from exposure to low LET radiation (Appendix H). However, it does not discuss either the widely divergent opinions on this subject, including those of Radford, Morgan, Mancusco, Steward, Kneele, Gofman, Bross, and Tamplin, supra, or the implications of the new Hiroshima and Nagasaki dose estimates for the BEIR-III results."

Response:

Appendix H provides a tabular comparison of these risk estimates as they have been recommended by such authoritative sources as the U.S. National Academy of Sciences (BEIR Committees) (21,22), the International Commission on Radiological Protection (ICRP) (23), the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) (24), the U.S. Environmental Protection Agency (25,26), and the U.S. Nuclear Regulatory Commission (27). Appendix H was included only to provide some perspective on the range of values agreed upon by these groups. None of these risk factors were employed in the Supplement. The risk factors that were employed are those appropriate to the high LET alpha particle emissions characteristic of transuranic elements; these risk factors were discussed (as noted in Appendix H) in Section VI.A(4) and in Appendix D.

The re-evaluation of Hiroshima and Nagasaki dose estimates will certainly have some effect in modifying risk estimates for exposure to low LET radiation, and possibly to neutrons. This re-evaluation is incomplete and conclusions cannot be drawn at this time. The situation is well summarized by the following excerpt from a commentary on a symposium at the 29th Annual Meeting of the Radiation Research Society, held on May 31, 1981 (28).

> "The papers and the discussion clearly indicate that there are many uncertainties yet to be resolved. Their effects would seem to be comparatively minor, but it is too early to be certain and thus speculation should be kept to minimum. However, since some speculation is unavoidable, the following may be justified. There is the prospect that these re-examinations of the dosimetry situation will lead first to a loss of information on the effects of neutrons on humans (and therefore a need to rely on animal data and other sources for neutron toxicity) and second to risk estimates for γ radiation which, because of the potential improved agreement between the two cities, may merit more confidence than before and may not differ markedly than those from other sources of human data."

In any case, the risk estimates employed in the Supplement are for alpha radiation to specific organs and have little relevance to the Hiroshima-Nagasaki data.

For the same reasons, the commenter's reference to "...studies of populations exposed to low doses of radiation, such as workers at Hanford..." is irrelevant, since the exposure of these workers was predominantly to low LET radiation -- not alpha emitters.

Comment (Letter #11, pages 66-68):

The "hot particle" hypothesis was not considered properly.

Response:

This hypothesis, put forward by A. R. Tamplin and T. B. Cochran in 1974 (29), has, as noted in the Supplement, been discussed at great length, and formally reviewed by specifically appointed groups representing a number of prestigious and authoritative bodies. These groups are more numerous than mentioned in the Supplement and include the National Academy of Sciences-National Research Council (30), the National Council on Radiological Protection and Measurement (31), the Nuclear Regulatory Commission (32), the Medical Research Council of the United Kingdom (U.K.) (33), the National Radiological Protection Board of the U.K. (34,35), the German Ministry of the Interior (36), and the International Commission on Radiological Protection (37). Some of these groups allow the possibility that, under special circumstances not yet experimentally or clinically defined, "aggregates of radioactivity that remain localized in specific regions" (22) may represent a greater cancer risk than the same quantity of radioactivity uniformly dispersed. However, none of these groups has accepted the quantitative implications of the Tamplin-Cochran Hot Particle Hypothesis, and none has recommended abandoning the practice of basing risk estimates on average organ dose. The commenter provides no new evidence that would alter the conclusions previously expressed by the groups referenced above, and there seems no need to review these conclusions in greater detail.

The commenter's statement that the lack of observed health effects in plutonium workers "...does not argue against the hot particle hypothesis" (pages 67 and 68) requires some response. The parenthetical comment "...(presumably excluding the Hanford worker studies)..." implies that the Hanford worker studies had specifically evaluated effects of plutonium exposure. This is not true; Hanford workers were exposed predominantly to low LET radiation. Epidemiologic studies are underway, encompassing large numbers of plutonium workers, but only preliminary results are as yet available from these studies (38,39,40). These preliminary data show no evidence of the extreme toxicity predicted by the Hot Particle Hypothesis.

To clarify the position on the Hot Particle Hypothesis and to avoid possible misinterpretations, the paragraph overlapping pp. 207-208 in the Supplement is changed to read, in its entirety:

> "Of greater interest are the possible consequences of inhaled particles. Is the intense radiation dose to tissue surrounding a particle more hazardous than the dose from the same quantity of radiation dispersed more uniformly throughout the lung? This question, the so-called "hot particle problem," has been addressed by several specifically appointed groups and international bodies (23,30,31,32). As referenced in greater detail in Appendix D, these groups have found neither theoretical nor experimental grounds for confirming the extreme toxicity attributed to "hot particles" by Tamplin and Cochran (29).
>
> "The possibility of enhanced effects from particulate irradiation of specific tissue regions cannot be excluded, but uniform exposure to total organs would generally be predicted to be more hazardous than exposure to 'hot particles.' The lack of any unusual incidence of health effects among workers that have inhaled plutonium (usually in particulate form) also argues against any surprisingly large hazard due to these particles (40). The use of an average lung dose in the estimation of health risks is therefore considered an appropriate procedure, which is not expected to underestimate risks."

In Appendix D, the section on p. D-9 entitled, "Problems of Averaging Dose," is changed to read, in its entirety:

Problems of Averaging Dose

This final Section of WASH-1535, Appendix II.G, was concerned with the so-called "hot particle hypothesis" of Tamplin and Cochran (29), which was a controversial issue at the time. The discussion remains valid. Since issuance of WASH-1535, this question has been addressed by several specially appointed groups, government agencies, and international bodies, including the National Academy of Sciences -- National Research Council (30), the National Council on Radiation Protection and Measurement (31), the Nuclear Regulatory Commission (32), the Medical Research Council of the U.K. (33), the National Radiological Protection Board of the U.K. (34,35), the German Ministry of the Interior (36), and the International Commission on Radiological Protection (37). Some of these groups allow the possibility that, under special circumstances not yet experimentally or clinically defined, aggregates of radioactivity that remain localized in specific regions may represent a greater cancer risk than the same quantity of radioactivity uniformly dispersed. However, none of these groups has accepted the quantitative implications of the Tamplin-Cochran Hot Particle Hypothesis, and none has recommended abandoning the practice of basing risk estimates on average organ dose.

REFERENCES

1. U.S. Atomic Energy Commission, Proposed Final Environmental Statement, Liquid Metal Fast Breeder Reactor Program, WASH-1535, Vol. 2, Appendix II.G, pp. II.G-67 to II.G-74, 1974.

2. U.S. Energy Research and Development Administration, Final Environmental Statement, Liquid Metal Fast Breeder Reactor Program, ERDA-1535, Vol. 1, Section III.G, pp. III G-7 to III G-20, 1975.

3. J. W. Gofman, Radiation and Human Health, Sierra Club Books, San Francisco, 1981.

4. K. Z. Morgan, "Suggested Reduction of Permissible Exposure to Plutonium and Other Transuranic Elements," Am. Indust. Hyg. Assn. J. 36, 567-575, 1975.

5. C. W. Mays, "Estimated Risk from ^{238}Pu to Human Bone, Liver and Lung," Biological and Environmental Effects of Low-Level Radiation, Vol. II, pp. 373-384, International Atomic Energy Agency, Vienna, 1976.

6. U.S. Department of Energy, Final Environmental Impact Statement, Rocky Flats Plant Site, DOE/EIS-0064, Vol. 2, Appendix G-1 (by R. C. Thompson and W. G. Bair), pp. G-1-22 to G-1-23, 1980.

7. J. A. Reissland and S. C. Darby, "Comments on the Increased Cancer Incidence Reported in Denver, USA," Radiol. Prot. Bull. 36, 16-22, 1980; and Dreyer, N. A., Fahey, F. H., and Harley, N. H., "The Feasibility of Epidemiologic Studies of Cancer in Residents Near the Rocky Flats Plant," Health Physics, 42, 65-68, 1982.

8. E. P. Radford, "Statement Concerning the Current Version of Cancer Risk Assessment in the Report of the Advisory Committee on the Biological Effects of Ionizing Radiations (BEIR-III Committee)," The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980, pp. 227-253, National Academy Press, Washington, DC, 1980.

9. E. S. Gilbert and S. Marks, "Cancer Mortality in Hanford Workers," Radiol. Res. 79, 122-148, 1979.

10. G. B. Hutchison, B. MacMahon, S. Jablon, and C. E. Land, "Review of Report by Mancuso, Stewart, and Kneale of Radiation Exposure of Hanford Workers," Health Phys. 37, 207-220, 1979.

11. U.S. National Academy of Sciences -- National Research Council, The Effect on Populations of Exposure to Low-Levels of Ionizing Radiation: 1980, National Academy Press, Washington, DC, 1980. (Specific reference to pp. 455-458.)

12. P. W. Krey, "Remote Plutonium Contamination and Total Inventory from Rocky Flats," Health Phys. 30, 209-214, 1976.

13. University of Heidelberg, Department of Environmental Protection, Radioecological Assessment of the Wyhl Nuclear Power Plant (NRC translation 320), 1978.

14. U.S. Nuclear Regulatory Commission, Staff Review of Radioecological Assessment of the Wyhl Nuclear Power Plant, NUREG-0668, 1980.

15. S. M. Haywood, "A Review of the Heidelberg Report," Radiol. Prot. Bull. 42, 27-30, 1981.

16. International Commission on Radiological Protection, Publication 30 Limits for Intakes of Radionuclides by Workers, Part 1. Pergamon Press, Oxford, 1979.

17. C. J. Johnson, "Evaluation of Cancer Incidence for Anglos in the Period 1969-1971 in Areas of Census Tracts with Measured Concentrations of Plutonium Soil Contamination Downwind from the Rocky Flats Plant on the Denver Standard Metropolitan Statistical Area," Book of Papers, 5th Intern. Cong. Intern. Radiat. Prot. Assoc. Vol. II, pp. 375-368, Israel Health Physics Soc., Jerusalem, 1980.

18. C. J. Johnson, "Cancer Incidence in an Area Contaminated with Radionuclides Near a Nuclear Installation," AMBIO 10, 176-192, 1981.

19. F. T. Cross, R. F. Palmer, R. E. Filipy, G. E. Dagle, and B. O. Stuart, "Carcinogenic Effects of Radon Daughters, Uranium Ore Dust, and Cigarette Smoke in Beagle Dogs," Health Phys. 42, 33-52, 1982.

20. C. W. Mays, H. Spiess, G. H. Taylor, R. D. Lloyd, W. S. S. Jee, S. S. McFarland, D. H. Tysum, T. M. Brammer, D. Brammer, and T. A. Pollard, "Estimated Risk to Human Bone from ^{239}Pu," The Health Effects of Plutonium and Radium (W. S. S. Jee, ed.), pp. 343-362, J. W. Press, Salt Lake City, 1976.

21. U.S. National Academy of Sciences -- National Research Council, The Effect on Populations of Exposure to Low Levels of Ionizing Radiation, Washington, DC, 1972.

22. U.S. National Academy of Sciences -- National Research Council, The Effect on Populations of Exposure to Low Levels of Ionizing Radiation: 1980, National Academy Press, Washington, DC, 1980.

23. International Commission on Radiological Protection, Publication 26. Recommendations of the International Commission on Radiological Protection, Pergamon Press, Oxford, 1977.

24. U.N. Scientific Committee on the Effects of Atomic Radiation, Sources and Effects of Ionizing Radiation, United Nations, New York, 1977.

25. U.S. Environmental Protection Agency, Environmental Analysis of the Uranium Fuel Cycle. Part I - Fuel Supply, EPA-520/9-73-003-B, 1973.

26. U.S. Environmental Protection Agency, Environmental Analysis of the Uranium Fuel Cycle. Part III - Nuclear Fuel Reprocessing, EPA-520/9-73-003-D, 1973.

27. U.S. Nuclear Regulatory Commission, Reactor Safety Study, Appendix IV. Calculation of Reactor Accident Consequences, WASH-1400 (NUREG 75/014), Washington, DC, 1975.

28. W. K. Sinclair and P. Faila, "Dosimetry of the Atomic Bomb Survivors," Radiat. Res. 63, 437-447 (1981).

29. A. R. Tamplin and T. B. Cochran, Radiation Standards for Hot Particles, Natural Resources Defense Council, Washington, DC, 1974.

30. U.S. National Academy of Sciences -- National Research Council, Health Effects of Alpha-Emitting Particles in the Respiratory Tract, Washington, DC, 1976.

31. National Council on Radiation Protection and Measurements, NCRP Report No. 46, Alpha Emitting Particles in the Lung, Washington, DC, 1975.

32. U.S. Nuclear Regulatory Commission, "Natural Resources Defense Council -- Denial of Petition for Rule Making," Federal Register 41(71), 15371-15379, 1976.

33. Medical Research Council, The Toxicity of Plutonium, Her Majesty's Stationery Office, London, 1975.

34. G. W. Dolphin, "Hot Particles," Radiol. Prot. Bull., 1974(8), 8-10, 1974.

35. G. W. Dolphin, "The Hot Particle Problem," Radiol. Prot. Bull. 1975(12), 18-19, 1975.

36. German Ministry of the Interior (Bonn), "On the Toxicity of Inhaled Hot Particles with Special Reference to Plutonium," Radiat. Environ. Biophys. 15, 1-11, 1978.

37. International Commission on Radiological Protection, Publication No. 31, Biological Effects of Inhaled Radionuclides, Pergamon Press, Oxford, 1980.

38. G. L. Voelz, J. H. Stebbings, L. H. Hempelmann, L. K. Haxton, and D. A. York, "Studies on Persons Exposed to Plutonium," Late Biological Effects of Ionizing Radiation, Vol. 1, pp. 353-367, 1978.

39. G. L. Voelz, L. H. Hempelmann, J. H. P. Lawrence, and W. D. Moss, "32-Year Medical Followup of Manhattan Project Workers," Health Phys. 37, 445-485, 1979.

40. G. L. Voelz, J. H. Stebbings, Jr., J. W. Healy, and L. H. Hempelmann, "Studies on Health Risks to Persons Exposed to Plutonium," The Medical Basis for Radiation Accident Preparedness, pp. 419-430, Elsevier, New York, 1980.

4. Safeguards and Nonproliferation

Comment (Letter #11, pages 36-41, #21, attachment 1, page 3 and pages 8-21, and attachment 3, pages 29-31):

LMFBR development is likely to lead to the proliferation of nuclear weapons to nations not presently possessing nuclear weapons. This impact should be addressed in the Supplement.

Response:

DOE is cognizant of recent studies that have addressed, among other things, the implications of LMFBR deployment to foreign nations with respect to the potential for proliferation of nuclear weapons. In addition, DOE has directed its own studies[1] and has been a participant in international studies[2] on this subject. DOE is also aware of the shades of difference in the conclusions of these studies with respect to the proliferation implications of the LMFBR fuel cycle.

With respect to the Supplement, however, the relevant question is the linkage, if any, between U.S. LMFBR development and the risk of further proliferation. DOE believes that such a linkage is remote and speculative for a number of reasons. First, DOE's efforts are directed toward conducting research, development, and demonstration on the LMFBR fuel cycle. No decision is currently being made either to deploy the LMFBR commercially or to export associated reprocessing facilities.

Second, the breeder, including its associated reprocessing technology, is

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1. Department of Energy, Nuclear Proliferation and Civilian Nuclear Power, Report of the Nonproliferation Alternative Systems Assessment Program, DOE/NE-0001, June 1980.

2. International Atomic Energy Agency (IAEA), International Nuclear Fuel Cycle Evaluation: Fast Breeders, Report of Working Group 5, Vienna, 1980.

under development in other countries. In this regard it should be noted that past U.S. efforts to persuade a number of developed countries to postpone their construction of reprocessing plants and their R&D on breeders were not successful. During the period 1977-1980, the previous Administration attempted to influence other nations to defer reprocessing and the recycle of nuclear fuel by unilaterally halting U.S. reprocessing activities and by attempting to cancel the CRBRP. The flaws of this unilateral U.S. policy were recently reviewed by two of its formulators.[3]

No evidence exists that U.S. continuation of its LMFBR program would adversely impact nonproliferation objectives. It is unlikely that the United States going ahead with the LMFBR development program would influence other nations not now developing the breeder to do so. The International Nuclear Fuel Cycle Evaluation (INFCE) studies support this conclusion.[4]

Third, there are other avenues for nations to obtain weapons usable materials. These include purchase and theft, and the construction of facilities dedicated to that purpose (as opposed to diversion from commercial systems) as well as diversion from non-LMFBR commercial systems. The particular avenue that a nation might employ in securing nuclear weapons depends upon desired objectives, for example, the size and development time of the weapons force desired and a variety of characteristics of the country itself, and for example, its technological capability, the availability of other nuclear facilities, sensitivity to detection, vulnerability to sanctions, and political relationships. Given

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3. Gerard Smith and George Rathjens, "Reassessing Nuclear Nonproliferation Policy," Foreign Affairs, pages 875-894, Spring 1981.

4. IAEA, op. cit., pages 15 and 16.

the great variety of factors, it is extremely difficult to establish any causative relationships between the development of a particular commercial fuel cycle and the proliferation of nuclear weapons.

Finally, in those nations now having advanced nuclear-power programs, full-scale deployment of breeders is unlikely before the year 2000, and therefore this allows substantial time to develop more effective technical safeguards and international institutional frameworks. Because of this time scale, the cost, and other factors involved, the likelihood that other nations would pursue major independent programs of breeder development is low.

In future decades when LMFBRs approach commercialization, nonproliferation and international safeguards issues must continue to be reexamined. In the meantime, strengthening safeguards institutions like the IAEA, and advancing the technologies of accountability and surveillance, are not only of interest for potential future LMFBR applications, but are of interest now for LWR applications.

Comment (Letter #21, Attachment 2, page 3):

"Present safeguards are acknowledged to be inadequate and whether or not adequate safeguards can ever be designed and implemented within our framework of freedom and constitutional liberties remains highly doubtful."

Response:

Fissile materials have been handled in the U.S. in both the civilian and military sectors over the past 35 years during which time the domestic safeguards measures have proven highly successful without any detraction from personal freedoms or constitutional liberties. There is no evidence to suggest that safeguards systems cannot be equally successful in the future with equally small impacts on civil liberties. With the LMFBR program outlined in the Supplement, commercialization of the LMFBR will not occur before the 21st century, which allows many refinements to take place in safeguards systems presently under development.

Comment (Letter #11, pages 36-37, #21, attachment 1, page 18):

In regard to domestic safeguards on LMFBRs, the Supplement lacks qualitative and quantitative data on projected threats, safeguards goals, safeguards capabilities, and costs.

Response:

The goals and other information for the DOE safeguards program are presented in WASH-1535 and ERDA-1535. The safeguards aspects of a deployed LMFBR fuel cycle were addressed in WASH-1535.

The Supplement explains current capabilities and summarizes what has been and is being done to improve efficiency and effectiveness. Inasmuch as an active program on domestic safeguards for the back end of the fuel cycle was underway in 1975 and was described in ERDA-1535, Vol. 1, Section III-C.2, it was considered appropriate to report on the current status of this program in the Supplement.

There are a number of studies cited in the Supplement that examined the threat to domestic nuclear facilities and supplement the discussion in WASH-1535 and ERDA-1535. Since a number of existing DOE facilities (reactors, reprocessing, fabrication) and shipments are similar in character to those for the LMFBR fuel cycle, a picture of the threat as presently understood has been directly described. However, as newly perceived threats evolve in time, the LMFBR safeguards and security technology and physical protection strategies will also evolve, as they have over the last 35 years.

New DOE facilities, such as the new plutonium storage vault at Rocky Flats, the small mixed-oxide fuel fabrication line associated with the FFTF, the fast breeder spent fuel reprocessing facility being developed by Oak Ridge National Laboratory, and the CRBRP, are all being designed for effective safeguards, emphasizing automation, massive containment, on-line measuring instruments, control of personnel and continuous surveillance. As each of these comes into operation, the safeguards/physical protection features will be tested in order to detect and remedy weaknesses and to learn how to design the next such facility for more efficient safeguards. The timetable throughout the proposed RD&D phase calls for simultaneous safeguards system design and evaluation along with the design and evaluation of the individual facilities.

Safeguards and operating requirements often complement each other. Isolation of plutonium fuels in nuclear fuel processing facilities, shielding, remote control, on-line measuring instruments, and automation may reduce exposure of personnel to radiation, reduce the risk of a criticality excursion, and improve production quality control. In addition they all contribute to safeguards effectiveness. The major direct capital and operating safeguards costs are associated with external barriers, intrusion detectors, hardened guard posts, and security personnel. These costs for present major LMFBR facilities amount to less than 3% of total facility operating costs. Similar costs can be projected for future LMFBR facilities.

The quality of a domestic safeguards system should not be assessed only on the basis of the accuracy of measurements or on the potential results of periodic material balances, but rather on a combination of measures which include controlled access, containment, surveillance, etc., which are the proper measures to deter or to detect and respond to attempted thefts or diversion.

Classically, material accounting has emphasized periodic physical inventories, comparing what was found to what the records of receipts, shipments, and discards indicated should be there, and determining the book-inventory difference and the combined uncertainties in the difference. Clearly, discovering that something might have been stolen after many months of operation would not be very useful for stopping or responding to a diversion. Systems have been designed and demonstrated which employ on-line instruments to continually measure the material fed into and that withdrawn from each unit process in a fuel fabrication plant. Algorithms have also been developed that use the data from these systems to detect small and abrupt or more prolonged diversion from each stage of the process. U.S. safeguards today employ containment, surveillance, material accounting, personnel portal monitors and other measures to catch any internal adversary before that person can remove materials from a facility. Periodic physical inventories and material balances continue to be useful to determine whether or not the prompt detection elements and safeguards as a whole are performing adequately.

Comment (Letter #11, page 37):

"The DEIS mentions that the Barnwell Nuclear Fuel Plant is being used to develop advanced safeguards and the latest measurement and control technology. To what extent is the BNFP to be incorporated in the LMFBR program? Is it designed for fully remote reprocessing and the utilization of advanced safeguards technologies?"

Response:

Although the BNFP is not a part of the LMFBR program, results of safeguards RD&D activities at the BNFP will be used as appropriate in LMFBR-related facilities.

The Barnwell facility is designed for a combination of contact and remote reprocessing. Since 1976, scientists at the Barnwell facility have conducted studies on spent fuel management, alternative fuel cycle materials, reprocessing methods, and safeguards. Since Barnwell has only processed cold uranium solutions, it has been possible to install additional equipment for safeguards and security. The Barnwell facility has an advanced domestic safeguards operating system. In addition, it has been used for studies of near-real-time process monitoring techniques which may be useful for international safeguards. The highly automated material control and accounting system, and the physical protection system, which includes continuous TV surveillance of all areas, are described in numerous papers and reports. In addition to those references cited in the Draft Supplement, some recent papers describing safeguards capabilities are listed below:

Charles Joseph, "Inspections - A Cost Effective Approach" (computerized nuclear material control and accounting system uses), Journ. Nuc. Mat. Man., Vol. 10, Proceedings Issue 1981, pages 52-57.

L. D. Barnes, "Access Control System Operation," ibid, pages 232-237.

D. D. Cobb, et al., "Development and Demonstration of Near-real-time Accounting Systems for Reprocessing Plants," ibid, pages 411-421.

D. D. Cobb, et al., "Demonstration of Near-real-time Accounting: The AGNS 1980 Miniruns," Journ. Nuc. Mat. Man., Vol. 10, No. 1, 1981, pages 34-43.

L. D. Barnes, et al., "Automatic System for Controlling Authorization, Identification, and Entry into Nuclear Facilities," Proceedings 1981 Carnahan Conference on Crime Countermeasures (May 1981).

Comment (Letter #11, pages 36 to 39, #23, attachment 1, pages 18 to 21):

"During the last five years, there have been a series of U.S. Government Accounting Office (GAO) studies critical of existing security measures to protect nuclear weapons, nuclear materials, and nuclear plants. Given the failure of the U.S. government and commercial operators to provide adequate protection for nuclear materials and facilities, what is the basis for the apparent optimism in the DEIS that DOE will be able to develop and implement an effective safeguards system for an LMFBR fuel cycle which would require much more extensive handling and transportation of weapons-usable materials?"

The breeder fuel cycle differs substantially from, and presents greater safeguards and security risks than, the LWR fuel cycle, either with once-through fuel or with plutonium recycle.

Response:

The commenter does not clearly specify what issues discussed in the GAO reports represent the basis for these assertions. The GAO reports contain a wide mixture of recommendations and findings about safety and safeguards applied to several agencies of the U.S. Government and to both domestic and international safeguards. The GAO reports do not contend that the concerns identified in these reports cannot be satisfied. What these reports do indicate is that the GAO, in performing its role of oversight and analysis, is continually trying to help improve U.S. safeguards, based on its own perspective.

INFCE and NASAP studies have analyzed the differences between the breeder fuel cycle and a wide variety of alternative breeder fuel cycles and LWR fuel cycles, including those of the once-through and of the plutonium recycle types. The INFCE study participants, including the United States and more than fifty nations and international organizations, concluded that although closed cycle systems might be less proliferation resistant if deployed today, no single judgment about the risk of diversion from the different fuel cycles can be made that is valid over time. Moreover, INFCE Working Group 5 concluded that the diversion risks of the fast breeder reactor fuel cycle were no greater than the light water reactor with recycle or the light water reactor with the once-through cycle in the long term.

The NASAP studies, directed by the Department of Energy, recognized that each reactor and its associated fuel cycle create unique safeguards and security requirements, and each will require a unique safeguards response and approach. However, NASAP also concluded that time and the evolutionary development of safeguards could be a major factor in reducing the differences in the relative proliferation resistance of alternative fuel cycles.

Sensitive points in the nuclear fuel cycle as identified by INFCE included breeder mixed oxide fuel, uranium enrichment facilities and technology, spent fuel storage, reprocessing, plutonium storage, MOX fabrication, once-through cycle spent fuel and transportation. Reactors with batch refueling were viewed as being less sensitive than other steps of the fuel cycle.

Both INFCE and NASAP recognized that safeguards and security risks are different for different fuel cycles, that these risks are affected by the degree to which appropriate safeguards are developed and implemented, and that over the long term, no particular fuel cycle will necessarily produce an exceptional proliferation risk.

5. Waste Management

Most of the comments on the Supplement concerning waste management issues were previously raised and addressed during the course of the NRC Waste Confidence Rulemaking proceedings (NRC Docket PR-50, 51; 44 Federal Register 61372). Responses to comments often include references to DOE's Statement of Position and Cross-Statement filed in the NRC Waste Confidence Rulemaking proceedings. Page and paragraph numbers of applicable material from DOE's statements are provided as appropriate.

Comment (Letter #21, attachment 2, page 2; and attachment 3, Appendix C):

"It is questionable that a waste disposal facility will be operational by the period 1997 to 2006, and that it will be in a geologic medium which meets NRC regulations and EPA performance standards."

Response:

DOE believes that its schedules for disposal activities represent an appropriate planning basis and adequately identify the activities (and their durations, including contingencies to allow for public hearings and public interactions, in both the site selection and site development stages) needed to complete the projects in a reasonable timeframe. The existing and developing NRC regulations, and developing EPA standards, have been taken into consideration in developing these schedules.

(Cross-Statement page II-46, paragraph 3; page II-52, conclusion paragraph; and page II-130, paragraphs 1 and 2.)

Comment (Letter #21, attachment 2, page 3; and attachment 3, Appendix C):

"Ten thousand years may not be sufficient time for storing nuclear waste in a mined repository which meets NRC and EPA requirements, unless significant containment integrity is achieved beyond this time period."

Response:

Most evaluations indicate that, during the first 10,000 years, the radiological hazard due to spent fuel or high level waste placed in a repository will decrease to approximately the levels of radiological hazard associated with naturally occurring uranium ore bodies. Therefore, reasonable assurance that isolation will be achieved during the first 10,000 years will be provided, with no prediction of significant decreases in isolation beyond that time. (Cross-Statement page II-72, paragraph 2 through page II-74, first pragraph.)

Comment (Letter #21, attachment 3, page 39, and Appendix C, pages 13 and 14):

The DEIS discussion of institutional obstacles to DOE's waste management program is almost nonexistent.

Response:

The purpose of the Supplement is to present an update of information pertinent to the LMFBR program. Institutional obstacles to waste management programs are not new. A program to deal with these obstacles has been better defined since 1975 and is described in the Supplement (Section VI.A.(3) and Appendix B). In its Cross-Statement, DOE agreed with other participants that in the past the federal government had not adequately addressed non-technical problems, i.e., institutional obstacles (DOE Cross-Statement at page III-5). This is not the case today. DOE has established agreements with states and accounted for institutional concerns in its planning. In addition, DOE believes that the nation has decided that resolution of the nuclear waste issue is essential. Therefore, the public will hold its institutions accountable for expeditious, good-faith efforts to resolve their differences. (Additional discussion of this matter is found in the DOE Cross-Statement at Sections II-A and III-A.)

Comment (Letter #21, attachment 3, page 39, and Appendix C, pages 14-16):

The DEIS does not address: 1) DOE's failure to maintain a consistent program; 2) the substantial changes in program goals with each successive administration; 3) the proliferation of decision makers in the federal government; and, 4) the division of jurisdiction in Congress over waste disposal.

Response:

There are examples of past performance which contributed to variations of the waste management program. However, since 1977 there has been a significant increase in funding, increased interagency cooperation, and the initiation of a formal, but flexible, management system to measure progress. These measures will enable DOE to maintain consistency in its effort to complete the waste isolation program successfully. (Additional information on this issue can be found in Section II-A.5 of the DOE Cross-Statement.)

DOE notes that the most recent change in administration did not result in changes to the basic structure and goals of the ongoing NWTS program. The current administration initiated efforts to accelerate the program and provide for a test and evaluation facility. In fact, the President's

Nuclear Policy Statement of October, 1981, emphasized the necessity of an accelerated waste management program. This has not resulted in a change in the goal of providing a mined geologic waste disposal system in a timely, safe, and environmentally acceptable manner. (Additional information on this issue can be found in Section II-A.2.2 of the DOE Cross-Statement.)

DOE acknowledges that there are a number of federal agencies involved in the decision process relative to waste management. This ensures consideration of diverse viewpoints. DOE and other involved agencies have recognized the need to cooperate and to this end have entered into and established various mechanisms, such as memoranda of understanding and interagency working committees. Examples are the Earth Sciences Technical Plan with the U.S. Geological Survey and cooperative efforts with the Bureau of Land Management and the U.S. Army Corps of Engineers. (Additional information on this issue can be found in the DOE Cross-Statement at pages II-8 to II-11.)

The Department does not believe that multiple committee jurisdiction in Congress has had an adverse effect on the waste management program.

Comment (Letter #21, attachment 3, page 39, and Appendix C, pages 16 and 17):

The DEIS does not analyze the problems associated with state and local concerns over waste disposal and the federal government's consistent failure to deal with these issues.

Response:

It is not the intent of the Supplement to discuss the details of the problems associated with state and local governnments opposing the siting of waste disposal sites within their respective boundaries. Appendix B of the Supplement does set forth DOE's policy that decisions will be made openly and subject to public scrutiny, participation, and review. As discussed in DOE's Cross-Statement, the mechanisms to incorporate state and local views are still evolving (DOE Cross-Statement at page II-16). Mechanisms to exchange information and to address the concerns raised by state and local governments are in place (DOE Cross-Statement at pages II-19 and II-20). For example, agreements have been entered into with states, and licensing, arbitration, and resolution by the President and/or Congress are always available conflict resolution mechanisms. Conflict resolution is also addressed in many of the nuclear waste management bills currently before Congress. (Additional discussion of this matter is found in Section II-A.4 of the Cross-Statement.)

Comment (Letter #11, page 49):

The Test and Evaluation Facility (TEF) was characterized as a major step to help identify issues that might significantly delay the waste management program. It was suggested that if the Test and Evaluation Facility is constructed at a potential repository site it will jeopardize the integrity of the proposed site.

Response:

The Test and Evaluation Facility (TEF) is intended to confirm design and practical considerations related to occupational exposure protection, waste handling, and shaft and ventilation performance. It is possible that the name Test and Evaluation Facility misconstrues the objective of the facility. It is not unlike a pilot plant or scaled-down version of the actual repository.

The TEF is not on the critical design and engineering path for constructing a repository. The TEF will not address site-specific issues related to the safety of permanently disposing of and isolating high-level waste. The lowering and physical emplacement of heavy canisters into an underground environment is not a particularly unique or complex requirement. Also, the physical protection of workers handling radioactive materials is not a new problem and has been successfully accomplished for years.

Consequently, the purpose of the TEF is to confirm and further evaluate the performance of prototypical equipment, instrumentation, and techniques. Its function is one of verification only. The TEF should not be confused with at-depth testing which will be performed at each repository site. The scientific research done during the at-depth testing phase will specifically address the capability of the local geologic environment to isolate high-level nuclear waste over long periods of time.

If a TEF is sited at a site proposed for a repository, DOE is committed to assure that the TEF does not in any way jeopardize the integrity of the proposed site.

Comment (Letter #11, pages 42 and 43):

"The DEIS seeks to gloss over the waste management issue with a brief and glowing discussion...The DEIS in this area is inaccurate and grossly misleading...The Waste Confidence Rulemaking comments...should be referred to at length in the preparation of the Final Environmental Impact Statement and in reaching a final decision on the LMFBR program."

Response:

DOE acknowledged in the Supplement that the major waste management issue is, and has been, the unavailability of a generally accepted method for removing and segregating high-level and transuranic radioactive wastes from man's environment for the long time periods required for these wastes to decay to safety levels (Supplement, page 173).

In addition, the Department acknowledged that the Nuclear Regulatory Commission (NRC) is conducting a rulemaking proceeding to reassess its degree of confidence that high-level radioactive waste will be safely disposed of, as well as to determine when such disposal will be available and whether such wastes can be safely stored until they are safely disposed of (Supplement, page 178). It was believed that these statements are sufficient to alert the public that there are organizations, state and local governments, and individuals that hold the opinion that there will not be a disposal system in place as planned for by DOE.

The issues associated with waste management raised by the commenters are addressed in the Confidence Rulemaking. DOE's response to these and other issues are contained in the Statement of Position of the United States Department of Energy (DOE/NE-0007) and the Cross-Statement of the United States Department of Energy (DOE/NE-0007, Supplement 1). The record of this proceeding is so voluminous that it is not possible, nor is it necessary, to address all these issues in the Supplement. Some specific responses to the issues raised in specific comments are provided, however.

Comment (Letter #11, pages 46-57):

"Failures and Deficiencies that Have Prevented Successful Waste Management to Date and that Preclude a Finding that the Public will be protected from LMFBR Wastes ...

a. DOE's Waste Management Program must be Viewed in Light of Its History of Consistent Failure ...

b. Lack of a Basis for Concluding that an Acceptable Site Has Yet Been Identified ...

c. Failure of the DOE Waste Management Program to Follow the Concepts of a Systems Approach and Defense-in-Depth ..."

Response:

The waste managment program in the United States has been underway for a number of years. During that time, however, and contrary to the commenter's assertion, significant progress has been made in both the technical and institutional areas.

Concerning comment "a," it is noted that steady and continuing progress has been made in both the technical and "institutional" aspects of waste disposal. For example, field tests are underway, or have been conducted, in a number of test media including salt, granite, basalt, tuff and clay. The tests have provided technical data for physical characterization of the various media and for utilization in the development of models. Further, ongoing field exploration activities continue to provide site specific data for use in the selection process.

The complexity of the waste disposal issue is fully recognized by the Department. As a consequence of this recognition, the Department has established a detailed plan for integration of both technical and institutional concerns including siting, regulatory, socio-political, and environmental requirements in a timely manner. The Department recognizes that the prediction and evaluation of socio-economic and political issues cannot be made with the same level of confidence as the case for technical issues but continues to maintain that evolving public and legislative awareness of the scope of the waste management problem, coupled with a recognition of the social implications of the program, will result in reasonable assurance that the program is continuing to make progress toward a safe and environmentally acceptable repository within the timeframes involved. (Detailed considerations of these points are found in the DOE Confidence Rulemaking Position Statement at pages II-244, II-288, III-65, and III-86, and in the DOE Cross-Statement at page II-28 and pages II-55 to 61.)

Regarding the commenter's second major point, DOE's site selection and testing program is being conducted in a number of media and potential sites with the recognition of a certain probability that some of the potential sites will be found to be unsuitable, or less suitable than others. Because of this conservative, step-by-step approach, the Department is confident that a safe and environmentally acceptable repository will begin operation between 1997 and 2006. (For further information see the DOE Cross-Statement at pages II-138 to 140, and the DOE Position Statement at page II-128.)

Contrary to the commenter's assertion that DOE is not applying a "system" and "defense-in-depth" approach to waste management, the Department has consistently reiterated its dedication to both of these concepts. The defense-in-depth considerations inherent in the DOE program are best illustrated in the redundancy of barriers found in the integration of the natural and engineered systems into an overall repository system, as well as consideration of the interaction of one part of the system with another in design of the system (for example, thermal impacts on the media). This approach not only enables the application of conservative design principles, but also provides a technique for adding the flexibility necessary to increase system effectiveness and to relate the waste form and package to specific media. Criteria have been developed and described relative to both the natural and engineered system which may not be deviated from without a clearly demonstrable benefit in overall system effectiveness.

In regard to the statement that potential sites have been selected on a "federal ownership" basis and without predetermined criteria, the DOE program is not limited to federally owned property but is actively investigating potential sites located on private property. Site selection factors were specifically chosen based on the characteristics needed to isolate the waste from the biosphere, and have been and will continue to be subject to review by recognized experts. The DOE program is structured to allow conservatism relative to safety by means of (a) a step-wise approach enabling continual re-evaluation of the existing state of knowledge, (b) the use of relatively independent multiple barriers to make overall system failure nearly impossible, and finally (c) the use of design and operating margins (safety factors) to account for any remaining areas of uncertainty. As the DOE has previously stated, the multiple barrier system is assumed to consist of three major subsystems, the natural system, the waste package, and the repository (engineered system).

The necessity for risk assessment and mathematical modeling is self-evident due to the periods over which a repository must function. The defense-in-depth concept is not inconsistent with the risk assessment approach, provided adequate margins of safety (conservatism) are consistently included to account for less than "complete knowledge" in any particular area. A definition of "acceptability" is only possible within the broader "systems" concept. Much of the information necessary for risk assessment will be derived from site specific studies, which, as previously noted, are now underway as part of the site selection program. In-situ studies now underway, and planned for specific sites, are enabling the Department to verify models at an increasing pace with a view to demonstrating that there is reasonable assurance of overall repository safety. (Detailed discussion of the these issues may be found in the DOE Position Statement at pages I-15 to 19, II-4, II-16 and 17, II-22 to 26, II-44, II-46 and 47, II-129 and 130, II-202 to 207, and III-32; and the DOE Cross-Statement at pages II-31 and 32, II-36, II-81 to 86, and II-130.)

Comment (Letter #11, page 57, #21, attachment 3, page 38):

Since there is no assurance that a safe permanent disposal repository will be available for LMFBR wastes, it must be assumed that LMFBR wastes will be stored in short-term facilities. The short-term facilities will become long-term and this is both practically and legally unacceptable.

Response:

In the DOE Position Statement and Cross-Statement, DOE concluded that (1) spent nuclear fuel from licensed facilities can be disposed of in a safe and environmentally acceptable manner, and (2) the Federal Government's plan for establishing geologic repositories is an effective and reasonable means for developing a safe and environmentally acceptable disposal system.

For the reasons given in the DOE Position Statement and Cross-Statement, DOE disagrees with the comment that a permanent repository will not be available for LMFBR high level and TRU wastes. In the unlikely event that waste from the LMFBR fuel cycle requires storage, it is not the intent of DOE to have any interim storage facility turned into long-term above-ground storage.

Comment (Letter #21, attachment 3, page 35):

"No method for the permanent disposal of waste exists, as DOE has admitted in its filings with the NRC in the waste confidence proceeding."

Response:

The DOE position in the Waste Confidence Rulemaking Proceeding has been that attempting to achieve absolute confidence that a permanent waste disposal method exists is unrealistic. The Department's position is based on the accepted principle of reasonable assurance. The NRC has concurred with this approach. DOE has shown, throughout its position and cross-statements in the Confidence Rulemaking Proceedings, that recognized technical and institutional issues are being addressed within the high-level waste management program, and that a commitment exists to address any new issues that may develop.

Institutional concerns including legislation, issue resolution, state/local/federal government interactions, legal proceedings (hearings), socio-economic impacts, and the regulatory process have been discussed extensively by the DOE in its Position and Cross-statements for the Waste Confidence Rulemaking Proceeding. In recognition of the importance of such issues, the Department has developed specific plans for, and devoted significant resources to, their resolution. The considerations involved include equitable treatment of the concerns of all parties involved, including mitigation planning where appropriate, close liaison with regulatory agencies; and the development of a National Siting Plan and associated environmental assessment.

Regarding the concern that resolution of technical questions may not occur in a timely fashion, the Department notes that its schedules have been derived based on anticipated R&D and regulatory requirements. Additionally, the DOE believes that the broad range and conservatism (step-wise approach) inherent in its technical development program preclude the necessity to place total reliance on satisfactory completion of individual R&D efforts. (Further information on these points is found in the DOE Cross-Statement at pages I-6, I-7, II-3 to 22, II-45 to 50, II-52 to 54, and II-70 to 79; and the DOE Position Statement at page II-298 and pages III-65 to 68.)

Comment (Letter #21, attachment 3, page 38, and Appendix C):

The number of sites needed for disposal should have been analyzed.

Response:

The question of availability of acceptable sites has been addressed previously and the DOE position continues to be that the current program, involving several media and a number of potential sites, provides reasonable assurance that an acceptable site, or sites, will be available. The Department maintains that the number of repositories ultimately needed (estimated at 3 to 6 depending on nuclear growth and repository heat loading assumptions) does not adversely impact current site selection and research and development programs. Construction and licensing of subsequent repositories will not occur in the same time period as the first facility, and there will be no dilution of either the Departments' or the NRC's activities. It should also be noted that since potential repository sites are widely distributed geographically, and are in several media, the cumulative impact of more than one facility will be minimal, and the chances of locating a number of acceptable sites are enhanced. (For additional information see the DOE Cross-Statement, Section II.A.11.)

Comment (Letter #21, attachment 3, page 36, and Appendix C, page 7):

"There is no real understanding of the interaction of waste with host rock and therefore no assurance that the physical, chemical, and thermal effects induced by the presence of the waste will not cause unmanageable disruptions."

Response:

The Department recognizes the need to understand and evaluate the effects of heat and radiation on a site. A body of knowledge on these effects has been developed. Studies have shown that the effects of radiation on rock strength are limited to within one meter of the waste canister and do not affect room or regional scale rock response. The radiolytic effects of brine chemistry (for salt as a host medium) are being factored into waste package material selection studies. Other effects of radiation have been shown to be insignificant. Thermal effects have been and are being studied and incorporated into models of local rock response.

The uncertainties that remain can be accommodated by use of conservative designs. Repository designs are being based on conservative temperature limits. Waste package designs are being developed to limit the effects of waste-rock interaction. (For further information see DOE Cross-Statement, pages II-94 to 96.)

Comment (Letter #21, attachment 3, page 37, and Appendix C, page 7):

"Little is known about water transport of radionuclides to the biosphere."

Response:

DOE's site characterization approach includes careful evaluation of site hydrology. Standard techniques exist for the evaluation of ground water flow that provide sufficient description of the hydrologic system to allow assessment of site performance. In fact, deep hydrologic systems (e.g., geothermal systems) have been modeled and successfully described. Where uncertainties do exist, bounding calculations are carried out to determine the consequences of the upper limits of uncertain parameters. In addition, model development and field and laboratory studies are in progress to reduce uncertainties in important areas such as refinement of models for flow in fractured media, radionuclide sorption and speciation, and to obtain site specific parameters. (See DOE Cross-Statement Section II.B.6.1 for further information.)

Comment (Letter #21, attachment 3, page 37; and Appendix C, page 8):

"The DEIS asserts that 'any of (the potential host rocks) can prove to be acceptable for the mined geologic repository' (DEIS, p. 185). Contrary to this assertion, none of the geologic mediums under study have been shown to be technically capable of assuring safe isolation. Each medium under consideration is know to present serious, time-consuming, and possibly insurmountable problems".

Response:

A large amount of technical data has been collected on the properties of potential sites. Sufficient information exists to bound the effects of uncertainty on site performance. There is no evidence that the uncertainty associated with scientific knowledge about any medium has adverse implications about the adequacy of the media being studied. (Issues specific to each medium are discussed in Section II.B.6.4 of the DOE Cross-Statement.)

Comment (Letter #21, attachment 2, page 3, attachment 3, page 37; and Appendix C, page 8):

"It remains to be established that repositories can be located to withstand future climatic changes such as re-glaciation or significant increases in precipitation or surface erosion."

Response:

The Department recognizes the need to understand the effects of climatic changes. The investigation of potential sites includes the evaluation of the potential for climatic changes and the possible effects on the site's hydrologic regime. Studies are in progress that incorporate consideration of a wide range of natural processes, including climatic changes. (See the DOE Position Statement, page II-97, and the DOE Cross-Statement, page II-125 for additional information.)

Comment (Letter #21, attachment 2, page 3, and attachment 3, page 37, and Appendix C, page 8):

"Expertise must be available to completely and permanently seal the shafts, boreholes, and exploratory openings used to develop and characterize sites. Decommissioned repositories must be sealed to prevent contamination of the biosphere."

Response:

The extent to which boreholes and shafts must be sealed must be determined on a site-specific basis. Systems assessments of repository performance have not indicated that complete sealing is required to ensure that adequate isolation is achieved. In addition, the final choice of sealing materials need not be made until after repository operations are concluded. Past experience with seals has shown seals to be effective in a variety of environments. Studies of seal longevity have been underway and have not revealed evidence of significant deterioration of seals. (For further information see DOE Cross-Statement at pages II-106 to 109.)

Comment (Letter #21, atachment 2, page 3; and attachment 3, page 37; and Appendix C, page 9):

"A fail-safe system of monitoring facility performance must be devised and installed at the time the repository goes into operation. The system must be capable of detecting all malfunctions that might occur in the repository during and after the operational period."

Response:

The Department believes that environmental monitoring following decommissioning will not be necessary. The time that will pass following repository closure before any radionuclide release could be detected extends far beyond the time span presently considered reasonable for reliance on institutional controls. Since monitoring falls within the category of institutional controls, it is not prudent to rely on such measures for safety. Therefore, the Department is designing the disposal system so that long-term monitoring is not a prerequisite to ensuring safety. Provisions will be made, however, to establish monitoring programs required by NRC or states or local communities. (See DOE Cross-Statement at pages II-114 to 116 for further information.)

Comment (Letter #21, atachment 3, pages 34 and 35):

"The DEIS' very framing of the waste disposal issue--the availability of a 'generally accepted method' for handling radioactive waste (p. 173) is improper. By characterizing the issue this way, the DEIS implies that there is an acceptable method for handling wastes."

Response:

It should be noted that the deep geologic disposal concept has been designated as the preferable alternative in both the Confidence Rulemaking Proceeding and in the DOE Final Environmental Impact Statement for the Management of Commercially Generated Radioactive Waste (DOE/EIS-0046F, October 1980). In addition, a record of decision was issued in May 1981

(46 FR 26677-26679) in which DOE documented its decision to adopt a strategy to develop mined geologic repositories and accomplish the necessary development activities.

The "technical" and "institutional" aspects of the Departments' Waste Management Program have been exhaustively discussed in the voluminous submittals prepared for the Waste Confidence Rulemaking proceeding and are summarized in response to other comments. A new paragraph was added on page 173 of the Supplement to show that a permanent disposal method (geologic disposal) exists and to add reference to the Final EIS on the Management of Commercially Generated Radioactive Waste and to the Record of Decision. These documents were referenced in the Supplement previously - reference 5, page 177; and reference 1, pages 174 and 178. (More detailed discussions of this point are found in the DOE Position Statement, pages II-28 and 29 and page III-38, and the DOE Cross-Statement, pages II-143 and 144.)

Comment (Letter #11, pages 43-46):

DOE lacks the commitment to achieve a waste disposal solution. The LMFBR program should not go forward until permanent, safe disposal of high-level waste can be demonstrated.

Response:

DOE believes that the Supplement amply demonstrates that a program is in place that will result in permanent disposal of high-level waste. The DOE Statement of Position and Cross-Statement contain several hundred pages describing DOE's program to achieve waste isolation. The time and resources currently being expended on this program certainly do not indicate a lack of commitment.

The issue raised by the comment is being addressed in the NRC Waste Confidence Rulemaking. Upon completion of NRC's Waste Confidence Rulemaking, the Commission will promulgate a rule addressing the consideration of disposal of waste in individual licensing proceedings. (For additional information see the DOE Cross-Statement, page II-27, last paragraph, and page II-29, first paragraph and conclusion paragraph.)

Comment (Letter #11, page 59):

" ... the DEIS essentially assumes that waste management issues will involve no environmental impacts that must be taken into account in deciding whether to proceed with the LMFBR program."

It was stated that this assumption is invalid and that the EIS on the LMFBR program must include a more balanced presentation, address the liabilities of inevitable long-term above-ground storage, and identify the significant risk of eventual human exposure to LMFBR wastes as "an environmental impact that must be taken into account."

Response:

This assumption is not found in the Supplement nor in WASH-1535 or ERDA-1535. The environmental risks associated with above-ground storage of LMFBR wastes were addressed in WASH-1535 (Section 4.6, Volume II). It was shown in ERDA-1535 that a permanent geologic disposal facility should be available well before it is required in order to handle high-level and transuranic wastes from commercial LMFBRs. As stated in the Supplement (page 173), LMFBR high-level and transuranic wastes do not pose new or unique problems.

> "This problem is not unique to the LMFBR fuel cycle, but also must be resolved for the LWR or other nuclear fuel cycles before there is a need for disposal of high-level and transuranic wastes for the LMFBR fuel cycle. Furthermore, the quantities of LMFBR high-level and transuranic wastes will be considerably smaller than the quantities of such wastes from the LWR fuel cycle or from defense programs until well into the twenty-first century. For purposes of the waste management program, LMFBR and LWR high-level and transuranic wastes are essentially the same."

Comment (Letter #21, attachment 3, page 37):

There is a gap in technical knowledge in rock mechanics.

Response:

The response of the local host rock to perturbations caused by excavation, heat, and radiation have been and are under extensive study in laboratory and in situ tests and in model development. Constitutive models to predict the response of the local host rock, which address the stress-strain response of the rock as a function of temperature, load, load-rate, strain-rate, load-path, and duration, have been developed. In situ tests of rock stability in the presence of temperatures beyond those expected in a repository have been conducted with no resultant indication of adverse effects. DOE believes that a wide range of knowledge on rock mechanics exists and that, within the range of conditions that will exist in a properly designed repository, no rock mechanics phenomena have been shown to have possible effects that would jeopardize the repository performance.

(Further information on rock mechanics can be found in the DOE Cross-Statement, pages II-100 to II-106.)

Comment (Letter #21, attachment 3, page 37):

There is a gap in technical knowledge in "canister degradation, waste form dissolution, reaction in the overpack region, ... and waste packaging."

Response:

DOE has an extensive program directed at developing long-lived multibarrier waste packages. These studies address the waste form and materials for stabilizers; canister, overpack, and sleeve materials; and hole backfill materials. In addition, package design, testing, and performance assessments are also in process. DOE believes that the body of information available supports its position that long-lived multiple barrier packages can be designed and built in a timely manner. (Specific issues relating to the waste package are discussed in detail in the DOE Cross-Statement, pages II-93 to II-100.)

Comment (Letter #21, attachment 3, page 37):

There is a gap in technical knowledge on "seismic and tectonic activity."

Response:

The determination of the rates of occurrences of potential seismic and tectonic events with absolute certainty is not required to ensure that isolation is achieved. The DOE's conservative approach incorporates the consideration of potential catastrophic events in its evaluation of system performance. The likelihood and potential effects of such events can be adequately bounded and accounted for by the use of conservative system design and the selection of sites to avoid areas where the likelihood and effects of such events are unacceptably high. The USGS supports the use of a conservative approach and feels that acceptable repositories can be constructed using such an approach. (See DOE Cross-Statement, pages II-127 and 128.)

Comment (Letter #21, attachment 3, page 37):

There is a gap in technical knowledge on retrievability.

Response:

DOE is committed to maintaining retrievability as a planned contingency in its approach to repository development and operation. The requirements imposed by retrievability are factored into waste package and repository design. Waste packages are being designed to contain the waste and to allow retrieval throughout the operational phase and beyond. Repository design features required to ensure operator safety during retrieval operations are within the state of the art applied in nuclear facilities and in recovery of nuclear materials. Reentry of emplacement rooms can be achieved using conventional mining techniques coupled with radiation protection measures. No substantive issues regarding retrievability have been raised. Designs and plans for retrievability will be finalized on a site-specific basis when NRC requirements for the retrieval period are established. (See DOE Cross-Statement, pages II-109 to II-113.)

Comment (Letter #21, attachment 3, page 38, and Appendix C, page 12):

"The DEIS alludes to 'predetermined criteria' for the waste disposal repository (DEIS, p. 181). However, environmental, site selection, and performance criteria for a repository are still speculative, as is a demonstration that the criteria can be met."

Response:

In addition to meeting licensing requirements, the DOE is independently responsible for the safety and environmental acceptability of any waste disposal system it develops. The DOE has developed guidelines and criteria for the conduct of its programs to ensure that safety and environmental acceptability are maintained. Therefore, the absence of regulatory criteria does not hamper the progress of the program.

The standards issued by the NRC are preliminary at this time and many changes are expected before a final rule is issued. When final standards are issued by NRC and EPA, the DOE will assess its program activities to ensure that they will result in a repository that complies with those standards. (See DOE Cross-Statement, pages II-31 through II-34, and II-36 through II-38.)

Comment (Letter #21, attachment 3, page 38, and Appendix C, page 10):

"A third technical problem that the DEIS fails to adequately address is the state of DOE's mathematical models (DEIS, p. 182). The models are used to compensate for uncertainties in technical knowledge (DEIS, p. 182). However, the DEIS fails to acknowledge that modeling is currently undeveloped, that there is no indication that it will be successfully developed, and that USGS has rejected reliance on models."

Response:

Modeling is used in the DOE program for two purposes, to aid in site selection and repository and waste package design, and to qualify and license a waste disposal system. Further development of modeling capabilities is required to support licensing decisions. However, the science of modeling is well advanced, and before licensing these models can be and are being used to assess performance of the system and its subsystems. These assessments are made using conservative, bounding assumptions that result in pessimistic predictions of repository performance, and are used to bound uncertainties so that they can be compensated for.

Currently, the DOE programs are directed toward refining and coupling models and extending the data to be used with them. Models are being verified using correlations with laboratory and in situ tests and natural systems. Extensive field, laboratory and in situ tests are underway to provide input data. In particular, plans for site-specific data acquisition are defined. The lack of site-specific data is not an indication of a "technical gap" but is rather the result of the fact that no specific site has yet been chosen.

In summary, the Department believes that the models presently available can be used with conservative assumptions to bound uncertainties and that development programs are underway or planned that are adequate to provide for the improvement of modeling capabilities necessary for qualification and licensing of a repository. (Further information can be found in the DOE Cross-Statement, pages II-81 through II-86.)

Comment (Letter #21, attachment 3; Appendix C, pages 5 and 6):

Actual assurance that geologic repositories can isolate radioactive wastes requires:

"'(C)omparing the results of field experiments to the model predictions and modifying the models. . . . The experiments must, of course, be carried out under conditions representative of those inside a loaded repository; that is, in situ. It is only under these circumstances that the isolation hypothesis can be validated and reasonable assurance achieved.'

"None of the waste experiments to date have utilized a vigorous scientific hypothesis testing and model verification method, and certainly no in situ test experiments have been performed which demonstrate verification of the geologic repository concept.

"DOE admits that in situ testing is necessary to assure adequate site characterization and verification and to verify the models used for performance assessment. However, in this area as in others, DOE looks to additional 'planned in situ tests to provide sufficient data.' DOE thus admits that concept feasibility has not been proven, and that its optimism that it will be shown is dependent upon successful completion of as-yet unperformed in situ experiments." (Footnotes and references were omitted.)

Response:

The approach being used by the Department is a conservative step-wise progression through siting and repository and waste package design. At each step in the process appropriate tests are to be conducted. In situ testing is an important part of this process and is included in DOE's plans. Numerous field tests are presently underway that have provided "in situ" data for the verification of models and input to the siting and design efforts. (For further information on the field tests presently underway, how in situ information is used, and what in situ testing is planned, see the DOE Position Statement, pages II-248 through II-258; and the DOE Cross-Statement, pages II-140 through II-143 and page II-82.)

6. Alternative Technologies

Comment (Letter #11, pages 29 and 30; #21, attachment 1, page 9 and attachment 3, pages 22-26; #8):

The discussion of alternatives was inadequate because many alternative technologies (e.g., geothermal, biomass, CANDU reactors, advanced/modified LWRs, cogeneration, hydroelectric, advanced converters, light water breeder reactors, fusion-fission hybrid breeders, etc.) were not addressed.

Response:

Discussion in the Supplement focused on major long-term technologies. Alternative nuclear technologies such as advanced/modified LWRs, CANDU reactors, advanced converters, and light water breeder reactors either extend the uranium resource base only modestly, or, based on industry plans, are not likely to be competitive; therefore, these options cannot be considered true alternatives to the LMFBR. Geothermal, biomass, cogeneration and hydroelectric are all expected to make small, regional contributions to the long-term electricity supply. However, at the present time, none of these technologies seems to be capable of providing a major portion of projected baseload capacity requirements. Fusion-fission fission hybrid reactors are considered to be one facet of the fusion option, which is discussed. It is recognized that while this concept is not the subject of extensive research in this country, it is receiving significant attention abroad, particularly in the USSR. As stated in the Supplement (page 94):

"Solar electric and fusion were the two technologies singled out in ERDA-1535 as major candidates, in addition to the breeder, to provide an essentially inexhaustible source of energy to help meet the Nation's electrical energy needs in the next century. These are still the primary candidates for meeting long-term U.S. energy needs. Government policy is that public spending is appropriate in long-term energy research, where the risks and potential payoffs are high.[12] The LMFBR, solar electric and fusion programs are all being pursued."

In addition, many of these alternative technologies were discussed in WASH-1535, as shown in the following table:

Technology	Section in WASH-1535
High-Temperature Gas-Cooled Reactors	6A.1.2 (Volume III)
Light Water Breeder Reactors	6A.1.3 (Volume III)
Gas-Cooled Fast Breeder Reactors	6A.1.4 (Volume III)
Hydroelectric	6A.3 (Volume III)
Geothermal	6A.4 (Volume III)
Biomass (Organic Wastes)	6A.6.5 (Volume III)
CANDU Reactors	- (Volume V)

Comment (Letter #11, pages 18-19):

The DEIS does not compare commercialization goals and readiness dates for alternative technologies. The DOE solar photovoltaics goal of $700/peak kw by 1986 was cited as making this technology competitive for central station utility applications.

Response:

The Supplement does consider wind, solar photovoltaics, solar thermal, and geothermal energy as potential long-term contributors to the national energy supply. However, the Supplement does not give equal weight to every contributing or potentially contributing technology, but rather emphasizes technologies that are expected to make major contributions to energy supply in the foreseeable future. Major contributions are not expected from wind, solar-electric, or geothermal energy in the near term. Midrange projections[1] to the year 2000 show primary energy displacement in electricity production to be 0.5 quads by wind, 0.4 quads by geothermal energy, and 0.14 quads by solar-electric technologies. This total of just over 1 quad compares with a projected total of over 32 quads due to coal and nuclear energy.

The projection of a relatively minor role for these technologies in the near term is consistent with the view of the CONAES study of the National Research Council:[2]

"Because of their higher economic costs, solar energy technologies other than hydroelectric power will probably not contribute much more than 5 percent to energy supply in this century, unless there is massive government intervention in the market to penalize use of non-renewable fuels and subsidize the use of renewable energy resources."

The DOE cost goal of $700 per peak kilowatt by 1986 is cited as evidence that solar photovoltaics could be competitive for central station applications. Installed in a utility system, this goal corresponds to about $2 per peak watt, as about two-thirds of the system cost is due to non-photovoltaic apparatus.[3] At this level, solar photovoltaic electricity

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1. DOE/PE-0029, "Energy Projections to the Year 2000," July 1981, pages 9-7, 9-8, 9-9, and 10-9.
2. CONAES, op. cit. page 71.
3. EPRI Journal, Dec. 1981, page 51.

begins to be competitive with the most expensive utility electricity today, peak-period electricity produced by oil-fired power units.[3] The cost target is still considerably above today's cost for electricity generated by new nuclear or coal-fired powerplants. Significant displacement of baseload capacity would require integration of storage capacity into the photovoltaic system, thus introducing a further economic disadvantage.

It should also be pointed out that $2 per peak watt installed is a goal, and that present photovoltaics system costs are around $30 per peak watt installed[3]. The target cost may be too optimistic,[4,5] and the outlook for achieving the goal by 1986 is uncertain.[3,4]

Peak-period electricity produced in oil-fired powerplants also represents the cost target for solar-thermal electric plants and wind turbines. These also represent intermittent electricity sources. Geothermal plants, however, provide baseload electrical capacity.

Reducing costs to acceptable levels is a major problem in the development of solar-thermal electric plants. Electricity from the Themis solar electric plant in France is expected to cost almost 25 times as much as that from Superphenix, the first full-scale LMFBR plant[6]. In the U.S., direct coupling of solar-electric plants with oil or gas-fired plants is considered a promising technology, provided significant cost reductions

4. CONAES, op. cit. page 368.
5. EPRI Journal, Dec. 1981, pages 46 and 76.
6. The Energy Daily, January 21, 1981, page 2.

can be effected.[7] Near-term competition with conventional baseload generating plants does not appear feasible and is reflected in the DOE projections.[1]

Similarly, wind energy can be expected to make small, local contributions in a fuel-saver mode over the next two decades. Economic development of high-grade geothermal resources is also expected. The 0.9 quads of primary energy projected to be displaced by these two technologies by the year 2000 is based on the assumption that present technological difficulties can be overcome[8].

The importance of the cumulative effect of small contributions from many technologies to the overall national energy supply is recognized. Nevertheless, it seems appropriate to restrict the Supplement to a discussion of major future contributors to the nation's electrical capacity. Indeed, solar photovoltaics is mentioned throughout the Supplement as a potentially significant contributor in the long term, along with coal, fusion, and the LMFBR. However, it is not obvious that photovoltaics will be in direct competition with these other technologies, given its intermittent nature as a power source. Operating as a fuel-saver in the utility mode, in industrial applications, and in areas not serviced by a central electricity distribution system, solar photovoltaics could contribute significantly in a complementary role.

Additional information concerning commercialization goals for alternative technologies is given in the following table.[9]

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7. EPRI Journal, December 1981, page 40.
8. DOE/PE-0029, pages 9-7 and 9-8.
9. DOE/PE-0040 (Vol. 2), Sunset Review, Program-by-Program Analysis, February 1982.

Technology	Goals
Solar photovoltaics	\$1.25 per peak watt installed by fiscal year 1988.[10]
	2,000 peak megawatts to be produced in fiscal year 1988.[10]
Wind energy systems	Reduce average cost of electricity from wind energy systems to level competitive with conventional systems by 1988.[11]
	Reach total wind energy system capability of 800 MWe by 1988.[11]
Ocean thermal energy conversion	As stated in Supplement (page 109) and installation of 10,000 MWe of commercial capacity by 1999.[12]
Solar thermal (utility electric power)	\$1,300 per kWe by 1985-87.[13]

10. DOE/PE-0040 (Vol. 2), page 146.
11. DOE/PE-0040 (Vol. 2), page 159.
12. DOE/PE-0040 (Vol. 2), page 162.
13. DOE/PE-0040 (Vol. 2), page 156.

7. Environmental Impacts of Alternative Long-Term Technologies

Comment (Letter #21, attachment 1, pages 14-16):

"We disagree with the statement at the beginning of the section on the Environmental Impacts of Alternative Long-Term Technologies which states: 'Comparative quantitative analyses of alternative long-term technologies are not possible at this time.' (DEIS p. 213) In fact, extensive quantitative environmental assessments have been done for both conventional and renewable energy sources....

"These works should be reviewed and incorporated into a comparative assessment of environmental impacts. They do not evaluate all environmental risks, nor do they claim to. Nevertheless, they provide useful information on risk assessment methods and drawbacks, actual occupational and public health and safety risks, and they are careful to highlight those risks that cannot presently be included due to lack of data."

Response:

The initial statement in the Supplement has been deleted and replaced with a revised introductory sentence for the second paragraph on page 214. The references referred to in the full comment, and related references, were reviewed. They were not incorporated into a comparative assessment of environmental impacts because there were substantial quantitative differences among them (e.g., impacts estimated by Holdren et al. often differed from those estimated by Inhaber by one or more orders of magnitude).

Comment (Letter #21, attachment 1, page 15; #6, page 1):

"The list of impacts in Table 11 is grossly incomplete: 'Land Use,' 'Water Use,' and two 'Construction Materials' estimates. On the basis of this scanty data, the DEIS concludes:

> 'It can be inferred from this table that the environmental impacts associated with construction will be less for the LMFBR than for most other long-term technologies.' (DEIS P. 213)"

This statement is misleading/incorrect.

Response:

It is agreed that this statement is misleading. It has been deleted from the text of the Supplement.

8. Purpose of and Need for the LMFBR Program

Comment (Letter #21, attachment 1, pages 10 and 11 and attachment 3, page 16; #11, pages 26 and 27):

The DEIS fails to provide data supporting its conclusion that LMFBR costs will be competitive with LWR costs. The DEIS conclusion that LMFBR development is favored by projected costs of electricity from the LMFBR is inappropriate when the uncertainty in LMFBR cost estimates is considered.

Response:

Estimated delivered costs of electricity, and the uncertainty associated with the estimate, are a consideration in DOE's recommendation for allocation of research and development funds.

It is true that studies exist which estimate that the LMFBR will not be economically competitive with LWRs until the second half of the next century.[1] It is also true that other studies exist which estimate a much earlier date for LMFBR competitiveness.[2] That so wide a variation exists simply reflects the sensitivity of the results to assumptions of future events (e.g., discount rates, uranium costs, future plant costs for both LWRs and LMFBRs, numbers and performance characteristics of plants deployed, etc.).

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[1] B. Chow, Economic Comparison of Breeders and Light Water Reactors, Pan Heuristics Corp. (1979).

[2] See, for example:

C. E. Till, et al., Fast Breeder Reactor Studies, ANL-80-40, Argonne National Laboratory (1980).

M. K. White and E. T. Merrill, Evaluation of the Commercial FBR Introduction Date, PNL-3597, Pacific Northwest Laboratory (1981).

The LMFBR is sufficiently advanced in the U.S. and other countries to allow cost comparisons with existing technologies. The British report a capital cost goal for their Commercial Demonstration Fast Reactor (CDFR) of no more than 20% above Advanced Gas Reactors (AGRs) or no more than 40% above the new U.K. PWR.[3] As with all comparisons between LWRs and LMFBRs, the latter can have a somewhat higher capital cost and still be cost-competitive since fuel costs with the LMFBR are expected to be lower.

In France, Superphenix I costs appear roughly in line with the conclusion above. Even an organization known for its opposition to the French breeder program (GSIEN) has reported a Superphenix I cost estimate of $2.2 billion (1981 dollars, see Nucleonics Week, March 12, 1981), or $1830/kwe. Such a capital cost for a nuclear plant with fuel costs even lower than those for an LWR simply cannot be termed uncompetitive.

In the U.S., the costs of the CRBRP (estimated at $3.2 billion) are appreciably higher than that which would be commercially competitive for a 350 MWe plant. Clearly, though, the CRBRP is not a commercial prototype. Among other factors it is first-of-a-kind and significantly smaller in size than is considered optimum for a commercial nuclear plant. In addition, the delays incurred by the project, for example during the Carter Administration where the Congress opposed cancellation but the Administration prevented construction activities, have added to the project cost.

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3 Nuclear News, American Nuclear Society, 4, page 67 (October 1981).

Comment (Letter #11, pages 17 and 18; #21, attachment 3, pages 14 and 15):

The Supplement does not justify the need to replace oil consumption with electricity consumption. The potential role for nuclear-generated electricity in any oil substitution process is small. Also, the Supplement does not consider the role of oil conservation in the transportation sector.

Response:

The role of nuclear-generated electricity has recently been stated[1,2] as contributing to the displacement of oil from the electricity-generating sector to other higher-value uses. The substitution for oil and natural gas is perceived to be a long-range problem, but there is a significant impetus to begin now to make available for the future large-scale, inexhaustible energy technologies. Since 70% of the U.S. energy demand is supplied by oil and natural gas, and since oil and gas production even at current rates through the year 2000 may be extremely difficult and expensive to achieve,[3] substitute energy supplies may become very desirable. Electricity can substitute for scarce oil and gas fuels in all end use sectors of the economy. Electricity price growth is expected to be less than for oil and gas.[4] Accordingly, additional electricity use could displace oil and gas in the residential sector (e.g., heat pumps), in the

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1 Report to the Congress, Department of Energy Organization Act, Sunset Review, Summary Report, DOE/PE-0040 (Vol. 1) page 19 (1982).

2 National Energy Policy Plan, House Document No. 97-77, July 1981, page 15; and DOE/S-0008, The National Energy Policy Plan, July 1981, pages 7 and 11.

3 Energy in Transition, 1985-2010, Final Report of the Committee on Nuclear and Alternative Energy Systems, National Research Council and National Academy of Sciences, W. H. Freeman Co., San Francisco, pages 21, 22, 128-145, and 170 (1979).

4 Energy Information Administration, DOE/EIA 1981 Annual Report to Congress.

industrial sector (e.g. new processes), and in the transportation sector (e.g., electric vehicles). Based on optimistic assumptions about expanded electricity use, the additional potential could be anywhere from one and one-half to five quads of electricity, equivalent to displacing between one and four million barrels of oil per day.

The Supplement uses the potential substitution of electricity for oil as part of the rationale for expecting electricity growth rates somewhat higher than growth rates for total energy. The present National Energy Policy Plan[5] and recent energy use data support this argument. For example, between the years 1979 and 1980, the total U.S. energy use declined 3.4% but electricity production increased 1.7% (1980 Annual Report to Congress, DOE/EIA-0713(80)/2 page 155 and page 7). About one million barrels of oil per day, mostly residual oil, are consumed in the production of electricity. For the past several years, the amount of oil used in electrical generation has been approximately equal to that imported from Saudi Arabia. Replacing oil and gas fired electrical generating capacity and using electricity generated by other fuels likely will contribute in some measure to substitution for oil and gas.

Some changes have been made on page 28 of the Supplement to clarify this issue. A second change on page 28 of the Supplement replaces the example of electric vehicle, with the example of high-efficiency heat pumps in the commercial/residential sector. Such heat pumps are expected to have a greater impact on oil substitution than the electric vehicle.

Conservation, efficiency improvements, and alternate liquid fuels are of great importance within the transportation sector and can have a significant effect on overall oil consumption. However, such advances

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5 National Energy Policy Plan, op cit.

are not likely to have a significant effect on any of the various long-term electricity supply options.

Comment (Letter #11, pages 20 and 21; #21, attachment 1, page 6 and attachment 3, pages 11-14):

The Supplement overestimates the future demand for energy in general and for electricity in particular and uses inappropriate analyses in establishing future demand.

Response:

The Supplement does take a reasonable position on possible future energy and electricity demand and the Supplement's discussion of future demand is supported by historical data and is in many instances not greatly at variance with the studies cited by the State of California.

It should be noted that the Supplement is not intended to be a detailed or exhaustive study of future trends in the economy or in energy use. There have been many such studies conducted recently and the current DOE energy supply and demand projections along with comparisons with other projections have been published.[1] A study of the interrelationships of energy and the economy was also published by DOE.[2] Appendix F (page 4) notes the wide range of projections considered by the CONAES panel.[3] The energy use data and economic data are used in the Supplement to present background information to support the need to develop long-range electricity supply technologies of all types. In order to to clarify the role of the economic and energy use date in the Supplement, additions have been made to the text of the Supplement on page 30.

As stated on page 30 of the Supplement, one purpose of writing the Supplement was because "there have been some significant quantitative changes in the trends in U.S. energy consumption and in the perceived future growth in energy demand" since 1975. It is specifically pointed out that the rate of increase in energy demand has been reduced. Historical data, including years through 1980, are presented in Appendix F to illustrate the GNP-energy consumption trends. The Supplement does recognize that the GNP-energy consumption relationship is flexible. No effort is made in the Supplement to draw quantitative projections from the GNP-energy consumption data. The only conclusion drawn is that future economic growth is likely to be accompanied by some future, positive energy demand growth.

The claim by the State of California that the Supplement asserts that a healthy economy depends on a "high" energy growth rate is a misinterpretation of the Supplement. After concluding that some future total-energy demand increase is probable, the Supplement cites historical evidence (pages F-3 and F-4) which indicates that electricity has, without exception in the years 1950-1980, increased its share of the total U.S. energy market. These data, combined with a long-term need to substitute for oil and gas consumption, lead to the conclusion in the Supplement that demand for electricity, from all sources, will probably grow at a faster rate than total energy demand. This conclusion is in agreement with the National Energy Policy Plan.[4]

The Supplement does recognize that any specific estimate of future energy or electricity demand is highly uncertain. The 3% value for electrical energy growth stated on page F-7 of the Supplement is the present DOE estimate and is considered reasonable.[2]

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1 Energy Projections to the Year 2000, DOE/PE-0029, July 1981.
2 Interrelationships of Energy and the Economy, DOE/PE-0030, July 1981.
3 CONAES, op. cit., page 9.
4 National Energy Policy Plan, op. cit., page 21.

Comment (Letter #11, pages 24 and 25; #21, attachment 1, pages 5 and 9 and attachment 3, pages 17 and 18):

Lower projections for LWR deployment with decreased uranium demands and increased estimates of uranium resources remove a fundamental rationale for development of the LMFBR.

Response:

The availability of natural uranium, i.e., depletion of uranium resources in LWRs, is but one facet of the total rationale for development of the LMFBR. The fundamental rationale is that inexhaustible energy technologies are essential to satisfying future U.S. and world energy needs. Failure to develop as advanced and promising an inexhaustible energy technology as the LMFBR on the premise that it is not presently needed could prove costly in the future.

If the expectation were that large numbers of LWRs would be deployed, with associated high demands on uranium resources, then a nuclear energy future is conditional on development of the LMFBR. Such was the case as late as the early 1970s, when several hundred LWRs were expected to deplete U.S. uranium resources by the end of this century. Relaxation of this demand does not mean that the LMFBR option should be closed, but only that the uranium resource issue may no longer be a dominant factor in the timing of LMFBR deployment. Nevertheless, resource depletion remains an issue in that LWRs will ultimately be drawing on a uranium resource base that is becoming more scarce and more expensive, thereby enhancing the competitiveness of all other technologies available, including the LMFBR.

Improved conditions with respect to uranium resources should be no more valid a reason to suspend LMFBR research and development, than it would be a valid reason to forego any other, or all, of the inexhaustible electricity technologies.

Comment (Letter #11, page 19):

The Supplement ignores potential savings in electrical generating capacity from end-use efficiency improvements in home appliances and commercial lighting.

Response:

End-use efficiency improvements are discussed in the Supplement on pages F-2, F-3, and 32. The specific savings quoted by the commenter have certainly not been demonstrated and are not reasonable. The commenter projects savings of 150,000 MWe by improvements in home appliances, with another 100,000 MWe savings projected for commercial lighting. These two projected savings (250,000 MWe) represent about 23% of the projected year 2000 U.S. generating capacity. In 1980, appliances and commercial lighting represented about 19% of the total U.S. electrical generating capacity. The projected 250,000 MWe savings appear unreasonable because home appliance and commercial lighting electricity usage cannot be reduced to zero.

Comment (Letter #11, page 22):

Per capita energy use data for California and absolute energy efficiency data for other countries invalidate the Supplement's conclusion concerning electricity growth rates.

Response:

The data in the Supplement (pages F-3 and F-4) show that electricity has increased its share of the total U.S. energy supply continually since 1950. In addition, the examples of California or other countries should not be taken as the basis for national policy since energy consumption patterns in California or other countries may not bear any relationship to the rest of the U.S. due to differences in industries, living patterns, and climate.

Comment (Letter #11, page 19; #21, attachment 3, pages 5, 6, 13 and 22-24):

The Supplement does not adequately take into account the contributions from conservation and end-use efficiency improvements.

Response:

The Supplement does present the recent data for energy efficiency improvements on pages F-2 and F-3. Total energy consumption trends are discussed on pages F-1 and F-2. In the context of the Supplement, conservation is the reduction of energy consumption (e.g., driving fewer miles) and improvements in energy efficiency (e.g., getting more miles oper gallon). The effects of conservation are reflected in energy consumption trends. End-use efficiency improvements provide the same end use with the consumption of less energy (e.g., driving the same number of miles with a higher miles-per-gallon vehicle). The Supplement examines end-use efficiency changes by examining the ratio of gross national product to total national energy consumption. These data on pages F-2 and F-3 show that energy efficiency increased very slowly from 1950 to 1965 and then decreased significantly between 1965 and 1970. Between 1970 and 1976 energy efficiency regained its slow increase. Beginning in 1977 the rate of efficiency improvements began to increase. The data for the decade of the 1970s are:

Year	%Efficiency* Improvement
1971	
1972	0.73
1973	1.25
1974	1.11
1975	0.86
1976	0.66
1977	2.71
1978	1.62
1979	2.63
1980	3.2 (estimate)**

The average of the 1972-1979 improvement values gives the 1.5% quoted on page 32 of the Supplement. Inclusion of the 1980 estimate gives an average of 1.6%. The issue in the analysis of the data is how many years to include in any extrapolation to future efficiency improvements. This issue was addressed in the National Energy Policy Plan[1] where it was noted that the importance of short-term changes in energy consumption patterns should not be exaggerated. The position in the Supplement is that it is inappropriate to include only the last few years of the decade of the 1970s because of the extreme rise in energy costs, which is not likely to be repeated. Similarly, the data from the late 1960s showing efficiency decreases are not included because it is unlikely that this "cheap energy" era will be repeated.

The 1971-1980 average of 1.6% annual efficiency improvement is considered a reasonable estimate of sustainable, decade-average annual efficiency improvements. The National Energy Plan projects efficiency improvements of 1 to 1.5% per year for the coming decades. The effects of energy

1 National Energy Policy Plan, op cit., page 16.

* Source - Supplement, Appendix F, references 1, 2, and 3.
** Source - Wall Street Journal, February 23, 1982.

efficiency improvements were also discussed in the recent ERAB report.[1] The inclusion in the Supplement of efficiency improvements is a significant change from earlier discussions and cannot be characterized as ignoring the contribution of conservation and efficiency changes. To clarify further the discussion in the Supplement, a wording change has been made on page 32 of the text.

<u>Comment</u> (Letter #21, attachment 3, pages 19-21):

The Supplement overstates the advanced state of development of the LMFBR.

<u>Response</u>:

It is true that significant work remains to be done to bring the LMFBR to the point where commercialization can occur. Indeed that is why the LMFBR program is federally-funded. But relative to other inexhaustible electricity technologies that can potentially satisfy a large demand, DOE believes that the LMFBR technology is significantly advanced.

In the U.S., the EBR-II has operated as an electrical power station since 1964. The California comment that "EBR-II was to be operated as a power plant but has operated at only about one-half of its design power level," is without any basis in fact. To the contrary, the EBR-II has operated at its design power level* of 62.5 MWt since 1969, following a five-year power ascent program. EBR-II has supplied nearly 20 MWe to a utility grid during this period, with impressive capacity factor statistics. In each of the last six years, for example, capacity factors have exceeded 70%, and reached 77% in 1981, in spite of the fact that EBR-II was conducting

1 Federal Energy R and D Priorities, Report of the Research and Development Panel, Energy Research Advisory Board, November 1981.

* Based on a design that included blanket fuel, which was later replaced by a reflector.

an experimental fuels irradiation program during this time which itself penalized capacity factor performance by at least 3-5%.

In France, progress has been even more impressive. It is hardly fair to characterize the 250 MWe Phenix reactor as a "small pilot plant," or vaguely to refer without amplification to Superphenix at 1200 MWe as non-prototypic for commercial breeder reactors. Phenix has performed well as a demonstration LMFBR, and the capacity factor exceeded 70% during 1981. Superphenix operation is scheduled for 1984, and following that France now intends to build Superphenix-2 and -3 at 1500 MWe. The likely result is that French LMFBRs will be commercially available in the 1990s. The statement that "France's breeder development program is decades away from making any significant addition to the country's nuclear power supply" is not valid.

In the U.K., the Prototype Fast Reactor (PFR) has not operated reliably since its construction. Problems have been due almost entirely to poorly designed steam generators, not with the reactor performance. The design and operation of reliable steam generators is precisely the kind of engineering problem that LMFBR programs, including that in the U.S., are designed to solve. While the steam generator issue can be an engineering problem (although EBR-II and Phenix steam generators have performed well), it is not the kind of problem for which scientific breakthroughs are required.

In the Soviet Union, the largest LMFBR station in the world (600 MWe) began operation in 1980 and has been reported to be operating quite successfully (Nuclear News, 24, page 72, October 1981). The U.S.S.R. intends to have an 800 MWe station in operation by 1990.

With respect to fuel reprocessing, it is true that LMFBR fuel reprocessing is more demanding than with LWR fuel for which commercial reprocessing is now offered in France. In the U.S., uranium/plutonium fuels have been reprocessed for decades in the defense programs. A great deal of reprocessing expertise now exists in the U.S., and based on this experience it is DOE's belief that the additional difficulties posed by breeder reactor fuels are problems that will be solved by orderly development. DOE agrees that "these modifications should be demonstrated before proceeding to full industrial-scale breeder fuel reprocessing," and that is one objective of the DOE fuel cycle programs. The need for a full industrial-scale breeder fuel reprocessing facility is decades away, and sufficient time is available to overcome any engineering difficulties.

Similarly, fuel fabrication is not a major issue in the LMFBR program. Oxide fuel fabrication has been demonstrated for the FFTF, and DOE's continuing fuel fabrication program will provide fuel for developmental plants. There is high confidence that the DOE fuel fabrication program is capable of leading to a successful full-scale breeder fuel fabrication facility, when it is necessary at some future time.

DOE wishes neither to gloss over nor overstate the problems that remain to bring the LMFBR to a point where the private sector could commercialize the technology. While breakthroughs as with proof-of-principle in fusion, or cost reductions as with solar photovoltaics, are not required, a significant amount of engineering and engineering-scale demonstration is required. DOE strongly believes that the present LMFBR program is designed to address these engineering problems in an orderly and systematic way. Evidence from other LMFBR programs increases confidence in the DOE position.

Comment (Letter #21, attachment 1, pages 4 and 12, and attachment 3, pages 3, 4, 8 and 26-28):

The Supplement is deficient because it does not discuss the effects of spending LMFBR program funds on other energy-related programs such as conservation or alternative technologies.

Response:

Discussions of energy research and development funding priorities are neither appropriate nor useful in this Supplement. The present Federal energy policy is summarized in the DOE Energy Policy Plan[1] and Sunset Review.[2] All energy-related programs are funded according to their merits and Federal funding guidelines. Basically, Federal research and development spending is being limited to "long-term, high-risk but potentially high-payoff technologies"[3] where "private firms could not expect to recoup, through profits, enough of the benefits of the new technologies to stimulate the necessary expenditures."[3]

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1 National Energy Policy Plan, op cit.

2 DOE/PE-0040 (Vol. 1), Department of Energy Organization Act, Title X, Sunset Review, February 1982.

3 Idem, page 12.

B. Specific Comments

Comment (Letter #19, pages 1 and 3):

Impacts on water quality in Virginia from a possible accident at the CRBRP should be addressed in the Supplement.

Response:

Matters relating to the site specific environmental impacts associated with the CRBRP have been addressed in NRC's final EIS for the CRBRP (NUREG-0139). If the NRC determines that significant changes have occurred since 1977, a supplement to NUREG-0139 will be prepared.

Comment (Letter #9, page 1):

"...text incorrectly states that the lifetime uranium requirements for a LWR varies between 140 and 200 ST U_3O_8. This is the annual uranium requirements for a LWR."

Response:

The text has been corrected (page 36, line 1).

Comment (Letter #9, page 2):

"Sentence does not make sense in its current form."

Response:

The text has been corrected (page F-6, line 19).

Comment (Letter #9, page 2):

3.3$ should be 3.3%.

Response:

The text has been corrected (page F-7, footnote).

Comment (Letter #7, page 2):

"The NSF transferred lead responsibility for solar and geothermal energy research to ERDA in 1975. Thus on page 107, reference to current NSF activities in these areas is incorrect."

Response:

This material has been deleted from the text.

Comment (Letter #6, page 1):

"Under 'Institutional' on page 106, the reference to 'licensing requirements' needing to be examined should be deleted since NOAA has published the licensing requirements for commercial OTEC plants (15 CFR Part 981)."

Response:

An appropriate footnote has been added (see page 106).

Comment (Letter #6, page 1):

"The paragraph starting with 'Research and development---' at mid-page on page 107 is another topic and should be differentiated with an appropriate heading."

Response:

An appropriate heading has been added.

Comment (Letter #9, page 2):

"What is the basis for the assumed AMAD of 0.3 μm?" (pg. 207, para. 1)

Response:

The basis is given in the following paragraph from WASH-1535 (Volume II, pg. 4.3-37).

"These radionuclides would be in the form of particulates of PuO_2, UO_2, and $(U-Pu)O_2$. The mass median particle diameter of the PuO_2 powder used in the mixed-oxide plant would be primarily in the range 0.2 to 30 μm; about 10% would have a size less than 1 μm. The UO_2 powder would have a mass median particle diameter less than 1 μm. The majority of the particulates released would be expected to have a mass median diameter of about 0.3 μm since this particle size has the greatest fractional penetration through a HEPA filter. Actual measurements at plutonium-fabrication plants showed radioactive particles downstream from glove box HEPA filters (and just upstream from the main building stack and its HEPA filters) to have an activity median aerodynamic diameter of 1.0 to 4.0 μm. Westinghouse reports that, of the particles downstream from the HEPA filters in their recycle-fuels plant, 74% will have a mass median diameter in the range 0.05 to 0.1 μm and 25% in the range 0.1 to 0.3 μm." DOE has reviewed the assumed value and considers it to be still valid today.

Comment (Letter #11, page 63):

"The extremely small source term used in the model -- 0.31 mCi of alpha per 1000 MWe year -- is nonconservative, and no uncertainty limits are provided. This source term is based on unvalidated assumptions regarding postulated release rates that represent goals for future technologies. In some instances, confinement factors are several orders of magnitude better than confinement factors for existing plants (Rocky Flats and NFS-Erwin), plants operated in the recent past (NFS-West Valley), or even proposed plants. . ."

Response:

The source term for transuranic releases is discussed in WASH-1535 (see especially pp. 4.3-47 to 4.3-39 and pp. 4.4-45 and 4.4-46), not in this Supplement. DOE has reviewed the source term and considers it to still be valid today. Confinement factors are, in fact, consistent with those from past experience and those for proposed facilities. The NFS experience is an example (see pg. 4.4-46 of WASH-1535, Volume II, as quoted in the following 2 paragraphs).

"The 1969 PHS survey included stack air samples from which Pu-238 and Pu-239 activities could be identified. From these measurements, an approximate calculation can be made which places the plant confinement factor for airborne plutonium at about 2×10^9 during a 28-day period of continuous fuel dissolving and reprocessing. From this base point, additional inferences may be made, as follows:

(1) Assuming that plant performance throughout 1969 remained consistent with the PHS measurements, the plutonium confinement

factor was about 3.6 times greater than that for beta particulates (2×10^9 vs 5.6×10^8).

(2) The improved beta particulate confinement in 1971 (5×10^9), achieved after installation and operation of an improved air ventilation system, implies a plutonium confinement factor of the order of 10^{10}, assuming that the ratio inferred above was maintained.

"From these considerations, the confinement factor assumption used in this Statement of 5×10^9 for beta particulates and transuranics, other than plutonium, seems reasonable. The assumption of 2×10^9 for plutonium nuclide confinement is consistent with early NFS experience but is probably conservative in the light of more recent experience."

Comment (Letter #5, page 1):

"Under Section IV, A, 2, c, (1) Fuel Reprocessing, we would suggest that some acknowledgement be made of the fact that LMFBR fuel reprocessing is well along toward being a demonstrated technology. Britain and France have already successfully reprocessed substantial quantities of spent LMFBR fuel from DFR, PFR, Rapsodie and Phenix at their respective reprocessing facilities at Dounreay, Scotland and at Marcoule and LaHague in France. (Ref. BNES Conference on Fast Reactor Fuel Cycles, London, November 9-12, 1981)"

Response:

An appropriate footnote has been added (see page 79).

Comment (Letter #6, page 1):

" ... a description of the OTEC process should be the first item of discussion, followed by mention of the pros and cons."

Response:

The OTEC process (including pros and cons) was described in WASH-1535 (Volume III, pages 6A.6-5 to 6A.6-8).

Comment (Letter #5, page 2):

"We would appreciate your adding the Atomics International Division of Rockwell International to your list of Industrial Organizations on page ix."

Response:

This oversight has been corrected.

Comment (Letter #5, page 1):

"Under Section VI, A, 4 Health Effects, some recognition should be given to the much lower dose rates received by LMFBR workers than by conventional LWR plant workers. For instance, the total exposure received by all workers in the first eight years of Phenix operation (60 person-rem) is less than that received in one month by all workers in a typical U.S. LWR in 1980 (65.9 person-rem). (Ref. 21. Section III and Inside Energy September 18, 1981)"

Response:

This information is useful, but it is not related to Section VI. A. (4), Health Effects, which was concerned with predicting the health effects in the general U.S. population due to releases of transuranics.

Comment (Letter #6, page 1):

"In discussing work conducted to date, the Mini-OTEC and OTEC-1 projects should be discussed."

Response:

The Mini-OTEC was a 50 kw demonstration facility. OTEC-1 was a heat exchanger test facility. They were not discussed in the Supplement because they were not considered as significant as the larger demonstration facilities that were listed and discussed (see pages 107 and 109).

Comment (Letter #9, page 2):

"The relative environmental impacts of alternative technologies are not supported in the text. For example, there is no basis for the different acreages reported for transmission lines. Water use for OTEC is reportedly very large and yet there is probably little or no actual consumption, as compared to, say, LMFBR cooling towers. The table is misleading."

Response:

The relative environmental impacts are supported by the references, not the text. Transmission line acreages were calculated assuming 20 or 21 acres per mile of transmission lines and reasonable assumptions concerning the miles of transmission required for each technology. Water use for OTEC is, in fact, very large, and associated environmental impacts could be significant (see Supplement, page 224). Consumption is not a major issue for OTEC or LMFBR water use since only about 1% of the water used is actually consumed (i.e., evaporated).

Comment (Letter #11, pages 69-73):

"The discussion in the DEIS of the CRBR site selection process is hopelessly inadequate," because it contains no new information relevant to site selection and because it does not address changes in NRC regulatory criteria concerning siting . . . .Thus, "the DEIS falls far short of NEPA's requirements for a reasoned and thorough discussion of alternatives to the proposed project."

Response:

The discussion in the Supplement considers the available relevant new information. In addition, the "changes in NRC regulatory criteria concerning siting" cited by the commenter are not applicable to the CRBRP.

NRDC pointed out that new information has been developed on the Clinch River site and alternative sites since issuance of the NRC FES (NUREG-0139) in February 1977. This new information is reflected in CRBRP's update to the alternative siting analysis in the CRBRP Environmental Report.[1] This information reconfirms the conclusion of the original siting analysis and supports the conclusions in Appendix G of the Supplement. The Clinch River site remains the best alternative for meeting program and project objectives.

NRDC references to revisions to the NRC reactor siting criteria are not relevant. The proposed revisions referred to by NRDC arise from the FY 1980 NRC Authorization Act (P.L. 96-295). The impression given is that this revision has some relevance to the CRBRP alternative site consideration. However, the FY 1980 NRC Authorization Act includes the statement: "Regulations promulgated under this section shall not apply to any facility for which an application for a construction permit was filed on or before October 1, 1979." As the CRBRP construction permit application was filed in April 1975, these revisions obviously do not apply.

NRDC also referred to new NRC emergency planning regulations (NUREG-0654, FEMA-REP-1, Revision 1, November 1980). These regulations might impose some additional requirements on CRBRP during the construction permit review. These requirements will be addressed in the CRBRP licensing process. No insurmountable obstacles have been identified regarding emergency planning for CRBRP. This topic is discussed on page 128 of the Supplement.

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[1] Letter, J. R. Longenecker, DOE, to P. S. Check, NRC, "Response to Request for Alternative Sites Information," February 12, 1982.

(Available from DOE upon request. NRC Docket No. 50-537.)

Comment (Letter #4, pages 1 and 2):

U.S. nuclear facilities are vulnerable to attacks by foreign governments (using both conventional and nuclear weaponry).

Response:

The weapons delivery systems accuracies needed to cause significantly greater numbers of casualties (than would be caused by the weapons themselves, especially nuclear weapons) exceed the capabilities of most existing deployed strategic weapons systems. Targeting of U.S. nuclear facilities is unlikely due to the very large numbers of weapons that would be required to cause sufficient damage to these facilities such that significant quantities of radioactivity would be released.

Comment (Letter #21, attachment 3, page 6):

"The DEIS fails to identify any adverse environmental effects which cannot be avoided and to discuss the relationship between short-term uses of the environment and the enhancement of long-term productivity and any irreversible commitments of resources which would be involved. In particular, long-term environmental impacts from the decommissioning and disposal of contaminated facilities, equipment, and wastes should be identified and discussed."

Response:

The State of California repeatedly refers to the Supplement as the DEIS. Many of the issues raised concerning the Supplement were addressed in the Final Environmental Statement (ERDA-1535) and/or the Proposed Final Environmental Statement (WASH-1535), as shown in the following table. These issues have been reviewed and DOE has determined that the discussions of them in ERDA-1535 are still valid.

Issue	Section of WASH-1535
Short-term benefits and long-term losses	Section 9 (Volume IV)
Irreversible and irretrievable commitments of resources	Section 10 (Volume IV)
Decommissioning	Section 9.2 (Volume IV)
Unavoidable adverse environmental impacts	Section 8 (Volume IV)

Comment (Letter #21, attachment 1, page 17):

"The DEIS contends that it is appropriate to exclude contamination of water supplies because of the "small fraction released to water, the low solubility of most transuranic compounds, and the great dilution volume ultimately provided by the world's oceans." (DEIS p. 192) This contention fails to fulfill the disclosure requirements of NEPA. We are concerned about the potential for transuranics to harm downstream drinking supplies. Analysis of the risk of contamination of drinking water, ground water, evaporation and subsequent rainfall, river and lakebed sediments and soil exposed by indirect means should be discussed in the EIS."

Response:

The questions posed with regard to "...the risk of contamination of drinking water, ground water, evaporation and subsequent rainfall, river and lakebed sediments and soil exposed by indirect means..." are important questions, which should indeed be considered in any environmental impact statement written for a specific plant and site. However, site-specific parameters are of such controlling importance to any consideration of aqueous dispersal pathways that it is difficult to incorporate such considerations into a generic environmental impact analysis in any meaningful manner. In the Supplement it was assumed that all plutonium deposited from atmospheric dispersal will be transported to man only via the soil-plant pathway. This oversimplification was incorporated by choosing parameters, descriptive of the soil-plant pathway, that lead to greater deposition in man than could conceivably be attained by alternative pathways.

Comment (Letter #21, attachment 1, page 17):

"The assumptions made for terrestrial dispersal are very confusing. If it is known that radionuclides migrate downward through the soil, why is it assumed they remain in the root zone? The DEIS states that this assumption makes estimates of exposure higher than expected. While this may be correct, the same assumption ignores possible entry into the hydrologic system via groundwater."

Response:

The parameters employed to describe the soil-plant-man pathway lead to the ultimate ingestion by man of approximately 0.1% of all of the source term transuranics (all assumed to be uniformly deposited, and to remain for their lifetime, in the top 20 cm of U.S. soil). See Table II.G-8 (replacement), on page D-12 of the Supplement. Any transuranics that might follow an aqueous pathway will be lost to the soil-plant pathway, and will thus reduce the amount reaching man unless this aqueous pathway is more efficient than the soil-plant pathway it replaces.*

*See page II.G-29, WASH-1535.

It is difficult to conceive of an aqueous pathway that could lead to an overall transfer of 0.1% of its transuranic content to man. The aqueous route is inherently inefficient, because transuranics will not remain for long in any aqueous state accessible to man. Because of their chemical characteristics they are apt to be largely adsorbed to inaccessible sediments. To the extent that they remain in aqueous solution or suspension they will become rapidly diluted with time. In any case, an extremely small fraction of any aqueous pool will ever find its way to human consumption. These are, admittedly, qualitative arguments. They seem more appropriate, however, to this generic appraisal than a detailed quantitative analysis, which would require consideration of a wide range of assumptions, and would lead to results with such a wide range of uncertainty as to be essentially meaningless.

The criticized assumption that transuranics do not migrate from the root zone is, of course, one of the assumptions designed to ensure that the greatly oversimplified food chain to man remains conservative overall. The assumption of a 10^{-2} concentration factor from soil to plant-derived food is another such conservative factor. More realistic factors could be justified, but one would then be constrained to consider alternate pathways in much greater detail.

Comment (Letter #9, page 2):

"Please define 'lifetime of the radioactive materials.' Is this ten half-lives, or the biological half-life, or some combination of the radiological and biological half-lives?"

Response:

The phrase, "lifetime of the radioactive materials" means total lifetime; i.e., every radioactive disintegration was considered until not a single atom of the radionuclide remained. In practical terms, of course, no significant quantity remains after 10 half-lives, but calculations included every atom of the radionuclide. (page 22, last line)

Comment (letter #9, page 1):

"Reasons are given as to why all of the source term is assumed to be released to the atmosphere. It would improve the argument to include an analysis to show that the contribution from the aqueous pathway to human exposure (& health effects) will be significantly less than the atmospheric pathway. With respect to the accident contribution to the source term, a cross reference to p. 134 and the footnote thereon would be useful." (page 192, paragraph 2)

Response:

The more detailed consideration of the source term in WASH-1535 (Appendix II.G) predicts a liquid transuranic effluent only for the fuel fabrication plant, in an estimated amount of 0.046 mCi/1000 MWe Yr. This liquid effluent was disregarded for two principal reasons: (1) it was small compared to the estimated 0.36 mCi/1000 MWe Yr airborne release from the fuel reprocessing plant and is certainly well within the uncertainty limits of that higher estimate, and (2) because the environmental dispersal of a liquid transuranic effluent is a site-specific problem that would be difficult to handle in any generic sense. It was stressed in WASH-1535 (Appendix II.G) that such liquid effluents would need to be considered in connection with the environmental impact of any specific fuel fabrication plant.

Comment (Letter #9, page 1):

"Terrestrial Dispersal - it is acknowledged that the assumption of uniform distribution of TRU over the U.S. will underestimate the deposition immediately downwind from the source, and may underestimate the TRU reaching man via food chains. It would be appropriate here to make a statement as to the possible magnitude of the underestimate." (page 195, paragraph 2)

Response:

The assumption of uniform distribution of deposition of transuranics over the U.S. will underestimate deposition immediately downwind from the source. This will result in a relative underestimate of transuranic elements reaching man via food chains only if food production per unit area is greater in this downwind area of enhanced deposition than it is, on average, throughout the U.S. The magnitude of this relative underestimate will depend very critically upon plant location and cannot be specified in any generic sense. An appropriate choice of plant location will avoid the problem. It should also be noted that, under any circumstances, an absolute underestimate of transuranics reaching man is highly unlikely in view of the many other conservative factors employed in the estimate, and in view of the wide dispersion of food production activities throughout the U.S.

Comment (Letter #9, page 2):

"It was assumed that the concentration of TRU in food resulting from LMFBR releases will be 1 percent of the concentration of the top 20 cm of soil. What is the range of uncertainty in this estimate?" (page 196, paragraph 2)

Response:

The assumption that food will contain a transuranic concentration equal to 1% of the concentration in the top 20 cm of soil cannot be bounded by any statistically derived uncertainty range. Data on which the estimate is based (as discussed and referenced in the Supplement, Appendix D) are mainly laboratory studies of uncertain relevance to real-world situations, particularly as these situations may develop after several hundred years of weathering. Probably the most relevant data are those relating to the concentration of plutonium from weapons test fallout in soil and food, where concentrations in food average about 0.1% of the concentration in soil. This fallout number is also an overestimate of uptake from soil, since it is derived in large part from direct fallout deposition on the food. The 1% assumption is retained in the face of much data favoring a lower number because of the possibility that uptake in the future may increase due to chemical changes in the soil or altered agricultural practices.

Comment (Letter #9, page 2):

"How would the possible 10-fold variation in the quantity of TRU inhaled affect the estimates of doses to the population?" (page 209, first full paragraph)

Response:

The 10-fold range in the quantity of transuranics inhaled was estimated for the direct inhalation from the initial plume, which amounts to about 30% of the total estimated inhalation.* The remaining 70% is inhaled following resuspension, over long time periods, and would be expected to show less

*See page II.G-24, WASH-1535.

variation with local population density. Inhaled transuranics are responsible for the total estimated dose to the lung, and for about 60% of the dose to other organs, as detailed in Appendix D. A 10-fold range in direct inhalation would therefore correspond to 3-fold range in lung dose and slightly less than a 2-fold range in dose to the other organs. It should be noted that this variation due to population distribution can be controlled by site location. The location on which the model was based was a poor site from the standpoint of minimizing population dose and any "real" site would probably be chosen to reduce this exposure.

Comment (Letter #9, page 2):

"Evidence, or a reference, should be cited to show the conservatism of the soil-plant-man pathway mentioned here." (page D-1, paragraph 4)

Response:

Elements of this conservatism are described, explained and/or referenced in the pages following the referenced paragraph in Appendix D, in the Health Effects chapter, and in responses to other comments.

Comment (Letter #9, page 2):

"What is the basis for the statement that the 50-year exposure period will overestimate actual exposure?" (page D-5, paragraph 2)

Response:

Use of a 50-year period for dose accumulation implies that for people living beyond age 50, dose will not be counted from intakes that occurred more than 50 years earlier. However, dose from intakes occurring less than 50 years before death are overcounted, since the person has died before the 50 years of dose accumulation has lapsed. The net effect is an overestimate of actual dose received unless the person lives beyond the age of 100.

Comment (Letter #4, page 1):

"The DOE spent six hundred million dollars on hardware for this project, but did not spend any for test of the damage done to human cells by low level nuclear radiation,by such eminent Molenuclear Biologist as Mr. Walter Gilbert and his colleagues---for to do so, would so prejudice your case for Nuclear power,(Of any kind.) it would make the Nuclear (let's borrow money to do it.) advocates look like clowns."

Response:

The Department of Energy and its predecessor agencies, the Energy Research and Development Administration and the Atomic Energy Commission, have supported molecular and cellular radiation effects studies for decades, thereby providing much of the bases for our knowledge in the field of radiation biology. The total support for these studies approaches two hundred million dollars. It may be of interest to note that scientific studies on the effects of radiation on living cells were carried out as early as the early 1900s, one of the first published reports having been printed in 1906.

Comment (Letter #4, page 2):

"In each case where stastitics have been collected and correlated, Enzyme Disfunction Diseases, (Heart,Fetal deaths,Strokes,and Cancer.) have accelerated the death toll in the populations who live near and adjacent to Nuclear Installations. Rocky Flats, Hanford,Washington,The Savannah River Atomic Energy Reservation at Barnwell,S.C. (Finial Impact Statement 1975) and Dr. Sternglass's correlations. Low level Nuclear Radiation kills folks, and as more escapes into our Environment, more bodies will fall."

Response:

In spite of allegations made by some individuals, to date there have been no confirmed scientifically valid epidemiological studies showing an increased incidence of radiation induced diseases among populations living near or adjacent to the nuclear facilties at Rocky Flats, Colorado; Richland, Washington; or Barnwell, South Carolina.

The allegations of Dr. Sternglass have received extensive attention both within and outside the scientific community. Many knowledgeable persons and organizations have reviewed his findings and found them to be unsubstantiated by the data he presents. A partial list of those reviewing his allegations and disagreeing with his conclusions include:

The Pennsylvania Department of Environmental Resources

("Summary Statement on Dr. Sternglass' Allegations Concerning Nuclear Power and Infant Mortality," Office of Radiological Health, Pennsylvania Department of Environmental Resources, February 8, 1971.)

A special investigating committee appointed by the Governor of Pennsylvania

(Report to the Governor, Shippingport Nuclear Power Station, Alleged Health Effects, prepared by Governor's Fact Finding Committee, 1974.)

The U.S. Public Health Service

(Preface to Evaluation of a Possible Causal Relationship between Fallout Deposition of Strontium 90 and Infant and Fetal Mortality Trends, Public Health Service, October, 1969.)

The U.S. Environmental Protection Agency

("Assessment of Environmental Radioactivity in the Vicinity of the Shippingport Atomic Power Station," an interim report by the Eastern Environmental Radiation Facility, July 20, 1973.)

The New York State Department of Health

("Is There Evidence for an Association of Radioactive Fall-Out to Leukemia and Fetal Mortality in New York State?," Dr. Peter Greenwald, Director, Cancer Control Bureau, and Sandra Kinch, Director, Health Statistics, New York State Department of Health.)

The Michigan Department of Public Health

("A Rationale of Dr. Sternglass' Paper 'Infant Mortality Changes Near the Big Rock Point Nuclear Power Station, Charlevoix, Michigan.'" The Michigan Department of Public Health, February 19, 1971.)

The State of Illinois

(Public Statement by Dr. Franklin Yoder, Director, Illinois State Department of Health, October 22, 1970.)

The American Academy of Pediatrics

(Committee on Environmental Hazards. American Academy of Pediatrics, Newsletter Supplement, April 15, 1970.)

Science Magazine

("Ernest J. Sternglass: Controversial Prophet of Doom," Science, October 10, 1969.)

Comment (Letter #21, attachment 3, page 7):

"An example of the poor quality of the analysis of alternatives is Figure 1 (DEIS, p. 31) which provides a dated (1976) comparison of energy available from renewable energy resources. Such information does not reflect significant recent advances in renewable energy technologies, particularly in photovoltaics, wind, small hydroelectric, etc."

Response:

This figure represents the most recent information available. Also, it shows that renewable energy technologies are inexhaustible. "Recent advances" in technology development have not changed resource estimates for renewable energy technologies. Data for the more conventional sources, however, have changed somewhat, as shown in the following table.

Energy Source	ERDA 76-1 Figure*	New Figure(s)*	Source of New Figures
Gas	1,030	688-958	USGS (1980 estimate)
Petroleum	1,100	545-783	DOE/EIA-0216(80)
Geothermal	3,434	710-3400	USGS Circular 790 (1978)
Oil Shale	5,800	6,187	DOE/EIA-0173(80)/3
Coal	13,300+	19,000	DOE/EIA-0280(79)
Uranium	-	-	
- Light Water Reactors	1,800	1,812	DOE/GJO-111(80)
- Breeder Reactors	130,000	139,400	

*In Quads (10^{15} Btu), potentially recoverable considering technological and economic (but not environmental) constraints.

Comment (Letter #11, pages 7 and 8; #2, page 3):

Many LMFBR cost/benefit analyses have been prepared since 1975 ("several of which were authored by DOE") and could have been used to revise the FES cost/benefit analysis.

Response:

The idea that material prepared by DOE already exists which could be used as an updated programmatic cost/benefit analysis is incorrect. The last comprehensive cost/benefit analysis of the LMFBR made by the Department of Energy or its predecessors was that presented in the "Final Environmental Statement - Liquid Metal Fast Breeder Reactor Program," (ERDA-1535), dated December 1975. Here, a total of 65 cases were analyzed in which the energy demand, U_3O_8 supply and cost, LMFBR introduction date, and LMFBR capital cost were varied parametrically with benefits calculated over a 50 year period using discount rates of 7.5 and 10%.

Since issuing ERDA-1535, ERDA and its successor DOE have performed a number of economic studies of single plants and comparative power costs of various breeder reactor designs along with other reactor types. These include the references cited in the NRDC comments in addition to a number of U.S. papers tabled in the International Nuclear Fuel Cycle Evaluation (INFCE) conference. These calculations are of two basic types, finite ore analyses and economic indifference determinations, and deal with the timing of an economic commercial breeder rather than with an overall cost/benefit of its application. For cost/benefit analyses, one would need to return to the methodology already utilized in ERDA-1535.

The usefulness of a cost/benefit analysis as a significant element in the decision process in a very long-range program such as the breeder program is questionable. About all that can be shown realistically is that there are circumstances which can be reasonably postulated in which the benefits from the program can materially exceed the cost and there are also future circumstances in which the absence of a breeder program can be very costly to this country. This was clearly demonstrated in the ERDA-1535 study and is still valid today.

Comment (Letter #21, attachment 3, page 29):

"It has been estimated that more than 10 million kilograms per year of fissile plutonium would circulate in fresh fuel in a plutonium breeder-based nuclear economy.[31]"

Response:

This number (10 million kilograms) appears to be in error. The reference LMFBR used by INFCE had an annual reload of 1466 Kg of fissile Pu for a 1 GWe breeder at 0.7 capacity factor. Coupled with the 10 million Kg, this implies 6800 GWe of fast breeders. The timeframe for this is unclear--the INFCE high case assumed only 3900 GWe total world nuclear capacity by the year 2025, and INFCE working group V did not assume such a total installed nuclear capacity (6800 GWe including both LMFBRs and LWRs) until 2075 for the high case.

Comment (Letter #21, attachment 1, page 5; #11, page 24):

DEIS fails to provide any meaningful rationale for the LMFBR program. The findings of DOE's Energy Research Advisory Board (ERAB) call for a delay in breeder reactor demonstration.

Response:

The rationale for the LMFBR program has been fairly presented and discussed in reasonable detail in the Supplement (pages 32-39). The citation of the ERAB findings can be misleading in that, taken out of context with the overall findings, one could be led to believe that the Board does not support the breeder program. As a point of fact, the Board does support the breeder program and provides as its rationale the following:

> "Breeders with attendent reprocessing could have a high ultimate impact on energy supply security."

Thus, the Board considered it desirable to maintain present levels of effort in the LMFBR base program and fuel cycle R&D.

On the matter of the desirability to proceed at this time with the Clinch River Breeder Reactor Project, DOE does not agree with the Board's recommendation because of the priority and importance of CRBRP to meeting overall breeder program objectives in a timely manner. The specific issue of the pace of breeder development is discussed in Section III.D of the Supplement. An important conclusion of this and other pertinent sections of the Supplement is that the CRBR Project should proceed expeditiously.

Comment (Letter #8):

The Supplement does not give sufficient consideration to fission reactor types other than the LMFBR.

Response:

The fission alternatives cited fall into two general categories -- converter reactors and alternative breeder reactors. The first category includes improved LWRs, the light water breeder reactor (LWBR), and such advanced converters as the high temperature gas cooled reactor (HTGR). The second category includes the gas-cooled fast breeder reactor (GCFR) and the fusion-fission hybrid reactor.

DOE does not consider reactors in the first category to be viable options for extending the potential for nuclear power to essentially inexhaustible proportions. At most, these reactors would extend the available uranium supply by a few years[1] (i.e., less than a decade) and therefore cannot be considered as competitors of the LMFBR for long-term electricity production. There may be substantial advantages for the private sector to develop some of these options that make more effective use of uranium resources.

The GCFR and the fission-fusion hybrid breeder do represent potential alternatives to the LMFBR. However, the decision was made years ago to concentrate fission breeder reactor development into the most advanced and promising technology, the LMFBR, in order to conserve technological resources and minimize funding requirements. Making the LMFBR the breeder of reference is consistent with decisions made in all other nations with advanced nuclear programs. Consequently, the GCFR concept has lagged far behind in terms of technological readiness. On the other hand, the fission-fusion hybrid breeder concept is being developed within the context of the fusion research program. However, it is not the focus of the fusion program within the U.S. Proceeding with the LMFBR development program does not preclude the emergence of either the GCFR or the hybrid breeder.

Comment (Letter #9, page 1; #11, page 28; #21, attachment 1, page 12):

The Supplement is deficient in its one-sided risk of delay argument.

[1] C. E. Till, et al., Fast Breeder Reactor Studies, ANL-80-40, Argonne National Laboratory (1980).

Response:

Letter #21 stated that the cost of delay is incorrectly based on LMFBR-generated electricity being lower than the average cost of electricity. In response to this comment, it should be noted that the LMFBR will be deployed only if the cost of LMFBR-generated electricity is economically competitive with other competing generating technologies at the time of deployment.

Letter #9 noted that the risk of delay analysis was quantitative and included indirect effects while the risk of too-early development was only qualitative and did not include indirect effects. The text (page 43) has been revised in response to the comment from Letter #9.

Comment (Letter #11, pages 20 and 21):

"The DEIS mentions the environmental concerns which may limit U.S. commitment to the expanded use of coal (29-30), but fails totally to mention the economic, social, and environmental problems plaguing the present generation of nuclear power plants. There has not been one new order for a nuclear power plant in the United States since 1975, while over 60 nuclear plants on order or under construction have been cancelled."

Response:

Problems concerning the present generation of nuclear power plants were discussed in the Supplement (see page F-7). The nuclear power plant cancellations are primarily due to current economic conditions (high interest rates) and reductions in U.S. electrical energy demand projections.

Comment (Letter #11, page 29):

"The DEIS fails to discuss alternatives in combination."

Response:

Combinations of alternatives, such as geothermal, biomass, cogeneration and hydroelectric power plants, were not discussed because, at present, even combinations of these technologies do not seem to be capable of providing a major portion of projected U.S. baseload electricity capacity requirements.

These alternatives provided 5 quads of U.S. energy in 1980 (out of a total of 78 quads, or about 6%) and are expected to provide 6.4* quads in 1990 (out of a total of 87 quads, or about 7%) and 9.7* quads in 2000 (out of a total of 100 quads, or about 10%).

These alternatives provided 3.2 quads of U.S. electricity in 1980 (out of a total of 24.8 quads, or about 13%) and are projected to provide 3.8 quads** in 1990 (out of 32.7 quads, or about 12%) and 5.5 quads** in 2000 (out of 41.4 quads, or about 13%).

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*DOE/PE-0029, page 1-9.

**Ibid, pages 10-8 and 10-9.

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