

# Breeder Basics

THE CLINCH RIVER BREEDER REACTOR PLANT PROJECT

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# BREEDER BASICS

. . . a handy guidebook containing basic information about nuclear power, the U.S. breeder reactor program and the role of the Clinch River Breeder Reactor Plant in our Nation's energy future.

*Published by*

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THE ORGANIZATION OF 753 U.S. ELECTRIC SYSTEMS  
SUPPORTING  
THE CLINCH RIVER BREEDER REACTOR PLANT PROJECT

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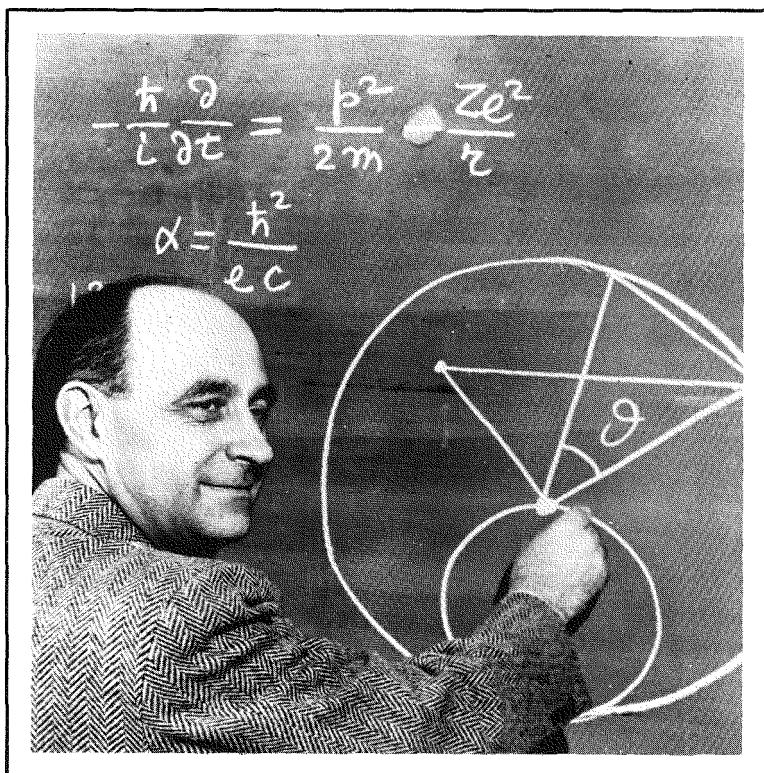
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*Enrico Fermi, a pioneer in the development of atomic energy, said "The country which first develops a breeder reactor will have a great competitive advantage in atomic energy."*

# Contents

	Page
<b>Preface</b>	<b>5</b>
<b>The Breeder Reactor in Perspective</b>	<b>7</b>
Why Develop the Breeder?	8
LMFBR History	10
Current Status	13
Economics of the LMFBR Program	15
Support from the Electric Power Industry for the LMFBR	17
<b>The Clinch River Breeder Reactor Plant</b>	<b>19</b>
Basic Information	19
Participants	21
Site	22
Cost	23
Status and Schedule	23
Employment	25
Licensing	25
Design Philosophy	26
Design Guidelines	27
Plant Design	27
The Breeder Concept	28
Liquid Sodium as Coolant	32
<b>Safety</b>	<b>34</b>
Environmental Impact	34



## Preface

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The economic vitality of the United States, the standard of living which all of us enjoy, and even our national security, depend upon adequate supplies of electric energy that our industrial base and our consumers can count on. The people who are responsible for providing this energy—power producers, distributors, equipment manufacturers and research and development (R&D) organizations—face the challenge of meeting the nation's growing needs for more electricity while dealing with declining fuel resources, increasing costs, and complex environmental, social and institutional considerations.

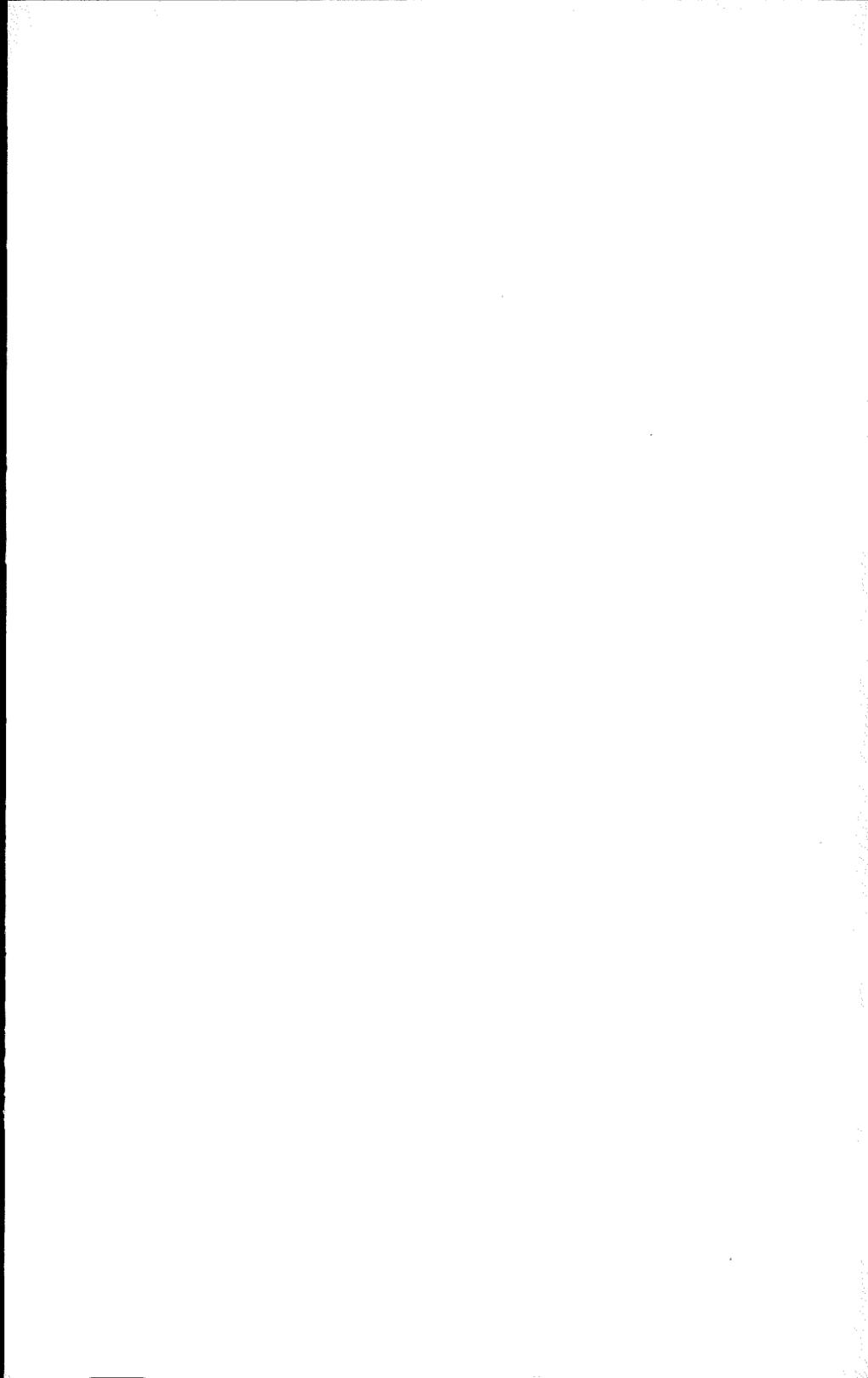
With requirements for electricity outgrowing our domestic fuel resources, we no longer have the luxury of a choice between coal, gas, oil or nuclear fuels. All are needed and must be fully developed in an environmentally acceptable manner. However, of all the country's options, nuclear power is clearly its best long-term energy resource for generating electricity.

Successful commercial development of the breeder reactor would extend nuclear energy's potential contribution as an energy resource from decades to centuries.

Because of this, the nation's electric power industry and the Department of Energy (DOE) are working together in a joint energy research and development project of unprecedented scope and importance—the Clinch River Breeder Reactor Plant (CRBRP) Project, the nation's first large-scale demonstration breeder nuclear power plant.

The CRBRP Project is a key step in this country's carefully planned, long-range program for development of the Liquid Metal Fast Breeder Reactor (LMFBR). The Project's primary objective is to demonstrate the practicality of the fast breeder concept as a safe, reliable, economically competitive and environmentally acceptable energy source and to make it available as a viable energy option within this century.

This booklet, *Breeder Basics*, has two major purposes: to explain how the Clinch River Project fits into the nation's overall breeder reactor program, and to serve as a primer on the plant design, function and safety considerations. It also should provide the basis for the reader's understanding of how the breeder reactor can contribute to the solution of our long-range energy problems.



## The Breeder Reactor In Perspective

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Various approaches to taking full advantage of the natural process of radioactive decay of uranium and of other metals have been the subject of extensive research and development in the United States and in other countries for decades. From all the studies, the type that has consistently revealed the most desirable characteristics is the LMFBR concept. For more than 30 years, the United States has been developing this type of advanced reactor for electric power production. In close cooperation with the U.S. electric power industry, DOE is continuing the intensive development effort that was started by the U.S. Atomic Energy Commission to make this type of power a viable energy option in meeting our country's expanding electrical energy needs in the latter part of this century.

DOE and the utility industry are performing and supporting research and development of other potential energy resource forms and improvements. An enormous effort is being made and very large sums are being spent to find safe, clean and economic ways to use coal, sun, wind, tides, streams, subterranean heat, ocean currents and even the ocean water itself to produce power. All of these forms give prospects of contributing to the solution of the future problem of national energy supply and production self-sufficiency. To make any new technology a dependable means of large-scale use requires decades of activity. The LMFBR is in the most advanced stage of research and development of any of the breeder alternatives—both in the United States and abroad.

An LMFBR can generate more fuel than it consumes and makes use of 60 percent of the energy available in uranium.

Present day commercial nuclear power plants can only convert about 1 percent of the energy contained in uranium into useful power. The LMFBR can also accommodate a fuel cycle using thorium that breeds fuel. This is something which water-cooled reactors cannot effectively do.

## Why Develop the Breeder?

The principal energy resources in the United States for many years have been the fossil fuels—natural gas, oil and coal. Each of these has limitations for long-term availability for electric power production. We know that the supply of natural gas is limited even though there may be large quantities yet undiscovered. We know that oil also is limited.

Coal is abundant in the United States. However, coal as a fuel for electric power generation, has severe problems of environmental effects, highway and railway transportation, handling and cost. In addition, we must conserve our fossil fuels for uses other than generating power. At present, there are certain energy uses for which we have no substitute. Aircraft fuel, fertilizers, plastics, lubricants, medicines and a vast number of petrochemical products are dependent on a large supply of natural fuels.

Uranium, on the other hand, has virtually no beneficial use to mankind other than electric power production. The U.S. uranium resources if fully exploited by means of the LMFBR, could provide electric power to this nation for more than a thousand years.

The nation is rapidly depleting its oil and gas reserves and increasing its dependence on foreign sources. According to the 1977 U.S. Navy Energy Plan, even with a conservative 2.5 percent annual consumption growth rate, the entire estimated range of recoverable resources will be exhausted between 2015 and 2025. Therefore, coal and uranium must play an increasing role in providing electricity now to preserve our energy options in the future. However, even the energy potential of uranium, as immense as it is, is severely limited so long as it is used only in present light water reactors.

Proven reserves identified by DOE are adequate only to meet the lifetime fuel requirements for nuclear plants which are already built or committed for construction. As a result the U.S cannot be assured of a supply of economic uranium to last for the life of any new light water reactors that might be built after the year 2000.

The development and subsequent large-scale application of the fast breeder concept will extend the potential use of our uranium resources from decades to centuries, providing this country with needed quantities of electrical energy at low, stable costs. Further advantages of implementing fast breeder technology include a reduction of environmental impact from waste heat and chemical air pollution, and a reduction in the mining, milling and enrichment of uranium.

The Liquid Metal Fast Breeder Reactor was selected from several breeder concepts for priority development because of (1) favorable performance characteristics and economics, (2) proven scientific and technical feasibility, (3) availability of a broad technology base, (4) potential for early commercial introduction and (5) interest of reactor manufacturers and electric utilities.

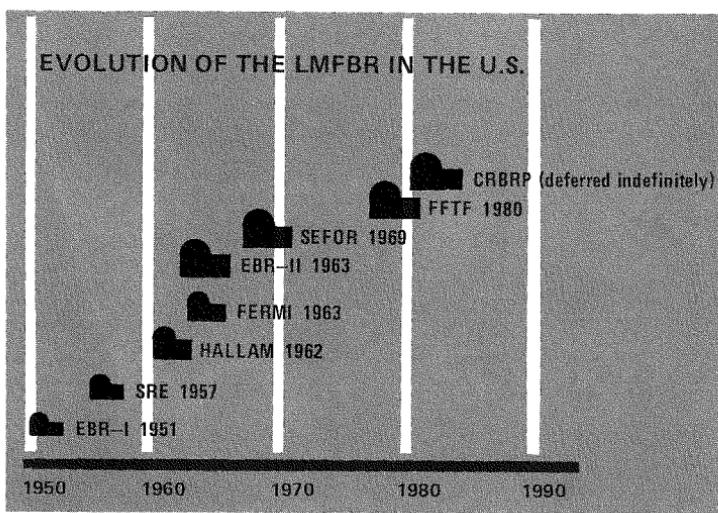
The LMFBR is a natural complement to the light water reactors being built today because both types operate on the uranium-plutonium fuel cycle. The abundant form of uranium (U-238) that has been mined, separated and stockpiled because it cannot be used in light water reactors, can be used in breeders. The LMFBR has another advantage. Some plutonium is produced in the light water reactor process. The breeder will initially provide a market for this plutonium. Ultimately, the excess plutonium produced in breeder reactors can be used to fuel light water reactors and other breeders.

## LMFBR History

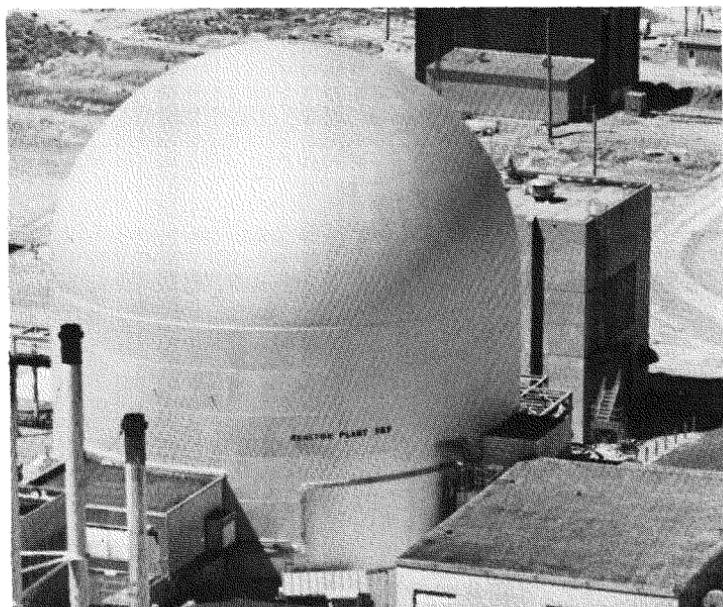
The U.S. interest in breeder reactors dates back to the days of World War II, when the possibility of breeding was first recognized by pioneers in the nuclear field. Much of the preliminary effort on the breeder was conducted in Atomic Energy Commission national laboratories.

One of the earliest steps in this program was the construction of an experimental reactor called Clementine at the Los Alamos Scientific Laboratory, Los Alamos, New Mexico. It was used from 1946 to 1953 to demonstrate the feasibility of operating a reactor with fast neutrons, plutonium fuel and a liquid metal coolant. The Experimental Breeder Reactor I, which produced the first nuclear-generated electric power in 1951, was built and operated by Argonne National Laboratory through 1963 to prove the feasibility of breeding and to demonstrate the technology of liquid metal coolants. This experience, along with later liquid metal-cooled experimental reactors such as the Sodium Reactor Experiment, the Hallam Nuclear Power Facility and the Submarine Intermediate Reactors Mark A and B, contributed important information to reactor design and enabled subsequent plants to be designed with increasingly greater inherent safety.

Later developments led to demonstration of the physics and safety of a breeder reactor and the construction in the U.S. of two fast reactors in the mid-1960s—the Experimental Breeder Reactor II (EBR-II) and the Fermi reactor. EBR-II has operated successfully from 1963 to date. Fermi experienced an accidental partial meltdown of its core in 1968, but resumed operation in 1971. It was eventually taken out of service, primarily for economic reasons. In the mid-1960s construction began on the Southwest Experimental Fast Oxide Reactor (SEFOR) facility which was a joint U.S./Federal Republic of Germany effort directed at research on the safety of LMFBRs. The SEFOR program was successfully concluded in early 1972. Parallel efforts initiated in the United Kingdom, Soviet Union, France, and later in West Germany and Japan have added to Liquid Metal Fast Breeder Reactor experience. France, the United Kingdom, Japan and the Soviet Union have completed demonstration plants.

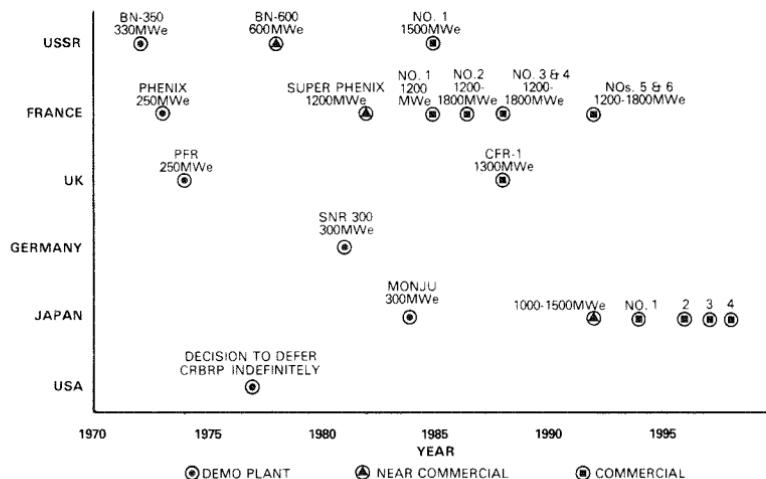


*Steps in breeder development as part of U.S. civilian nuclear power program.*



*The EBR-II facility in Idaho has produced over one billion kilowatt hours of electricity in addition to providing valuable experimental data since startup in mid-1960s.*

The French lead the world in breeder reactor power plant operating experience. They began their program in the early 1950s. Their Rapsodie breeder achieved criticality in 1966. Phenix, a demonstration plant of 250 megawatts, went into operation in 1973. Now they are building Super Phenix—the next step up in the evolution of the breeder. Super Phenix will generate 1200 megawatts of power and is scheduled for criticality in 1982. West Germany has a demonstration plant under construction. All are moving ahead vigorously with plans so they have the option of tapping the potential of breeders by the end of this century.



*Illustration of U.S. and foreign breeder development programs.*

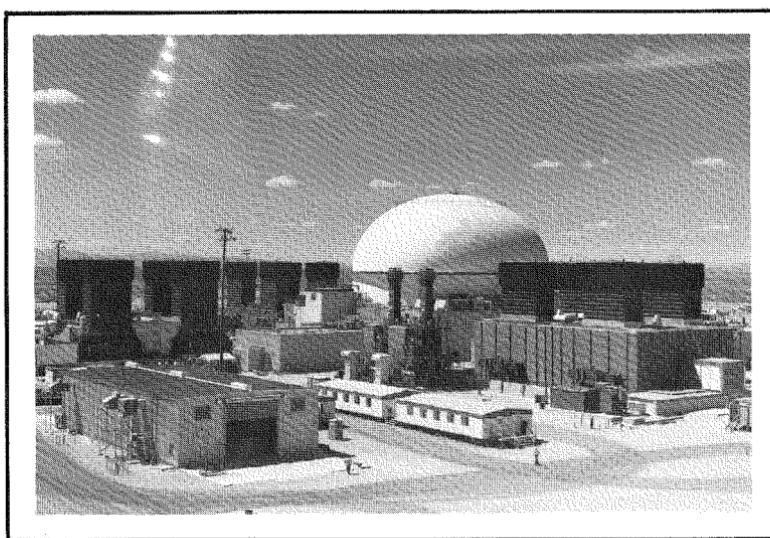
## Current Status

A principal element of the U.S. fast breeder reactor program is the Fast Flux Test Facility (FFTF). The largest test reactor facility in the world, FFTF will focus on the testing of fuels and materials at the Hanford Engineering Development Laboratory, Richland, Washington.

The next step toward timely commercial breeder capability is construction of the Clinch River Breeder Reactor Plant. Work on this Project is currently proceeding at a modified pace pending resolution of the national debate over CRBRP.

As of the publication date of this booklet, CRBRP is scheduled for initial operation in 1988.

Reactor vendors and architect-engineer firms are already at work on designs for larger-scale breeder plants which will be the forerunners of commercial plants. The concepts developed in these design studies will build upon the accumulated U.S. and foreign LMFBR engineering and operating experience. In addition, vital data to be generated from the Clinch River Breeder Reactor Plant Project will be factored into the studies.

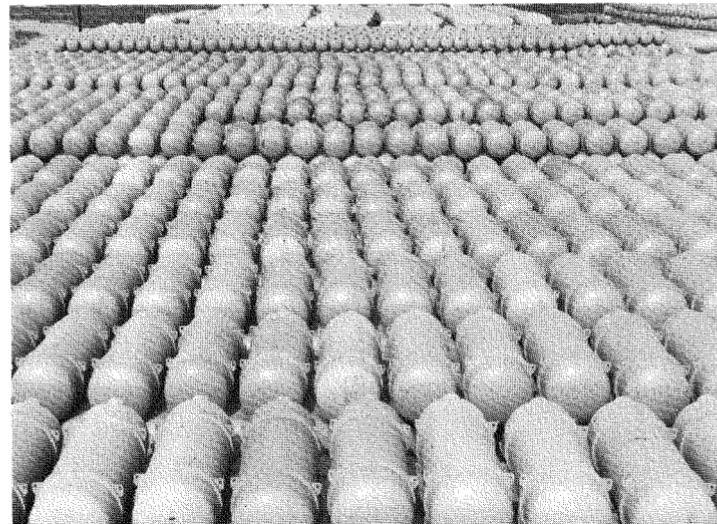


*The recently completed Fast Flux Test Facility (FFTF), near Richland, Washington, is the major research and development reactor for testing breeder fuels, components and systems.*

## Economics of the LMFBR Program

Long-term cost-benefit analyses are inherently imprecise because of the inability to project with certainty important variables such as future energy demand, uranium supply and the availability of alternate technologies. Another complicating factor is quantification of costs or benefits to society arising from such considerations as the environmental impact of coal, gas or oil versus nuclear plants. Despite these limitations, a number of cost/benefit studies have been completed. The ERDA (now DOE) Final Environmental Statement for the Liquid Metal Fast Breeder Reactor Program (ERDA-1535) concluded that the LMFBR can have the following effects:

- a. Free the electric power industry from a dependence upon depletable fuel supplies, which have been and can again be restricted by international political concerns;
- b. Provide a large decrease in the production cost of electricity from nuclear power plants, primarily by reducing costs to mine and process uranium and to enrich the fuel. With a 1993 introduction, the cost of electrical energy will be \$14 to \$16 billion less depending on the rate of inflation and other economic factors. Uranium ore requirements would be cut in half. The need to enrich fuel would be reduced by a factor of four;
- c. Early introduction of the breeder may reduce the capital investment required to develop the nuclear industry, since the investment in uranium mining, milling, and uranium enrichment facilities saved by the breeder may be much greater than the added investment for breeder power plants.
- d. The earlier the introduction of the breeder the greater the benefits. Society incurs added costs by adopting a wait-and-see attitude. A delay in the introduction of the LMFBR by seven years to the year 2000 will cost from 7 to 20 billion dollars. This additional cost—produced by higher cost electrical energy—is simply a foregone saving;
- e. Provide economic benefits far in excess of the R&D costs required to develop the concept to the commercial stage.



*The U-238 stockpiles already in existence at gaseous diffusion plants are right now worth tens of trillions of dollars if used in breeder reactors. The U-238 stockpiles are the equivalent in energy to all coal reserves known in the United States today.*

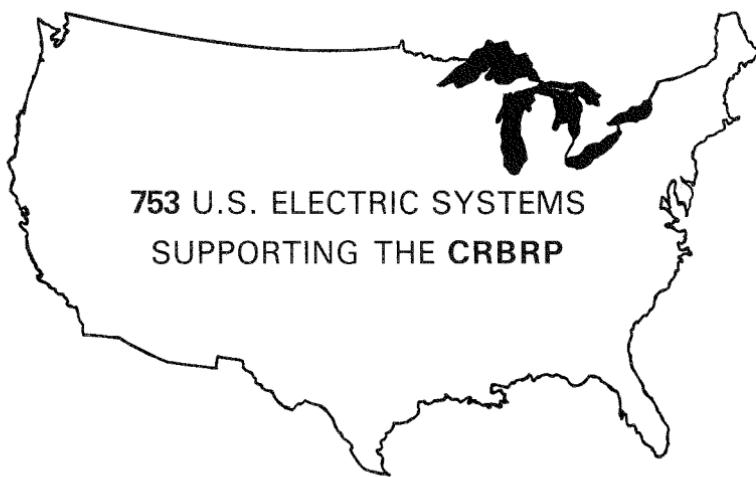
## Support from the Electric Power Industry for the LMFB

In 1971, the Electric Research Council issued the Research and Development Goals Task Force Report. This report—containing then current thinking on where the utility industry should apply research dollars through the end of the century—placed development of a commercially feasible breeder reactor at the top of the research and development priority list.

Previous appraisals by the government scientific leaders and industry groups over a number of years had also concluded that the fast breeder should be developed at the earliest possible date. In response to this growing consensus, the federal government, nuclear industry and electric utilities throughout the country endorsed the concept of a government-industry cooperative effort to develop the nation's first large-scale demonstration breeder. In August 1971, Congress enacted legislation providing funding for a proposed demonstration project.

Meanwhile, the concept of a cooperative effort by government and industry was drawing positive responses from industry. Before the end of 1971, the U.S. Atomic Energy Commission requested and received a number of suggestions for cooperative arrangements. Early in 1972, the government selected the joint proposal submitted by Commonwealth Edison Company of Chicago and the Tennessee Valley Authority (TVA).

In March 1972, based on the Commonwealth Edison-TVA proposal, two new corporations—Project Management Corporation (PMC) and the Breeder Reactor Corporation (BRC)—were created to implement a broad cooperative agreement unprecedented in the history of the nation's electric power industry. The U.S. Atomic Energy Commission agreed to combine resources through PMC and BRC. Firm support was provided by Edison Electric Institute, the American Public Power Association and the National Rural Electric Cooperative Association. The total financial assistance to be provided by the electric power industry—some \$240 million—became the largest total ever pledged for a single energy research and development project. Since that date, the original goal has been far surpassed. Firm commitments of some \$257 million have been made by U.S. electric systems.



**753 U.S. ELECTRIC SYSTEMS  
SUPPORTING THE CRBRP**

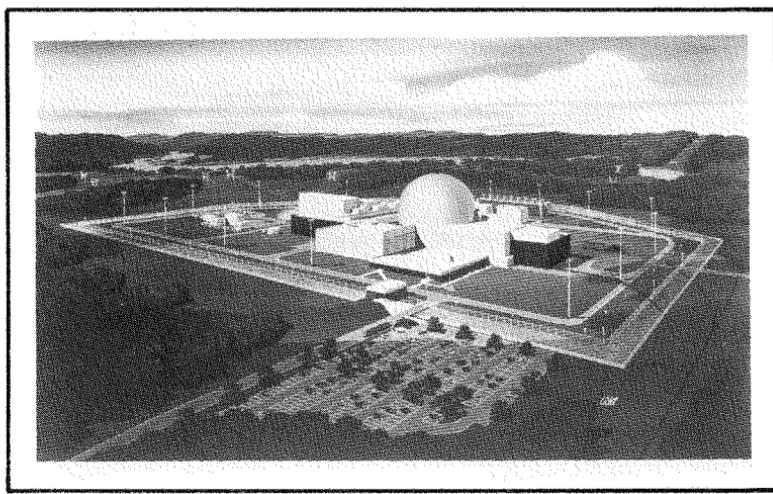
# The Clinch River Breeder Reactor Plant

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## Basic Information

The Clinch River Project is a partnership effort of government and industry. CRBRP is the nation's first large-scale demonstration breeder. The Clinch River Plant will be interconnected with the TVA power grid and deliver 350 megawatts of electricity. The Project's objectives are to:

- Demonstrate that the necessary technology is available to scale up and successfully construct and operate commercial-sized LMFBRs,
- Provide a technical basis for extending the technology to future commercial plants where improvements in fuel life, plant capacity and thermal efficiency will be made for economic reasons,
- Develop operating data on the environmental impact of the LMFBR before large numbers of commercialized LMFBRs are constructed,
- Provide a demonstration of the nuclear parameters necessary for commercial development,
- Demonstrate the minimal impact from disposal of radioactive waste materials,
- Demonstrate the equipment on a large scale and
- Demonstrate the breeder concept in an industrial environment.



Artist rendering of the Clinch River Breeder Reactor Plant

## Participants

DOE has the lead responsibility for managing the Clinch River Project. Day-to-day management is carried out by a single integrated organization in which the DOE people work closely with people drawn from the utility industry—Commonwealth Edison Company, TVA and PMC.

PMC is a non-profit organization formed especially for the Clinch River Project. It represents the interest of the utility industry in the Project. PMC is responsible for utility fund management, arranging participation of utility personnel in the program by providing staff members who have technical and managerial skills gained from industrial experience, assuring that the plant will satisfy the industry's needs for a licensable, economic demonstration of the LMFBR technology and preparation of information for the public and utility industry.

A second non-profit group, the Breeder Reactor Corporation, provides senior counsel on behalf of the utility industry and serves to keep the public and the electric power industry informed of Project progress. BRC is composed of more than 750 electric systems from the public, private, municipal and cooperative sectors of the electric power industry. The design of the Project is done under government contract by the most experienced and competent companies in this technology area in the United States.

Westinghouse Electric Corporation is the lead reactor manufacturer, responsible for designing and furnishing the nuclear steam supply system for the Clinch River plant. Westinghouse is supported by the General Electric Company and the Atomics International Division of Rockwell International as subcontractors.

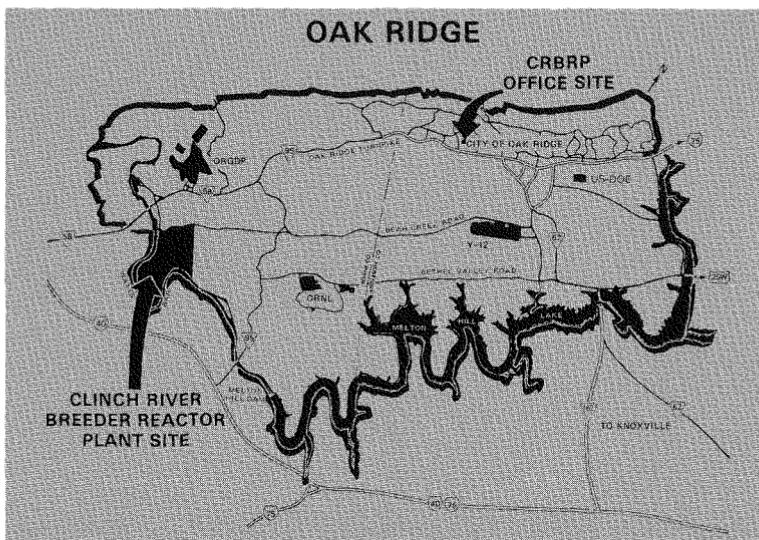
Burns and Roe, Incorporated, is providing architect-engineering services for the entire plant except for the engineering design services for the nuclear steam supply system.

Stone & Webster Engineering Corporation is the general contractor, with responsibility for constructing the plant and installing components, systems and equipment procured by others.

TVA will operate and maintain the plant for the five years of the demonstration period. TVA has an option to acquire the plant as a part of its regular power system at the end of the five-year period.

## Site

The Clinch River Breeder Reactor Plant is to be built on about 100 acres of TVA's 1,364-acre Clinch River site in Oak Ridge, Tennessee. Bordering DOE's Oak Ridge reservation, the site offers good road, rail and water access, and the convenience of existing TVA power transmission lines. Within 30 miles of the site is metropolitan Knoxville, which has a population of about 200,000. Oak Ridge has a population of about 30,000, and most of the residents live at least 10 miles from the site.



*Map of Oak Ridge, with locations of Clinch River Breeder Reactor Plant Site (left), and principal DOE facilities.*

## Cost

The total Project cost is estimated at about \$2.88 billion. This includes funds for construction, research and development and operation during the first five-year demonstration period. Sponsoring utilities are furnishing more than \$257 million—the largest industry commitment ever made for a single energy research and development project. Participating research and equipment manufacturers are contributing \$10 million. The federal government is to provide the remainder of the funds.

## Status and Schedule

Status of the CRBRP as of publication date is as follows:

- About \$700 million has been spent on the Clinch River Breeder Reactor Plant Project. At the end of FY80 expenditures were about \$930 million.
- More than 92 separate companies in 24 states and Washington, D.C., are working on the Project. About 4,100 people are presently employed on the Clinch River Breeder Reactor Plant Project.
- Ninety percent of the research and development to be borne by the Project is finished.
- Project design is over three-fourths complete.
- Over \$530 million worth of components are already on order, and fabrication of these orders is over 50 percent complete.
- Expenditures on component fabrication stands at approximately \$225 million.
- Components already delivered total \$103 million.

Based on the current activity level, initial clearing, grading and excavation of the site could begin in late 1980 under a Limited Work Authorization requested from the Nuclear Regulatory Commission. Major construction would follow about a year later with a target date



*One of three intermediate heat exchanger (IHX) guard vessels is shown being placed in storage at the Hake Associates warehouse, Memphis, Tennessee, in January 1979.*

for initial operation in 1988. This will be followed by a five-year period of demonstration operation. Commercial operations will then continue for the life of the plant.

## Employment

About 2,000 scientists, engineers and administrative personnel from participating government and industrial-contractor organizations are engaged in the plant design and supporting research and development activities across the country. Of that number, about 350 professionals work in Oak Ridge. At the peak of construction, some 3,050 persons will be employed in building the plant.

A permanent staff of 240 employees will operate the plant when it goes on line.

## Licensing

All nuclear power plants built in the United States must meet Nuclear Regulatory Commission (NRC) licensing requirements. CRBRP must follow much the same licensing procedures and safety standards as the conventional light-water reactors, which now provide almost 13 percent of our electricity. The Environmental Report for CRBRP, as well as the Preliminary Safety Analysis Report (PSAR), have already been accepted by NRC.

A Final Environmental Statement (FES) for the Clinch River plant was issued by NRC in 1977 with the conclusion that CRBRP could be built and operated without significant environmental degradation or risk to the health and safety of the public. The planned start of the public hearings based on the FES in June of 1977 has been indefinitely deferred at the request of DOE pending a Congressional decision on the future of CRBRP.

## Design Philosophy

The Clinch River Breeder Reactor Plant is an essential step from today's experimental breeders to large scale future plants. For the past eight years it has been a principal feature of the successful transition from the federal government's 40-year research and development effort toward demonstration of the breeder reactor as an energy option for commercial application. The next breeder plant would be considerably larger than CRBRP as shown in the progress of plants abroad.

In the Clinch River plant, all of the components of a large LMFBR power plant will be assembled and operated as an integrated unit for the first time. The vitality of the assumptions regarding economics, operating characteristics, reliability, safety and environmental impact will be demonstrated in an operating utility company environment. The data will be made available to both industry and government for further LMFBR development and use.

Development of the fast breeder is following a sequence similar to that which led earlier to the successful introduction of light water reactors as power producers: technology development, experimental reactors, the demonstration phase and then commercial plants. Assuming successful development and demonstration, and no better alternative electric power generation choices have been developed, it is expected that substantial commitments will be made near the turn of the century for construction of large commercial-size LMFBR plants. This technology will then be playing a significant role in supporting this country's economic vitality.

# Design Guidelines

The Clinch River Breeder Reactor Plant design is based on the following major guidelines:

- Reliability achieved through the use of proven technology and simple, practical design.
- High plant availability and ease of inspection and maintenance.
- Minimal environmental impact and good public acceptance.
- Demonstration of breeding capability.
- Ease of operation based on many years of light water reactor experience.
- Prospect of economic competitiveness for future Liquid Metal Fast Breeder Reactors.
- A sound licensing philosophy based on meeting the requirements for commercial licensing.
- Safety based on preventing abnormal occurrences rather than on mitigating consequences.

# Plant Design

Virtually all electricity is produced by using energy from either falling water or heat from power generating units. Since there are relatively few suitable sites remaining for hydroelectric plants, most new power plants being built today or projected for the future are "thermal plants" in which heat is used to produce steam to turn turbine generators.

Thermal plants generate heat either by burning fossil fuels (coal, oil or gas) or by controlled nuclear fission. Conventional nuclear reactors "burn" or fission a specific isotope of uranium known as U-235 as the basic fuel to generate the heat. Since both types of thermal plants produce steam, their principal difference is in their heat source.

## The Breeder Concept

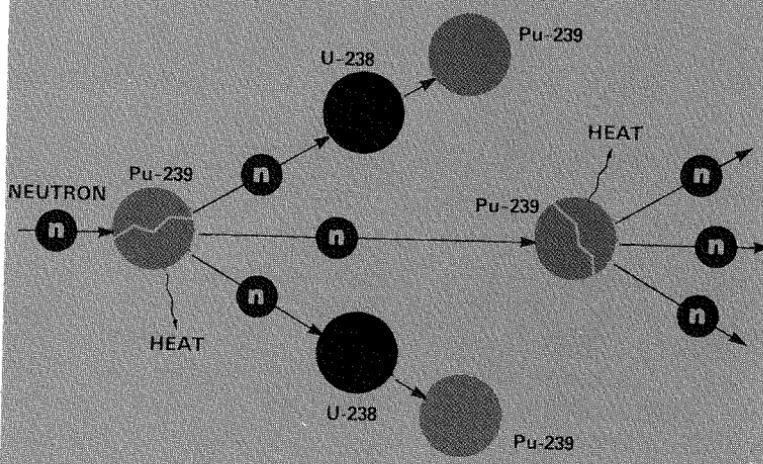
A Liquid Metal Fast Breeder Reactor is a special type of nuclear power plant that produces electricity and nuclear fuel. Those features of the LMFBR that make it "special" are embodied in its name. "Liquid Metal" refers to the liquid metal coolant (sodium) that is used to remove the heat produced in the nuclear reactor. "Fast" refers to the high speed neutrons which initiate the nuclear fission reaction that produces the heat and permits the reactor to breed. "Breeder" refers to the fact that this type of reactor actually produces, or breeds, more nuclear fuel than it consumes in its production of heat.

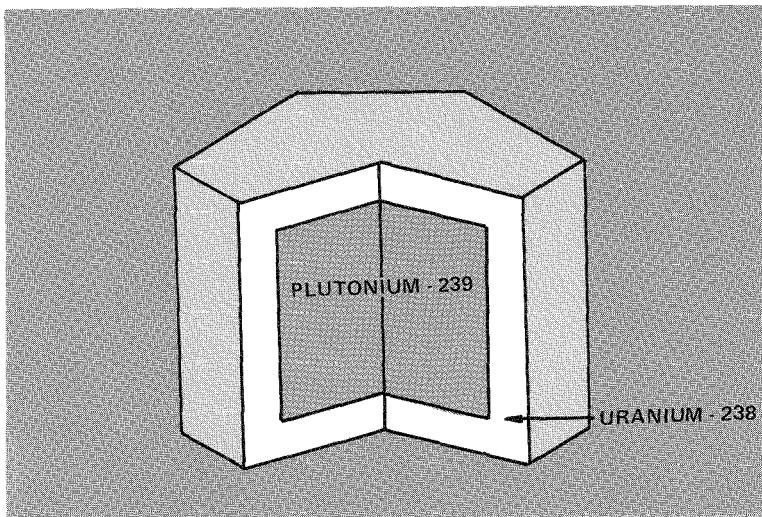
Nuclear fission is a process that occurs when a freely moving neutron (an atomic particle) strikes a peculiar type of atom, becomes absorbed in the atom and subsequently causes it to become so unstable that it splits apart into two smaller particles of approximately the same size.

The fission process can be initiated by either a "fast" neutron, that is, one which moves at a high speed, or a "thermal" neutron, which is nothing more than a fast neutron that has been slowed to a relatively low speed. The importance of the fission process lies in its two basic outputs. First, the process is accompanied by the release of a considerable amount of kinetic energy which is immediately transformed into heat for use in generating electricity. Second, the process, which is initiated by a neutron, is also accompanied by the release of two or three more neutrons ("fast" neutrons). This makes it possible, under controlled conditions, for the process to be self-sustaining and for energy to be generated continuously.

Numerous heavy elements, called fissionable materials, are capable of fission. However, only uranium 233, uranium 235 and plutonium 239 are practical as basic fuel (fissile) materials for nuclear reactors. Uranium 235 occurs as a minor constituent (less than one percent concentration) of natural uranium. U-235 presently serves as the fissionable material for fueling light water reactors. The other two elements, uranium 233 and plutonium 239, do not occur in nature, except for trace amounts. These particular fuels are produced in nuclear reactors by the absorption of neutrons in certain materials called fertile materials. Both fuels can be used as the primary fuel in either breeder reactors or the conventional light water reactors of today.

THE BREEDER REACTOR CONVERTS  
URANIUM-238 TO FISSIONABLE  
PLUTONIUM-239





*Illustration of LMFBR's core and blanket configuration that makes fissioning and breeding possible.*

An LMFBR operates most efficiently with plutonium (predominantly plutonium 239) as the fissionable material and uranium 238 as a fertile material, both in oxide form.

Fast neutrons are used to initiate the fission reaction in the plutonium fuel. When the plutonium fissions, it produces heat and two or three more neutrons. Under proper conditions, some of these neutrons can be absorbed in the uranium 238 which then becomes plutonium 239. The new plutonium can then fission to continue the process of generating heat and making new fuel. Nuclear breeding, by definition, is said to occur whenever the rate of production of new fuel exceeds its rate of consumption.

In practice, the plutonium-uranium nuclear reaction takes place in the core and blanket regions of an LMFBR.

The central region of the reactor is called the reactor core and it holds the fuel assemblies containing a mixture of plutonium fuel

and fertile uranium oxides. The blanket region surrounds the core and holds the uranium bearing assemblies. Most of the fissioning occurs in the core region. Most of the breeding occurs in the blanket region.

At periodic intervals, the reactor is shut down to remove selected core and blanket assemblies and replace them with fresh ones. The spent assemblies can then be processed to reclaim the fuel and fertile materials for eventual recycling into new and existing reactors.

## Liquid Sodium As Coolant

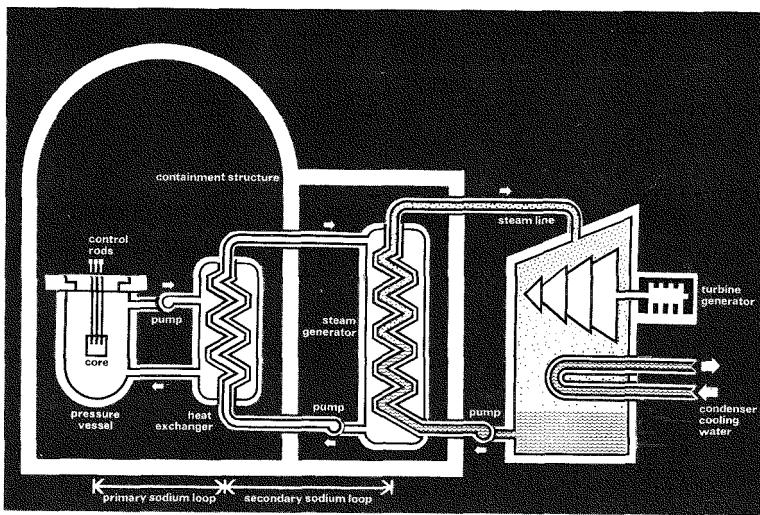
A typical LMFBR power plant consists of a reactor, three (or four) primary cooling loops, companion intermediate cooling loops, steam generators and conventional turbine-generators.

The reactor is operated to maintain a steady fission process in the core (and blanket) regions.

Heat developed by the fission process is transferred to the liquid sodium coolant which is circulated by the primary sodium pumps through the reactor regions. Liquid sodium is used as a coolant because of its good heat transfer properties, its high boiling point and its limited effect on the energy of fission neutrons. The high boiling point of sodium allows the reactor plant to be operated at the high temperatures (1000° F) desired for maximum efficiencies without requiring pressurization of the sodium to prevent its boiling. Three (or four) primary cooling loops are used to minimize the size of the heat transfer components and to provide redundant cooling paths as a safety precaution and for maintenance considerations.

When exposed to neutrons in the reactor, the primary sodium coolant becomes radioactive. Furthermore, sodium reacts with water. For these reasons, LMFBR power plants contain intermediate cooling loops or buffer zones, between the radioactive primary sodium on one side and the steam generator on the other. In this way, radioactive sodium is prevented from ever coming in contact with water and/or steam. Sodium is circulated in the intermediate loops to pick up heat from the primary loops and transfer it to the water in the steam generators. Here the water is converted to steam which in turn is used to drive conventional turbine-generators to produce electricity.

For those interested in more detailed, specific information on the design of CRBRP and its components, a booklet entitled *Clinch River Breeder Reactor Plant Design Description* is available free upon request. (See inside front cover.)



*Schematic outline of Clinch River Breeder Reactor Plant systems.*

## Safety

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Nuclear power—with its excellent safety record and unique energy potential—offers one of the best immediate prospects for reconciling the nation's growing needs for electricity with its equally demanding fuel-supply problems and environmental goals. The atom as an energy resource may not be perfect, but each year it improves its position relative to other available sources of energy for producing electricity.

Never before has any major technology evolved with such care, conservatism and rigorous regulation and control—so much so that today's nuclear power reactor is among the safest of all man's complex machines. The record speaks for itself—millions of reactor-hours of operation without a single radiation fatality to the public or to any worker in a commercial nuclear power plant. Nuclear ranks among the nation's best in overall safety as well. CRBRP is designed to continue this enviable safety record of nuclear power.

## Environmental Impact

The LMFBR generally shares or improves upon the basic advantages nuclear power enjoys over other sources of electrical energy. Like other nuclear power plants, for example, the breeder will not add combustion products to the atmosphere. A typical coal plant releases 350-400,000 tons of pollutants to the air each year. This can be reduced to about 15,000 tons with extremely expensive stack-gas cleanup systems and other environmental controls.

Breeders and other nuclear plants, by comparison, release no combustion products whatever and only minimal radiation which is well within prescribed standards.

Conventional nuclear plants are less efficient than coal plants and, therefore, give off slightly more waste heat. Breeder reactors, however, will be more efficient than light water reactors and comparable to coal plants in the amount of heat released to the atmosphere.

The breeder will also require less land use than other energy options. About 200 acres of land must be strip-mined each year to provide fuel for a coal plant. Approximately five to seven acres of land must be mined each year to provide the uranium fuel for a conventional nuclear plant. Breeders will require less than a single acre to yield fuel with the same potential. In addition, the large stock-pile of "tails" of uranium—left over from the enrichment process—will be available for use. Because of the stockpile, breeder reactors would require no mining for at least a hundred years and probably more.

A major portion of radioactive fission products, now released under controlled conditions by conventional light water reactors, will normally be retained within the breeder system. These fission products can thus be controlled and disposed of off site.

In addition, certain fission products which normally constitute radioactive waste can be "burned" in a breeder reactor. This will convert them to waste products which do not require elaborate, long-term disposal and storage facilities.

ERDA (now DOE) has released an environmental statement regarding breeder technology and assessing the expected total impacts through the year 2020. The document discusses breeder economics as well as the environmental, social and political aspects of each element of the fuel cycle from mining through reactor operation to disposal of wastes. In addition, detailed environmental information on the Clinch River plant has been developed by participants in the demonstration project. Assistance in obtaining more information on either CRBRP or the LMFBR in general, is available through the CRBRP Project Information Office.

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