REPORT TO THE CONGRESS ON ALTERNATIVE FINANCING OF THE CLINCH RIVER BREEDER REACTOR PLANT PROJECT

MARCH 1983

DO NOT MICROFILM
COVER

U.S. DEPARTMENT OF ENERGY
ASSISTANT SECRETARY FOR NUCLEAR ENERGY
OFFICE OF BREEDER REACTOR PROGRAMS
WASHINGTON, D.C. 20545

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

DOE/NE--0050

DE84 004734

REPORT TO THE CONGRESS ON ALTERNATIVE FINANCING OF THE CLINCH RIVER BREEDER REACTOR PLANT PROJECT

MARCH 1983

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

U.S. DEPARTMENT OF ENERGY
ASSISTANT SECRETARY FOR NUCLEAR ENERGY
OFFICE OF BREEDER REACTOR PROGRAMS

This document is

PUBLICLY RELEASABLE

Larry O. Williams
Authorizing Official

Date: *04/19/2007*

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

EWB

TABLE OF CONTENTS

	<u>Page</u>
Executive Summary	ii
Chapter I Introduction and Background	1
Chapter II DOE Studies and Synopsis of Utility Task Force Report	7
Chapter III Next Steps	13
Appendices	
A. Project Background and Existing Arrangements	14
B. Project Costs	27
I. Capital Costs to Complete Project	27
II. Operation and Maintenance Costs	30
III. Fuel Cycle Costs	34
C. Project Reliability	43
I. Plant Availability/Plant Capacity Factor	43
II. CRBRP Power Generation Capability and Useful Life	50
D. Project Revenue Projections	52

EXECUTIVE SUMMARY

This report was prepared in response to Congressional direction in conjunction with the Further Continuing Appropriations Act for Fiscal Year 1983 (Pub. L. No. 97-377), which required that DOE explore alternatives for securing additional private sector financing for the Clinch River Breeder Reactor Plant (CRBRP) Project.

Our approach was to develop Government technical input concurrent with and for use in the development of financial alternatives by the private sector Utility Task Force organized under the auspices of the Breeder Reactor Corporation. The Utility Task Force concentrated on evaluating the financial aspects of various funding options from the private sector perspective.

The Utility Task Force report found that there is a wide range of possible alternatives for funding a portion of the CRBRP costs which could reduce Federal outlay requirements and attract significant private sector participation. These alternatives range from off-budget Federal guaranteed project financing, to user fees levied on electric generating utilities, to relatively traditional financing of the market value of the plant. The Task Force report considers the family of concepts that are based on seeking private investment commensurate with the market value of the CRBRP as the most viable alternative funding approach although it may be necessary to augment this concept with others of the discussed alternatives depending on the amount of private funding required.

The Utility Task Force has indicated that it intends to immediately proceed with discussions aimed at developing specific investment and marketing strategies. This will include developing both the structure of a private investment venture and beginning discussions with potential customers for CRBRP power.

Negotiations with the potential investors and customers and any necessary change to the existing four-party contract need to be vigorously pursued on a schedule that permits required legislation to be enacted by October 1, 1983.

o Background

The Clinch River Breeder Reactor Plant (CRBRP) Project is a national research and development project. It is an integral part of the Liquid Metal Fast Breeder Reactor (LMFBR) program being conducted by the Department of Energy (DOE). The LMFBR has long been recognized as a virtually inexhaustible energy

option with the highest potential for meeting the future energy needs of the United States.

The CRBRP Project in Oak Ridge, Tennessee, is the nation's first large-scale demonstration breeder reactor. A breeder is a type of nuclear reactor that creates more fuel than it uses as it generates electricity.

CRBRP is a partnership effort of the U.S. Department of Energy, Commonwealth Edison Company, Tennessee Valley Authority, and Project Management Corporation, which represents the 753 utilities that have pledged to contribute \$347 million including interest to the Project.

The Project is now ready to proceed to completion. Design is almost completed, over 70 percent of the equipment is on order or delivered, site preparation activities are underway, Project environmental hearings have been completed, and all aspects of licensing are proceeding rapidly. In late Calendar Year 1983, the Project expects to have the necessary Nuclear Regulatory Commission approvals to begin plant construction. Initial plant start-up is scheduled for late 1989 with the sale of significant quantities of electricity beginning in June 1990.

o DOE Studies

The Department established four principal objectives for the Utility Task Force:

- 1) increase private sector financing for CRBRP,
- 2) establish a stable and predictable financial basis for cost-effective completion of the project,
- 3) allocate project costs to research, engineering development and market values, and
- 4) partition risks associated with the project between those associated with any powerplant project and those associated with a unique developmental project.

The DOE has developed the technical and cost related information for the project in order to support the financial evaluation conducted by the Utility Task Force and to provide a technical basis for use by the Congress in evaluating alternative financing proposals. The DOE evaluation of Project Costs, Reliability, and Revenue Projections are contained in the appendices to this report.

The estimate of the additional funds required to complete the plant is approximately \$2.3 billion for the period FY 1984 to June 1990 when significant revenues will begin from the sale of electricity. Since \$.2 billion remains and is available from utility and contractor pledged contributions and interest, additional funding required from Government and private sources is about \$2.1 billion. This information was utilized by the Utility Task Force in evaluating the amount of new private financing needed.

Operation and maintenance costs were projected for the 30-year life of the plant and adjusted to reflect recent experience by utilities in the operation of light water reactors particularly to reflect post-Three Mile Island experience. A conservative estimate of about \$40 million per year (1983 dollars) in operating costs was developed.

The fuel cycle was analyzed and costs were estimated for supply of plutonium, fuel fabrication, fresh fuel shipping, CRBRP fuel reprocessing, and waste management. The DOE study concluded that there was considerable confidence in the availability of an adequate supply of plutonium and in the annual cost estimate of about \$18 million (1983 dollars). Additionally, DOE assumed that nuclear waste would be handled in accordance with the Nuclear Waste Policy Act after 1998 and that a charge of 1 mill per KWH would be levied on CRBRP electricity in accordance with the Act.

The Project reliability, net output, and useful life were the subject of another study. This study concluded that the design goal of 82 percent availability and 75 percent capacity factor were reasonable and achievable but a 65 percent capacity factor after initial startup and shakedown were assumed for conservatism. The plant is conservatively designed for a 30-year useful life which is in accordance with industry standards. The plant will produce 330 MWe of net saleable power for the first 10 years and 380 MWe thereafter. These figures represent the effect of deducting power consumed in the operation of the plant which reduces the gross output of 375 MWe gross (430 MWe gross after 10 years).

A study was also performed of the need for new electrical generating capacity in the Southeastern United States in the 1990's and beyond. This study shows a need for over 16,000 MWe additional capacity to serve peak loads by 1995. CRBRP would provide only about 2 percent of this need. Since new plants in that region are planned to be coal-fired, projections of the cost of baseload electricity using coal as fuel were made which provided a range of 14.6¢ to 15.7¢ per KWH in 1991 in year of expenditure dollars.

o Utility Task Force Report

The category of financing which the Utility Task Force focused on to reduce Federal outlays and secure greater private participation is based on the value of the project as an electrical generating plant.

The Utility Task Force evaluated the reasonable bounds of private financing which could be forthcoming for this Project based on this "value". This analysis is based on the net cash flow expected to be available to the project from the sale of electricity and the benefits to equity investors in generating capacity.

Based upon the assumption that the electric revenue from the plant is equivalent to firm baseload capacity for a coal-fired plant, the Utility Task Force report concludes that income should be sufficient to cover operating costs plus an investment of as much as \$1.1 billion (including debt, equity, and interest of about \$300 million). The variables in the analysis which would affect the project's economic viability are the level of Government funding and amount of cash equity invested by the private sector.

The Utility Task Force has not recommended a single option but has identified a range of alternatives to be considered. The Task Force considers that there are many different ways to structure private investment in the Project. The Task Force also points out that while a number of Federal assurances and warranties are required many of these are contingent in nature and may never be actually called upon.

o Government Responsibilities

At present, the Government has assumed all the direct and indirect Project risks and financing requirements above the financial contributions of the utilities and others (a total of \$347 million with interest). The Government-borne risks include those of Project completion, performance, licensing, and operation and maintenance during the 5-year demonstration period as well as long term operation and/or disposal of the facility if the Project cannot be sold or transferred as provided in the current project arrangements.

The Utility Task Force report concludes that the Government must continue to bear certain project risks in order to attract private investment which would place equity funds at risk and seek loans to cover a significant amount of the CRBRP capital costs. By continuing to carry these risks, the Government will be able to shift a considerable amount of the

financing from the public to the private sector. Government assurances or contingencies which may be required as described in the Task Force report include the following:

- long-term contracts for fuel supplies
- performance warranties
- assurances of continued Government funding for construction and demonstration purposes
- possible power purchase or marketing commitments.

Overall, the net effect of implementing private financing would be to significantly reduce the future Federal outlays required to complete the Project, and would provide a more stable and predictable funding for the Project.

o Legislative Action

In order to implement the general financing approach recommended by the Utility Task Force, modifications to the existing four-party contract between DOE, TVA, Commonwealth Edison, and Project Management Corporation would be required or at least additional arrangements among the principal parties and additional Congressional authorization or approval such as:

1. Appropriate authorization required for DOE funding for FY 1984-1990.
2. Modification to the existing cooperative arrangement to recognize the undertaking by DOE and private investors to fund and own the Project on a proportional basis.
3. Contractual authority which commits the Government to contingencies and risks which are beyond the normal investor risks.
4. Long-term market commitments for electric sales (based on debt services needed) to the extent long-term firm sales contracts are unavailable.
5. Long-term contracting authority.

The Department's experience in financial transactions indicates that a financial structure must be worked out with all the parties involved to assure that there is adequate protection to parties against a number of unforeseen contingencies. Therefore, the specific structure selected should await discussions with investors and lenders.

CHAPTER I

Introduction and Background

A. Introduction

The Clinch River Breeder Reactor Plant (CRBRP) Project is an endeavor of strong national importance. It is an integral part of the Liquid Metal Fast Breeder Reactor (LMFBR) program being conducted by the Department of Energy (DOE). The LMFBR has long been recognized as one of the energy options with the highest potential for meeting the future energy needs of the United States. The CRBRP Project is now at a crucial juncture. Design is almost completed, over 70 percent of the equipment is on order or delivered, site preparation activities are underway, Project environmental hearings have been completed, and all aspects of licensing are proceeding rapidly. In late Calendar Year 1983, the Project expects to have the necessary Nuclear Regulatory Commission approvals to begin plant construction.

Congress in conjunction with the Further Continuing Appropriations Act for Fiscal Year 1983 (Pub. L. No. 97-377), required that DOE vigorously evaluate alternatives for securing additional private sector financing for the Project. During the past 2 months, DOE and a Task Force formed under the auspices of the Breeder Reactor Corporation have been conducting such an evaluation and the results of these efforts are contained herein.

OBJECTIVES:

The Department has established four principal objectives for the Utility Task Force:

- 1) to increase private sector financing for CRBRP,
- 2) to establish a stable and predictable financial basis for cost effective completion of the project,
- 3) to allocate project costs to research, engineering development and market values, and
- 4) to partition risks associated with the project between those associated with any powerplant project and those associated with a unique developmental project.

Our approach was to develop Government technical input concurrent with and for use in the development of financial

alternatives by the Utility Task Force. The Government evaluations focused mainly on consideration of the relevance of the project's technical aspects while the Utility Task Force concentrated on evaluating the financial aspects of various funding options from the private sector perspective.

B. Background

This section briefly summarizes the background of the CRBRP project. Additional information is contained in Appendix A, Project Background and Existing Arrangements.

1. History of the Clinch River Project

Public Law No. 91-273 authorized the Atomic Energy Commission (AEC) to enter into cooperative arrangements with industry for the design, construction, and operation of a Liquid Metal Fast Breeder Reactor Plant in accordance with criteria submitted to the Joint Committee on Atomic Energy. On August 7, 1972, a Memorandum of Understanding (MOU) was entered into among AEC, The Tennessee Valley Authority (TVA), Project Management Corporation (PMC), Commonwealth Edison Company (CE), and Breeder Reactor Corporation (BRC) which generally stated the Project arrangements to be included ultimately in a definitive contract. PMC was to serve as the central management and contracting organization for the Project. BRC's role was to obtain financial and other participation of the 753 utilities contributing funds to the Project. The MOU contained an estimate of the cost of the Project at \$699 million based on conceptual designs submitted by the three reactor manufacturers in their proposals to supply the plants' nuclear steam supply system. It also contained a commitment by AEC to seek additional funding if it appeared that the resources available to PMC were insufficient to permit continued effective conduct of the Project. Program Justification Data Arrangement No. 72-106, submitted to the Joint Committee on Atomic Energy (JCAE) on August 11, 1972, restated the AEC's commitment to seek additional funds for the Project if necessary, and also contained the \$699 million cost estimate. It was recognized, however, both in the justification data and in JCAE hearings which followed, that the design of the plant was not yet firm and could change significantly.

A "four-party contract" for carrying out the Project (between AEC, TVA, CE and PMC) was executed on July 25, 1973. Under the terms of the four-party contract, PMC was authorized to manage the Project in accordance with agreed upon Project objectives. PMC was to use the utility-pledged contributions and AEC's funds for Project costs. The AEC, aside from providing direct funding assistance, was to furnish indirect assistance from the LMFBR Base Program, special nuclear materials and technical supervision and administration of the Nuclear Steam Supply System (NSSS) aspects of all contracts. The TVA was responsible for the lead role in planning for plant operation and maintenance and was also to provide personnel to fill certain key management positions in the Project. Under the contract TVA has the option to ultimately acquire title to the CRBRP after completion of the demonstration period. CE was to furnish the General Manager, the Project Manager, the Engineering Manager, and the Technical Services Manager as well as procurement and other services.

The four-party contract was modified in May 1976 to substantially realign the responsibilities of the parties. The impetus for the contract modification was the growth of the Government's investment relative to the utilities' investment. The modification, upon becoming effective, provided the Energy Research and Development Administration (ERDA) with the responsibility for the management of the Project and ownership of the plant. The parties agreed that PMC, while no longer directly managing the Project, would continue to administer the utilities' interests by monitoring the Project, preparing and sending out Project information to the BRC and the utility industry, arranging for participation of the utility personnel in the conduct of the Project, investing and disbursing the utilities' funds, and exercising the contractual rights on behalf of the utilities. TVA's responsibilities under the modified contract remained relatively unchanged except that TVA agreed to transfer custody of the plant site to ERDA rather than retaining such custody.

2. Cost Estimate Development

The four-party contract recognized that the design of the plant had not been selected on a detailed and firm basis. Therefore one of the first tasks embarked upon after execution of the four party contract was the establishment of a firm design and cost estimate for the Project. In

June 1974 a reference design for the Project was developed which was estimated at \$1.736 billion with initial criticality projected in July 1982. The increase in estimated cost prompted the Government to seek, and Congress to authorize, the change in the Project arrangements transferring management responsibility to ERDA with support and assistance from PMC within an integrated Project Office composed of representatives of the Federal Government and the utility industry. This change in arrangements became effective May 1, 1976. Delays imposed on the Project by budget reductions, delays in the licensing process, and a further reassessment of the cost to complete the Project resulted in a 1975 reestimate of \$1.95 billion, with a delay of 15 months in initial criticality to October 1983. The 1975 estimate remained the baseline until the previous Administration's decision in 1977 to suspend licensing activity and seek termination of the Project. Since 1977 the project cost estimate increased to \$3.6 billion, and initial criticality was delayed to September 1989. In the FY 1983 continuing resolution Congress has directed DOE to explore proposals to reduce Federal budget requirements for the Project and to secure greater participation from the private sector.

3. Reasons for Cost Growth

Since the development of the initial CRBRP baseline cost estimate of \$1.736 billion in 1974, more than 68 percent of the subsequent cost increases have been beyond the control of the Project. The majority, or 56 percent, is attributed to actions of the Government which have reduced the Government's funding profile for the Project, delayed completion, or threatened termination of the Project. Another 12 percent were cost increases due to requirements imposed by the Nuclear Regulatory Commission (NRC). Only 32 percent of the increase was theoretically within the control of the Project, and these resulted from the developmental nature of the Project.

4. Project Restart

The present Administration directed that the CRBRP be completed as expeditiously as possible. Accordingly, CRBRP funding was included in its FY 1982 budget request in the amount of \$254 million. Congress authorized \$228 million for the CRBRP in the Omnibus Budget Reconciliation Act of 1981, and appropriated \$193.9 million for FY 1982.

The Conference Report, accompanying the Budget Reconciliation Act expressed the intent that:

***[T]he plant should be constructed in a timely and expeditious manner, so that a decision on the commercialization and deployment of breeder reactors can be made on the basis of information obtained in the operation of the plant. The plant should therefore be constructed on the basis of that objective, and not on the basis of providing needed power in the specific region of the Clinch River site.

In August 1981, DOE requested that NRC reestablish its review of Project safety documentation, and in September 1981, the NRC established a program office to conduct the licensing review of CRBRP.

5. Site Work

In response to President Reagan's direction that Government agencies proceed with demonstration of breeder reactor technology, including completion of Clinch River, DOE submitted to NRC a request for authorization to commence site preparation activities. The NRC denied the request on March 16, 1982, and also denied a subsequent request for reconsideration of its denial on May 14, 1982. A new request for authorization to commence site preparation activities was filed on July 1, 1982, and on August 17, 1982, NRC issued an order granting the request. Litigation initiated by intervenors both in the U.S. Court of Appeals for the District of Columbia and in the U.S. District Court for the Northern District of Georgia resulted in short delays as a result of injunctions issued by the courts. The D.C. Court lifted its own 2-day temporary stay when it denied an emergency stay of the NRC order authorizing site preparation. The ruling of the Georgia District Court that site preparation work could not commence prior to the issuance of a National Pollutant Discharge Elimination System Permit was reversed on appeal. Significant progress in site work has been made with completion of rock excavation scheduled for late September 1983.

6. Safety and Licensing

On June 11, 1982, NRC's updated Radiological Site Suitability Report for CRBRP concluded that the Clinch River site was suitable for a reactor of the general size

and type described in the Project's application. The Final Supplement to the Final Environmental Statement was issued by the NRC on November 3, 1982. Environmental hearings by the Atomic Safety and Licensing Board (ASLB) were concluded in January 1983 and on February 28, 1983, the ASLB issued a partial initial decision recommending a Limited Work Authorization. The NRC Safety Evaluation Report was issued on March 11, 1983. This will allow hearings to begin in early summer 1983 and permission to begin safety-related construction in November 1983.

7. FY 1983 Funding

Funding for Clinch River in FY 1983 is contained in the FY 1983 Continuing Resolution with certain restrictions as contained in the Conference Report. These restrictions generally limit the progress of plant construction and also directed the submission of this report to the cognizant congressional committees by not later than March 15, 1983.

CHAPTER II

DOE Studies and Synopsis of Utility Task Force Report

A. DOE Studies

DOE established a working group in January 1983 to conduct studies and develop information on the CRBRP Project which would be complementary to the financing analysis being conducted by the Breeder Reactor Corporation Utility Task Force. The information developed by this study is contained in this report and was used by the Utility Task Force in its study. The information will also be useful to the Congress in evaluating alternate financing proposals.

DOE's working group conducted studies in three principal areas:

o Project Costs

- Capital cost to complete
- Operation and maintenance costs
- Fuel cycle costs

o Project Reliability

- Plant availability and plant capacity factor
- Power generation capability and useful life

o Project Revenue Projections

The studies were performed with the assistance of outside technical experts as well as DOE's technical staff in Headquarters and the CRBRP Project Office. Contractors who contributed to the studies were S. M. Stoller Corporation, Technology for Energy Corporation (TEC), and Union Carbide Corporation, Oak Ridge National Laboratory. The appendices to this report contain the results of the DOE studies which are summarized below.

o Capital Cost to Complete Project

In March 1982 a detailed bottoms-up cost estimate for completion of CRBRP was concluded by DOE with agreement by the Project contractors. Two key assumptions were made that have since changed: NRC authorization to start site work was received in August 1982 rather than March 1982, and the FY 1982 and FY 1983 funding was approved by

Congress at about \$194 million each year rather than higher levels assumed in the estimate.

An assessment of the impact of the above changes in assumptions has been made and there is a high degree of confidence that the cost to complete the Project after FY 1983 is \$2.3 billion. Subtracting remaining utility and contractor contributions leaves about \$2.1 billion as the amount of new financing required from the Government and private investors. The Utility Task Force utilized \$2.4 billion due to differences in round off and consideration of budget carryover.

o Operation and Maintenance (O&M) Costs

Previous estimates have projected operation and maintenance costs in detail only through the 5-year demonstration period. With the assistance of the S. M. Stoller Corporation, DOE has studied the O&M costs which would be expected over the 30-year life of the plant. As a result, the estimate has been updated to include the results of current utility industry experience which reflects increased costs experienced in the last 2 years due to lessons learned from Three Mile Island. A conservative estimate based on light water reactor (LWR) experience was developed which accounts for fundamental differences between LWR's and LMFBR's but does not reflect substantially reduced operating costs which EBR-II and FFTF experience indicates may be achievable for LMFBR's. The average annual O&M cost in 1983 dollars is projected to be \$39.4 million.

o Fuel Cycle Cost Analysis

DOE has analyzed the fuel cycle for CRBRP with an independent review by S. M. Stoller Corporation. The study looked at costs of plutonium supply, fuel fabrication, fresh fuel shipping, spent fuel reprocessing and waste management.

- Pu supply. It was concluded that plutonium can be obtained from reprocessing spent CRBRP fuel, spent LWR fuel, or by purchasing reprocessed plutonium. The cost is estimated at about \$6 million per year in 1983 dollars.
- Fuel fabrication. Fuel will initially be fabricated at the Secure Automated Fabrication (SAF) line at the DOE Richland, Washington, facility. After the year 2005, it was assumed that the need for breeder fuel and plutonium recycle in light water reactors would be sufficient to

support a commercial fuel fabrication plant. Assuming a conservative learning curve for the fabrication costs in both Government-owned and private facilities, an estimate of \$12 million per year in 1983 dollars was developed for fabrication of fuel and blanket assemblies, reflectors, and other replaceable core components.

- Fresh fuel shipping. Past experience in shipping fresh fuel was used to develop an estimate for shipping fresh fuel from Richland, Washington, to Oak Ridge, Tennessee, at an annual average cost of \$180,000 (1983 dollars).
- Reprocessing CRBRP spent fuel. Reprocessing of CRBRP spent fuel was evaluated using an R&D reprocessing system, a commercial LWR reprocessing plant, and reprocessing overseas. The resulting estimate is that a cost of \$7 per gram of fissile plutonium would result (1983 dollars).
- Waste management. It was assumed that after 1998, spent fuel and blanket assemblies would be provided for by the 1 mill per kilowatt hour charge under the Nuclear Waste Policy Act.
- Summary. Considering all of the above, the annual fuel cycle costs are estimated to be about \$18 million plus a 1 mill/KWH surcharge for waste disposal.

o Project Reliability, Net Output, and Useful Life

Studies were performed in these areas by DOE with independent assessments by Technology for Energy Corporation. It was concluded that although CRBRP is a research and development project and the first-of-a-kind, it has been designed from the ground up as a highly reliable central station electric power generator. CRBRP has benefited from the latest approaches to systems engineering which the present generation of light water reactors did not. The result is that the entire plant has availability targets assigned to each system and an overall goal of 82 percent. This goal and the planned 75 percent plant capacity factor were verified by TEC. Nevertheless, in making revenue projections for purposes of this study, DOE recommended that a conservative 65 percent capacity factor be assumed which is similar to LWR experience.

Additionally, the DOE studies support the use of a 30-year planned lifetime for the plant. The net output (saleable power) is assumed to be 330 megawatts electric (MWe) for the first 10 years of life (375 MWe gross less 45 MWe maximum "hotel" load) and 380 MWe net thereafter. All of the plant components have adequate margin to operate at 430 MWe gross which is 380 MWe net after deducting 50 MWe for "hotel" load at full design power.

o Revenue Projections

DOE was assisted in studying the projected need for new capacity in the region surrounding Oak Ridge, Tennessee, by the S. M. Stoller Corporation and the Oak Ridge National Laboratory. S. M. Stoller Corporation conducted a survey of utilities and ORNL did extensive research using this existing detailed data base and a thorough literature search.

The results of the studies identified the need for new capacity in the Southeastern Reliability Council (SERC) area. Except for Florida, the entire region is considered within transmission range of CRBRP. The area is projected to require 16,000 MWe of additional capacity to serve peak demand periods by 1995. The CRBRP output would displace only about 2 percent of the projected new demand in 1995.

Utilities are expected to provide for new capacity requirements in the near future with coal-fired baseload generating stations. To build a single coal-fired 350 MWe plant (comparable to the CRBRP output) utilities are projected to spend \$584 million (1984 dollars) for a plant going on line in 1991.

An analysis of the cost of baseload electricity using coal as fuel was performed for the period during which CRBRP will operate. Analyses covered a range of cost projections between 14.6¢ and 15.7¢ per KWH in 1991 in year of expenditure dollars.

B. Utility Task Force Report

The Task Force performed a financial evaluation of various funding options for completing CRBRP from the perspective of the private sector.

Following are the key conclusions reached by the Utility Task Force:

1. \$1.1 billion can be raised in new-source funding which includes about \$300 million in interest. This would displace about \$800 million in costs which would otherwise be funded by the Government under the existing arrangements and would reduce the remaining Government appropriations to complete the Project to about \$1.4 billion. In addition, under existing arrangements, U.S. utilities and project contractors will contribute almost \$200 million more as research and development expenditures.
2. Private funding will be obtained partially by capitalizing on the market value of the plant's electrical output and partially through the availability of those Project-related tax incentives normally available to private investors.
3. Congress, DOE, and the private investors must ensure that funding for remaining work is timely and sufficient to maintain construction schedules because of the significant cost impact of schedule slippages.
4. Legislation is required to ensure Federal funding in the amounts and on the schedule needed to support construction. Federal commitments regarding completion, licensing, and operation of the plant will also be needed to make private investment possible.
5. Regulated utilities in the Southeastern United States may be able to use CRBRP power to displace some new capacity which is projected to be required in the 1990's and beyond. The present regulatory climate and difficulty of projecting electricity costs 10 years from now make it unlikely that the customers for the CRBRP power could contract for firm prices today. Accordingly, some type of Federal action may be required to assure an adequate resource stream from power sales.
6. Private financing could be facilitated through creation of a new entity such as a joint venture in which the Federal Government and private investors could join as partners. This arrangement would be similar to those used for financing other large construction projects and would allow allocation of tax benefits among the private partners.

7. The Utility Task Force has not recommended a single option but has identified a range of alternatives to be considered. The Task Force considers that there are many different ways to structure private investment in the Project. The Task Force also points out that while a number of Federal assurances and warranties are required many of these are contingent in nature and may never be actually called upon.

CHAPTER III

Next Steps

This report provides the results of the effort by DOE and the BRC Utility Task Force to evaluate alternatives for securing additional private sector financing for CRBRP. The Utility Task Force Report concludes that there is a substantial market value for the CRBRP over and above the Project's research and development value such that a large private capital investment in the Project is feasible. In the time available for the study, however, it was not possible to enter into discussions with potential customers for the power output from the Clinch River plant, with potential investors for the Project, or to structure specific arrangements to facilitate private financing.

The utility industry intends to immediately proceed with discussions aimed at developing specific investment and marketing strategies. This will include developing both the structure of a private investment venture and to begin discussions with potential customers for CRBRP power. Since a most important element of maximizing the commercial value of the Project is to sell electricity as firm baseload capacity, it is possible that one of the best approaches to marketing the power will be for the customers for firm capacity to participate in the private entity or entities investing in the Project.

Based on preliminary discussions, the three major prime contractors on CRBRP, Westinghouse, Stone & Webster Engineering Corporation, and Burns and Roe, Inc., expect to participate in discussions regarding formation of appropriate structures for private investment. Until such discussions take place, it is not possible to predict whether any or all of those companies would actually join as investors in the Project. Decisions by these and other potential investors are necessarily dependent upon development of more specific structures and they also depend upon the final form of legislative authority provided to DOE. In addition, various factors may constrain participation by these companies under existing law.

Negotiations with the potential investors and customers and any necessary changes to the existing four-party contract need to be pursued on a schedule that permits required legislation to be enacted by October 1, 1983.

APPENDIX A

Project Background and Existing Arrangements

A. BACKGROUND

1. History of the Clinch River Project

The Clinch River Breeder Reactor Plant Project (CRBRP or "the Project") has its antecedents in the Atomic Energy Commission (AEC) Authorization Act For Fiscal Year 1970 (Pub. L. No. 91-44) which authorized AEC to conduct the "project definition phase" of a liquid metal fast breeder reactor demonstration program under cooperative arrangements with reactor manufacturers and others. The basic CRBRP authorization followed 1 year later in the AEC Authorization Act For Fiscal Year 1971 (Pub. L. No. 91-273) which authorized AEC to enter into cooperative arrangements for the design, construction, and operation of the plant in accordance with criteria submitted to the Joint Committee on Atomic Energy (JCAE). The AEC Authorization Act For Fiscal Year 1972, Pub. L. No. 92-84, increased the Government's participation in the Project by increasing direct assistance funding and by increasing the assistance allowed from the base program to 50 percent of the estimated capital cost of the plant.

In 1972, in contemplation of entering into agreements with the AEC for the Project, the Breeder Reactor Corporation (BRC) and Project Management Corporation (PMC) were incorporated. BRC's role was to obtain financial and other participation of the 753 utilities contributing funds to the CRBRP. PMC was to serve as the central management and contracting organization for the Project.

A memorandum of understanding was executed among AEC, BRC, PMC, the Tennessee Valley Authority (TVA), and the Commonwealth Edison Company (CE) in August 1972 which specified the basic project arrangements to be included ultimately in a definitive contract. The memorandum of understanding specified the Project cost estimate as \$699 million based on the conceptual designs submitted by reactor manufacturers in their proposals to supply the plant's nuclear steam supply system. The memorandum of understanding also contained a commitment by AEC to endeavor to obtain additional funds for the Project if it appeared that the resources available to PMC were

insufficient to permit continued effective conduct of the Project.

Pursuant to the statutory authorization for the Project, the AEC presented to the JCAE a description of the principal features constituting the bases for the contemplated arrangement for construction and operation of the plant in a Program Justification Data Arrangement, No. 72-106, dated August 11, 1972. The Justification Data restated the AEC's commitment to seek additional funds for the project if necessary, and also contained the \$699 million cost estimate. It was recognized, however, that the design of the plant was not yet firm, and the estimated cost could be changed when a more definitive basis for revision was available. After conducting hearings, the JCAE agreed that the proposed arrangement was in accord with the requirements of the enabling statute, section 106 of Public Law Number 91-273, as amended by Public Law Number 92-84.

2. Cost Estimate Development

A four-party contract (AEC, TVA, CE, and PMC) for carrying out the Project, Contract AT(49-18)-12, was then negotiated and presented to the JCAE in early 1973. The parties recognized that there could be significant, but unavoidable, uncertainties regarding a preliminary estimate for a research and development project. Therefore, after the execution of the four-party contract on July 25, 1973, one of the first tasks embarked upon was the establishment of a firm design basis and cost estimate for the Project. As a result of the completion of a reference design in June 1974 the first baseline project cost estimate of \$1.736 billion was established along with a reference schedule for initial criticality in July 1982, based upon site clearing commencing on September 1, 1975. This cost estimate as well as the Project cost estimates previously submitted to the Congress were based on the cost of constructing the CRBRP and conducting a 5-year demonstration program during which time the electricity generated would be sold to offset total Project costs.

As a result of this increase in the Project cost, in 1975 Congress authorized a change in the arrangement among the four parties to the basic contract. This change established that the Federal Government would manage the Project with support and assistance from PMC within an integrated Project Office composed of representatives of the Federal Government and the utility industry. This change in arrangement became effective May 1, 1976.

In 1975, the Project cost estimate was reassessed at \$1.95 billion, with a delay of 15 months in initial criticality to October 1983. This action was the result of delays imposed on the Project from reductions in budget needed to maintain the schedule developed in 1974, delays in the licensing process, and a further reassessment of the cost to complete the Project. The 1975 Project cost estimate revisions remained as the baseline cost and schedule until the decision by the previous Administration in 1977 to suspend licensing activity and seek termination of the Project. Since 1977, the estimate increased to \$3.6 billion, and initial criticality was delayed to September 1989. Following these revisions in cost and initial criticality, Congress passed the FY 1983 continuing resolution with direction in the report of the Conference Committee (H.R. Rep. No. 97-980 at 186, 97th Cong. 2d Sess. December 20, 1982) to "explore proposals, including a reconsideration of the original cost-sharing arrangement, that would reduce Federal budget requirements for the Clinch River Project or project alternative, and secure greater participation from the private sector." The funding provided by the continuing resolution for 1983 for the CRBRP is \$193.9 million. Since this funding is below that required by the \$3.6 billion estimate, a newly revised assessment of the cost to complete the plant, described in Appendix B of this report, is being prepared that will assist in the exploration of proposals.

3. Reasons for Cost Growth

Since the development of the initial CRBRP baseline cost estimate of \$1.736 billion in 1974, more than 68 percent of the subsequent cost increases have been beyond the control of the Project. The majority, or 56 percent, is attributed to actions of the Government which have stretched out the Government's funding profile below that required to support the Project schedule, delayed completion, or threatened termination of the Project. Another 12 percent were cost increases due to requirements imposed by the Nuclear Regulatory Commission (NRC). Only 32 percent of the estimated Project cost increases were theoretically within the control of the Project, and resulted from the developmental nature of the Project. It is extremely inefficient and costly to delay or extend a large project once work is well under way and thousands of workers employed. The externally-imposed delays on the Project are clearly responsible for most of the cost growth and result from the combined effects of inflation and costs of maintaining management and supporting organizations over a longer period than would be needed to complete the job without constraints.

Following is a summary of the cost increases beyond the original \$1.736 billion baseline estimate:

ESTIMATED PROJECT INCREASES FROM 1974 BASELINE
DUE TO FUNDING LIMITATIONS AND LICENSING

	Cost Impact (\$ Millions)	Schedule Impact (No. Months)
<u>Cost Increases Due to Funding Levels Below Those Required to Support the Project Schedule:</u>		
Reduction in Funding Required by Baseline Schedule	\$ 117 ^{1/}	12
Proposed Termination by the Previous Administration from April 1977	694 ^{2/}	56
<u>Recent Licensing/Funding Limitations:</u>		
FY 1982	235 ^{3/}	12
FY 1983	14 ^{4/}	1
<u>NRC/Licensing Requirements:</u>		
1974 Delay in the Licensing Process	78 ^{5/}	7
All Other	140 ^{6/}	
Total	\$ 1,278	88

Notes:

- 1/ The \$117 million in funding limitations prior to April 1977 consists of \$90 million (8 months schedule delay) due to FY 1976 funding limitations (part of the cost growth from \$1.736 billion to \$1.95 billion) and \$27 million (4 months schedule delay) due to the FY 1978 initial funding reduction (in February 1977 from \$235 million to \$150 million).
- 2/ The impact of a subsequent FY 1978 funding reduction after April 1977 (from \$150 million to \$80 million) and the subsequent funding reductions through FY 1981 resulted in \$694 million increased costs (56 months schedule delay).
- 3/ The combined impact in FY 1982 of delaying the start of site work from April 1982 to September 1982 (based on NRC action on the 10 CFR §50.12 request) and the funding limitations (from the \$353 million required to support start of site work in April 1982 to the \$194 million actually received) resulted in \$235 million increased costs (12 months schedule delay).
- 4/ The combined impact of actual FY 1983 funding (reduction from \$227 million to \$194 million) resulted in \$14 million increased cost and one month schedule delay.
- 5/ In 1973, based on a decision from the U.S. Court of Appeals for the District of Columbia Circuit, the Scientists' Institute for Public Information was successful in requiring AEC to submit an environmental report on the Liquid Metal Fast Breeder Reactor Program. The \$1.736 baseline estimate was prepared in 1974 prior to the court decision. The environmental issue delayed the licensing process and resulted in \$78 million increased costs (7 months schedule delay).
- 6/ Other NRC/licensing requirements increased the costs by \$140 million. These increases include (1) additional design, analysis, and plant changes to demonstrate the suitability of CRBRP to sustain an increased seismic load from 0.18g to 0.25g, (2) increased design, analysis, and plant modifications to demonstrate acceptable site boundary doses for the source term, and (3) added design, analysis, and plant hardware revisions to demonstrate acceptable margins for core disruptive accidents.

Approximately \$611 million (32 percent) of the increased costs is attributable to the Project. This \$611 million is applicable to all Project elements (design, hardware, construction, operations and maintenance, fuel) and includes the following examples:

- o Hardware increases resulting from inaccurate initial estimates and fabrication problems.
- o Engineering and management increases resulting from more stringent project control practices, inaccurate initial estimates, and design changes.
- o Construction increases resulting from design omissions, bulk quantity changes due to design evolution, added quality assurance and quality control activities, and inaccurate initial estimates.

Some of this increase includes improvements to keep technology up to date and advance the state of the art and design changes which will facilitate construction activities. These improvements include:

- a. Incorporation of heterogeneous core into the design, a very significant design improvement for the following reasons:
 - (1) It results in a breeding ratio of 1.3 that not only exceeds the CRBRP design goal (1.2) but also easily surpasses that of Phenix (1.14), Super Phenix (1.2), or any other LMFBR in the world;
 - (2) It simultaneously reduces the fuel sodium void coefficient roughly by half, greatly enhancing the ability to demonstrate increased safety margins for hypothetical core disruptive accidents;
 - (3) It provides a degree of flexibility for accommodating alternate fuel cycles (such as uranium/thorium) and fuel management variations of interest to utilities (such as the improved economics associated with longer fuel lifetimes, as advanced materials become available);
 - (4) It permits usage of the poorer grades of plutonium (high Pu-240 content) that have no strategic value for the United States; and

- (5) It reduces fuel costs by substituting less expensive blanket assemblies for some of the fuel assemblies required by the previous homogeneous core.
- b. Incorporation into the design of many advances in the state-of-the-art, e.g., multiplexing of monitoring and control functions, advanced techniques for computer redundancy and distributed processing, application of advanced leak detection techniques, and use of state-of-the-art solid state programmable logic for the control and action of safety-related equipment; and the addition of new features such as automated generation of effluent reports to the NRC, ultra high sensitivity source range flux monitoring, and integrated incorporation of post-TMI requirements (including a plant simulator, expanded accident monitoring equipment, emergency response facilities, emergency planning, and increased emphasis on human factors in control room design).
- c. Advanced planning of construction activities from final design documentation which will result in significant reduction in construction delays. The constructor was able to perform extensive constructability reviews for developing timesaving plans in areas considered difficult to construct. Models and erection drawings have been developed for such activities as excavation of nuclear island, reactor cavity area, cell liners, reinforcing steel, equipment installation using unique lifting equipment, etc. The advanced stage of planning has allowed for a disciplined interchange of information between designer and constructor.
- d. Changes brought about by lessons learned from TMI and a detailed review of the key CRBRP Plant Safety systems, which provided particular attention to the operations, maintenance, and test aspects of the design to assure that these functions could be carried out without adverse safety consequences.

As the preceding figures show, chief among the Government actions contributing to cost increases and schedule delays was the decision of the previous Administration to seek termination of the Project. On February 23, 1977, at the President's direction, the Energy Research and Development Administration (ERDA), the successor agency to AEC, undertook to review the LMFBR program in general and the CRBRP in particular. For the review, ERDA

utilized a committee composed of individuals of widely differing views about both nuclear energy and the breeder program. The review committee's report concluded that a demonstration plant of the approximate size of CRBRP was necessary and that the CRBRP objectives were appropriate to that plant. Nevertheless, on April 20, 1977, the previous Administration announced its decision to cancel the Project. Shortly thereafter, ERDA filed a motion with the NRC Atomic Safety and Licensing Board requesting an indefinite suspension of the hearings on the Project's application for a Limited Work Authorization.

Notwithstanding the decision of the previous Administration to cancel CRBRP, the Congress continued to provide funds for the Project although at an amount below that required to keep the Project on its baseline schedule. The funding provided by Congress permitted continuation of design efforts and fabrication of plant components already ordered. Licensing was suspended, construction could not begin, and new procurements of plant components were restricted.

4. Project Re-Start

The present Administration recognized the importance of the breeder reactor to our energy future and directed that the CRBRP be completed as expeditiously as possible. Accordingly, CRBRP funding was included in its FY 1982 budget request in the amount of \$254 million. Congress, however, authorized \$228 million for the CRBRP in the Omnibus Budget Reconciliation Act of 1981, Public Law Number 97-35 and appropriated \$193.9 million for FY 1982, Public Law Number 97-88 and Conference Report No. 97-345. House Conference Report No. 97-208, accompanying the Budget Reconciliation Act (Pub. L. No. 97-35) expressed the intent that:

***[T]he plant should be constructed in a timely and expeditious manner, so that a decision on the commercialization and deployment of breeder reactors can be made on the basis of information obtained in the operation of the plant. The plant should therefore be constructed on the basis of that objective, and not on the basis of providing needed power in the specific region of the Clinch River site.

In August 1981, DOE requested that NRC reestablish its review of Project safety documentation, and in September 1981, the NRC established a program office to conduct the licensing review of CRBRP.

5. Site Work

President Reagan in his Nuclear Policy Statement on October 8, 1981, directed that "government agencies proceed with a demonstration of breeder reactor technology, including completion of the Clinch River Breeder Reactor." In response to this direction, the Department of Energy (DOE), for itself and on behalf of its co-applicants, PMC and TVA, requested the NRC to authorize site preparation activities pursuant to 10 CFR §50.12. The NRC denied the initial request in a 3 to 2 decision. DOE requested reconsideration of that decision on May 14, 1982, which was denied by a 2-2 vote. Thereafter, on July 1, 1982, DOE, PMC, and TVA filed a new request for authorization to conduct site preparation activities. In connection with the new request, the parties provided an updated assessment of the impact of site preparation activities and showed that the grant of the request would advance the schedule for completing CRBRP by 6 to 12 months. In addition, detailed analyses established that granting the request and acceleration of Project completion would: (1) yield substantial informational benefits to the LMFBR program; (2) enhance the effectiveness of the Administration's international nuclear program objectives; and (3) avoid substantial adverse impacts in both of the foregoing areas.

The NRC subsequently, by a 3 to 1 majority vote granted the Section 50.12 request. On August 17, 1982, it issued an Order granting the request to begin site preparation activities. In accordance with the NRC order, the construction contractor promptly awarded a subcontract to begin site work. However, the Natural Resources Defense Council (NRDC) and the Sierra Club, intervenors in the NRC licensing proceedings, petitioned the United States Court of Appeals for the District of Columbia Circuit on August 19 for review of the NRC Order. In addition, NRDC sought to invalidate a memorandum of understanding between DOE and the Environmental Protection Agency (EPA) in the U.S. District Court for the Northern District of Georgia. This memorandum of understanding allowed site preparation work to begin prior to issuance of a National Pollutant Discharge Elimination System Permit. The District Court enjoined the start of site preparation work. That order was promptly overturned by the U.S. Court of Appeals for the Eleventh Circuit on September 21, 1982, and site work began the next day.

On October 4, 1982, the U.S. Court of Appeals for the District of Columbia Circuit in its review of the NRC Order, ordered a temporary stay of the effectiveness of the NRC Order pending its determination as to whether an emergency stay should be granted. Two days later, the court decided that an emergency stay would not be granted and lifted the temporary stay. The court then held a hearing on NRDC's petition and on December 2, 1982, ruled that the NRC should have held an adjudicatory hearing on the Section 50.12 request and ordered NRC to do so. The court, however, did not enjoin site preparation activities. On December 7, the court withdrew its opinion and order of December 2 and issued a modified opinion and order. The modified order no longer mandated an adjudicatory hearing but required NRC to either conduct such a hearing or to reconsider the availability of Section 50.12. The court ordered that site preparation activities could continue subject to the further order of the court or of the NRC. By Order dated January 5, 1983, the NRC, in a 3 to 2 decision, reaffirmed its earlier order authorizing site preparation activities.

Considerable progress has been made on site preparation under the 10 CFR §50.12 authorization. Mass excavation started on December 21, 1982. Completion of the rock excavation is now scheduled for late September 1983. Placement of leveling and mud mats will begin in October 1983; assembly and lifting of rebar modules into place will begin in November 1983; and placement of structural concrete for the nuclear island mat will begin in December 1983.

6. Licensing and Safety

On June 11, 1982, the NRC staff issued its update to the 1977 radiological Site Suitability Report for CRBRP. This report concluded that, from the standpoint of radiological health and safety, the Clinch River site was suitable for a reactor of the general size and type described in the application. The Final Supplement to the Final Environmental Statement was issued by the NRC on November 2, 1982. The NRC Atomic Safety and Licensing Board (ASLB) conducted full environmental hearings in Oak Ridge, Tennessee, beginning August 23, 1982, and ending in January 1983. The ASLB issued a partial initial decision dated February 28, 1983, recommending issuance of a Limited Work Authorization.

The NRC Safety Evaluation Report was issued on March 11, 1983. This will allow hearings to begin in early summer 1983 leading toward permission to begin safety related construction in November 1983.

7. FY 1983 Funding

During the consideration of DOE's FY 1983 budget request, the CRBRP received a great deal of attention in the appropriation process. The conference committee report on the FY 1983 continuing resolution (Pub. L. No. 97-377) described the House-Senate agreement to continue funding the Project and stated:

- "1. The Department will not initiate construction of any permanent facility structures or place any additional major equipment orders during the period of this resolution.
2. Ongoing activities related to the NRC licensing process should be continued.
3. The current rate of Federal funding for the Clinch River Project shall be determined so as to take into account the anticipated \$19,000,000 available from non-Federal contributions in 1983.
4. Up to \$1,000,000 shall be available to vigorously explore proposals including a reconsideration of the original cost-sharing arrangement, that would reduce Federal budget requirements for the Clinch River Project or project alternative, and secure greater participation from the private sector. The Department is to submit its findings to the cognizant congressional committees for consideration by not later than March 15, 1983.

The conferees strongly urge the cognizant authorizing committees in the House and the Senate to consider this issue early in the 98th Congress."

B. EXISTING ARRANGEMENTS

The existing arrangements for the CRBRP, in effect since May 1976, are based on a four-party contract, executed on July 25, 1973. Under the terms of the 1973 four-party contract, PMC was authorized to manage the Project through a Project Steering Committee, to which CE, AEC, and TVA each appointed one member, and in accordance with agreed upon Project objectives PMC was to use the utility-pledged contributions (\$257,000,000) and AEC's funds for Project costs. The AEC, aside from providing direct and indirect funding assistance, was to furnish special nuclear materials and technical supervision and administration of the Nuclear Steam Supply System (NSSS) aspects of all contracts. TVA was responsible for the lead role in planning for plant operation and maintenance and was also to provide personnel to fill certain key management positions in the Project. Under the contract TVA had the option to ultimately acquire title to the CRBRP after completion of the demonstration period. CE was to furnish the General Manager, the Project Manager, the Engineering Manager, and the Technical Services Manager as well as procurement and other services.

The contributions made by the members of the utility industry, including CE and TVA, did not entitle contributors to any unique benefits which were unavailable to noncontributing utilities. Contributors obtained no beneficial ownership interest in the plant; no exclusive rights to patents, data, copyrights, processes or technical information (although contributors as well as other noncontributing utilities receive a non-exclusive royalty-free license); and no financial return on their investment. Even the right to assign employees to the Project was available to noncontributing utilities on an equal basis with contributing utilities.

The four-party contract was modified in May 1976 to substantially realign the responsibilities of the parties. The impetus for the contract modification was the growth of the Government investment relative to the utilities' investment.

Revisions to the authorizing legislation permitting the proposed changes were made in Pub. L. No. 94-187 and in the Statutory Criteria and Program Justification Data. The modification, upon becoming effective, provided ERDA with the responsibility for the management of the Project and ownership of the plant. The parties agreed that PMC, while no longer directly managing the Project, would continue to administer the utilities' interests by monitoring the Project, preparing and sending out Project information to the BRC and the utility industry, arranging for participation of the

utility personnel in the conduct of the Project, investing and disbursing the utilities' funds and exercising the contractual rights on behalf of the utilities. TVA's responsibilities under the modified contract remained relatively unchanged except that TVA agreed to transfer custody of the plant site to ERDA rather than retaining such custody.

APPENDIX B

Project Costs

In order to conduct meaningful analyses of private investment scenarios the costs to complete the Project must be accurately known and the costs to operate Clinch River over its lifetime must be understood. This Appendix addresses these costs.

I. Capital Cost To Complete Project

The estimate of capital costs is based on an in-depth assessment of a detailed cost estimate prepared in 1982 which assumed that NRC would authorize site work to begin in March 1982. This detailed cost estimate was a complete "bottoms-up" estimate of the costs to go based on achievable schedule milestones. The detailed estimate of the costs to go was negotiated with and concurred in by the Project's principal contractors. NRC authorization to begin site work, a major milestone for the Project, was not received until August 1982. This change in the start of site work required associated adjustments to the earlier detailed Project cost and schedule estimates. An assessment of the impact of the delay to August 1982 in the start of site work and of the the impact of anticipated funding limitations in FY 1983 and FY 1984) resulted in a revised estimated net cost to go of about \$2.2 billion and delay of initial criticality to September 1989. This was the last assessment of estimated costs prior to the FY 1983 continuing resolution.

Subsequently, preparation of another cost assessment (rather than a detailed "bottoms-up" cost estimate) has been initiated for this report. Since the actual funding level in FY 1983 is \$193M, the planned pace and sequence of work which would have led to initial criticality in September 1989 has been impacted and initial criticality is now assumed to be October 1989. This revised estimate excludes revenues and operating costs during the 5-year demonstration. The differences in the estimates to complete the plant for initial criticality in September 1989 and October 1989 are due to the 1 month delay caused by reduced FY 1983 funding and by a more conservative estimating technique for operation and maintenance costs. The present assessment (that is ongoing) indicates that the impact of these events is a \$25 million increase in costs, resulting from:

Cost of Escalation and Stretch-out	\$14 million
More Conservative O&M Estimate	<u>11</u> million
	\$25 million

Those cost increases have been factored into the capital cost estimate.

The estimate for the additional funds required to complete the plant and operate the plant until June 1990 is about \$2.3 billion (for the period FY 1984 to June 1990, See Table B-1 for the display of this \$2.3 billion by category of work per fiscal year.)

There is a high degree of confidence in this preliminary assessment of the range of the expected cost of these delays. Analyses of cost estimation in new technologies have shown that a cost estimate is indeed "definitive" when project engineering is complete, contracts have been costed, schedules have been established, and construction is ready to begin. At that point, estimates are expected to be within plus or minus 5 percent of actual plant costs (A Review of Cost Estimation in New Technologies, Rand Corporation, Santa Monica, California, July 1979). For CRBRP, the design of the plant is almost complete and approximately 70 percent of the plant equipment is either delivered or on order. The schedule has been established and site preparation is in progress. Because of the advanced state of the CRBRP design at the start of construction, cost uncertainties from internal causes are greatly reduced.

The following key bases and assumptions were used in developing the cost assessment:

- a. The estimate is expressed in year-of-expenditure dollars; that is, an estimate of an 8 percent annual inflation rate has been included.
- b. The estimate includes all costs to design, procure equipment, and construct the plant, and the cost of operating the plant until June 1990.
- c. The estimate is based on a CRBRP schedule that reflects start of site work in September 1982 and continued progress towards initial criticality in 1989.
- d. The estimate assumes receipt of necessary approvals from NRC in a timely manner; this includes issuance of an

TABLE B-1

CRBRP CAPITAL COST ESTIMATE TO COMPLETE CONSTRUCTION
IN MILLIONS OF YEAR OF EXPENDITURE DOLLARS
1989 CRITICALITY

	<u>FY84</u>	<u>FY85</u>	<u>FY86</u>	<u>FY87</u>	<u>FY88</u>	<u>FY89</u>	<u>FY90</u>	TOTAL FY84 THRU MAY 1990
RM ENGR/MGMT	78.7	57.3	28.0	16.4	13.4	11.1	2.6	207.5
RM HARDWARE	123.7	145.1	74.6	16.8	1.7	.8		362.7
AE ENGR/MGMT	26.5	25.1	11.4	8.5	7.4	7.9	1.9	88.7
AE HARDWARE	23.0	86.4	45.9	8.7	.1			164.1
CONSTRUCTION (CN)	143.6	233.3	317.3	200.0	121.8	(13.9)		1,002.1
CN CONTINGENCY	12.9	25.9	23.2	18.5	9.5			90.0
LABS	.1	.1						.2
FUEL/SNM	2.9	10.3	29.0	36.8	25.9	42.2	39.7	186.8
FUEL CONTINGENCY	.3	.9	3.6	5.6	10.6	8.4	7.9	37.3
PROJECT OFFICE	13.0	12.0	11.9	12.3	12.7	12.4	7.3	81.6
OPNS/MAINT (O&M)	.8	6.0	11.4	14.0	20.1	29.3	27.9	109.5
REVENUE							(33.7)	(33.7)
OTHER CONTINGENCY	10.2	20.5	15.5	13.0	11.3	9.1	9.0	88.6
TOTAL COSTS	<u>435.7</u>	<u>622.9</u>	<u>571.8</u>	<u>350.6</u>	<u>234.5</u>	<u>107.3</u>	<u>62.6</u>	<u>2,385.4</u>

TOTAL FUNDS REQUIRED ^{1/}	499.0	656.9	516.6	321.5	202.7	96.1	47.0	2,339.8
UTIL. CONTRIB ^{2/}	20.7	23.8	23.8	22.8	21.0	21.0	39.0	172.1
OTHER CONTRIB.	1.4	.2	.2	.2			2.5	4.5
NET FUNDS REQUIRED	<u>476.9</u>	<u>632.9</u>	<u>492.6</u>	<u>298.5</u>	<u>181.7</u>	<u>75.1</u>	<u>5.5</u>	<u>2,163.2</u>

^{1/} Total Costs of \$2,385.4 minus funds available to start FY84 of \$45.6 = \$2,339.8 funds required.

^{2/} Assumes utilization of all utility contributions prior to commercial operations.

March 3, 1983

authorization to start safety-related construction activities by November 1983.

- e. Funding as needed to optimize construction after FY 1983 is assumed.

II. Operation and Maintenance Costs

The operation and maintenance (O&M) costs in the previous CRBRP cost estimates have been updated for this assessment. The estimate includes the following costs:

- a. Plant Operation and Maintenance--On-site permanent operating staff, home office support, field service staff, O&M materials and supplies, licensing fees, downtime electric power consumption, contingent fund for plant modifications and improvements;
- b. Insurance and Taxes--Nuclear liability insurance, property damage insurance, and property taxes (to the extent applicable); and
- c. Decommissioning Fund.

The operating and maintenance costs were derived by adjusting experience data (1980) based primarily on TVA nuclear plants and moderated where necessary by experience at Duke Power and Commonwealth Edison. Adjustments were made to account for a significant increase in O&M costs experienced by utilities in the past two years, caused principally by incorporating lessons learned from Three Mile Island. TVA supplied input on its latest O&M requirements, and S. M. Stoller Corporation and ORNL each reviewed the estimate independently.

TVA's operational experience was used as the primary basis for developing applicable O&M requirements for CRBRP. These costs were adjusted to account for size and complexity between CRBRP and TVA plants. This LWR operating experience, modified to reflect fundamental design differences, is considered applicable to CRBRP for the following basic reasons:

- a. CRBRP will be operated as a power generating station for baseload generation.
- b. The general regulatory requirements and the same specific requirements applicable to LWRs (except when design differences dictate otherwise) will apply to CRBRP.
- c. The utility operator will have personnel trained and conditioned in LWR systems so that existing satisfactory

operating practices will be appropriately incorporated into the operation of CRBRP.

- d. Although the electric generating capacity of the CRBRP is smaller, the physical size of the plant is comparable to a large LWR unit whose operating experience was used as the reference. Also, because it contains an intermediate loop, the plant contains a comparable quantity of piping, valves, cable, instrumentation, and components.

The above conditions justify using the experience in LWRs at TVA, augmented by that of Duke Power and Commonwealth Edison, as a base for developing CRBRP O&M estimates.

However, the CRBRP has fundamental differences from the LWRs used as reference, so they were carefully analyzed and accounted for. These differences are:

- a. Basic reactor technology, i.e., sodium-cooled systems with an intermediate heat transfer loop as compared to an open or closed cycle water-cooled system. These conceptual differences define the size of the physical plant, coolant handling and purification, transport of radioactivity to plant systems, area environments, and component accessibility. These conditions also dictate differences in maintenance planning, techniques, and operations.
- b. CRBRP is a first-of-a-kind plant while the reference LWR plants are, at least, third generation.

The details of LWR O&M cost experience were analyzed to determine the applications directly appropriate to CRBRP and which must be modified for use. The reviews of TVA, S. M. Stoller Corporation, and ORNL focused on modification of previous O&M experience on LWRs. The determination of O&M costs for the CRBRP is shown in Table B-2.

The experience with LWRs for on-site permanent operating staff and office support was adjusted only for physical size and CRBRP's classification as a single unit plant. The field services staff (labor and materials) for normal outages were modified to account for plant layout, care regarding sodium coolant, radioactivity level, and compartments filled with inert gas. It was assumed that special tools for carrying out inspections and tests where sodium was involved would be properly provided.

Operating supplies and non-outage maintenance materials were also analyzed to account for specific design differences, e.g., sodium coolant, intermediate loops, differences in handling and processing coolant leakage, compartments

TABLE B-2

CRBRP O&M COST ESTIMATE SUMMARY

IN MILLIONS OF 1983 \$

	Major Refueling Outage Year	Alternate Year Minor Refueling Outage
I. TVA Division of Nuclear Power (Operating Division)		
A. On-site Permanent Operating Staff (Labor)	\$12.2	\$12.2
B. Home Office Support (Labor and Materials)	1.9	1.9
C. Field Services Staff (Outage)		
Maintenance Expense	5.5	3.0
Capital Improvements and Modifications	5.5	-
D. Operating Supplies and Maintenance Materials	4.7	4.7
E. Contingency @ 5% on the above O&M Expenses	<u>1.5</u>	<u>1.1</u>
TOTAL	\$31.3	\$22.9
II. Support from Other TVA Divisions	\$ 4.3	\$ 4.3
III. Miscellaneous Expenses		
A. Licensing	\$ 0.2	\$ 0.2
B. Nuclear Liability Ins.	0.4	0.4
C. Decommissioning	1.8	1.8
D. Property Damage Insurance	2.3	2.3
E. Local Taxes	<u>3.3</u>	<u>3.3</u>
TOTAL	\$ <u>8.0</u>	\$ <u>8.0</u>
TOTAL I, II, and III	\$43.6	\$35.2

Average = \$39.4

filled with inert gas, minimal liquid radwaste system (and its impact on the solid radwaste system), and plant capacity.

In addition to the base costs of O&M discussed above, general costs (for example, licensing and insurance) were estimated. This expense, in part, was based on LWR experience. An estimating contingency of 5 percent was added to the estimated costs of the operating division, shown as Item I in Table B-2. This 5 percent is considered adequate when combined with a fund of \$2.7 million per year for plant modifications and improvements as shown in Item I.C. of Table B-2.

The NRC licensing fee expense was included based on the existing NRC fee schedule. Nuclear liability insurance was based on the assumption that the entire plant would be covered by this insurance.

In estimating property damage insurance costs, LWR premium rates were applied to the private investment share of CRBRP. A decommissioning fund was included as part of the operating expense to accrue at \$1.8 million per year (1983 \$), approximating the amount currently being set aside by TVA for its PWR units. This should be more than adequate because worldwide LMFBR experience has shown significantly lower levels of contamination and activation for LMFBRs than for LWRs.

It was assumed that the private ownership interest would not be exempt from local property taxes as is the Federal Government's interest. A new taxable investment of the size contemplated here would probably enable DOE to cease providing financial assistance to the City of Oak Ridge and Roane County, Tennessee, under the Atomic Energy Community Act. In FY 1983 such payments are budgeted for \$3.3 million. This amount was included in the cost estimate as the local property tax. Under the terms of a self-sufficiency agreement with the City and County, DOE will reduce its assistance payments if the tax base is increased.

Based on the CRBRP design personnel staffing assumptions and projections extrapolated from actual EBR-II and Fast Flux Test Facility (FFTF) operating experience to CRBRP size, the LMFBR operating cost experience indicates the potential for substantially reduced operating and maintenance costs (compared with the current LWR experience assumptions used). Projections based on LMFBR experience could lead to an annual savings in operating and maintenance costs of upwards of \$10 million.

For sensitivity purposes, the case assuming a \$10 million reduction was treated relative to the net revenue calculations which assume LWR experience.

III. CRBRP Fuel Cycle Cost Analysis

In evaluating the fuel cycle costs and availability for the extended operation of CRBRP, various options were investigated with the goal of demonstrating a basis for confidence that complete fuel cycle services will be available to CRBRP over its lifetime at reasonable cost.

The CRBRP fuel cycle includes mixed oxide fuel fabrication, blanket element fabrication, reprocessing, management of the wastes generated by facilities in the fuel cycle and transportation of wastes and products among the various facilities.

The program plan for the CRBRP is to reprocess the CRBRP fuel assemblies to recover the plutonium for recycle back to the CRBRP. For purposes of this analysis, however, a range of alternative fuel cycles were reviewed.

During the 5-year demonstration period, the CRBRP project goals will be achieved regardless of the fuel cycle used for the long term. The actual fuel cycle used after the 5-year demonstration period will depend on the availability of services and fuel and the economics at that time.

Any examination of the nuclear fuel cycle must be based on a realistic assessment of present and projected availability and costs of fuel and the associated costs of fabrication, shipment, reprocessing, and waste management. The following describes the results of the analysis of those elements as they relate to the CRBRP. The results of both DOE's analysis and an independent review by the S. M. Stoller Corporation support the conclusion that it is realistic to project that plutonium fuel will be available through reprocessing of breeder fuel or commercially from LWR reprocessing at a cost that will not affect the cost projections presented herein, and that fuel can be fabricated and can be reprocessed or stored at a reasonable cost for the life of the plant.

The goal of the breeder development and demonstration program has always been centered around demonstrating powerplant technology through a series of increasingly larger demonstration plants (of which CRBRP is a key element) and to demonstrate closure of the breeder fuel cycle. For years, we have conducted extensive R&D in breeder reprocessing and fuel fabrication technology as an essential element of the breeder research and development program.

These efforts have led to the development of advanced reprocessing equipment and processes and in the design of breeder reprocessing equipment with remote handling and maintenance capability. The building of a small scale breeder fuel reprocessing system as a

research and development activity to conduct engineering tests of the reprocessing of breeder reactor fuel is being investigated. Such a system should be operational in time to serve all of CRBRP's needs. Reprocessing of breeder fuel in conventional reactor reprocessing facilities could be done by blending the breeder fuel with greater quantities of conventional low enriched uranium fuel. This approach would likely require the addition of equipment at the front end of such a reprocessing facility to shear and leach the breeder fuel. As a result of the R&D program in fuel fabrication, the Secure Automated Fabrication line is being constructed at the Hanford Engineering Development Laboratory. This facility is intended to demonstrate remote and automated fabrication of breeder fuel for health and safeguards control and to demonstrate the economics of breeder fuel fabrication. This facility is an integral part of the breeder technology development program which will meet the fuel fabrication needs for FFTF and can provide fuel fabrication services as needed for CRBRP at cost. The facility is scheduled to become operational in 1986.

Plutonium Supply

This part of the analysis examines the availability and cost of plutonium for fuel over the life of the plant. Factors indicate that there will be quantities of plutonium available that will be considerably in excess of the requirements for plutonium to fuel the CRBRP for the 30 year life of the plant.

It has always been the goal and plan to reprocess the CRBRP fuel. As is discussed in more detail in the section dealing with reprocessing of CRBRP fuel, for the purpose of this study several options were identified to reprocess the CRBRP fuel and the costs of the various options examined. The costs varied from less than \$500 to about \$1,000 (1983 dollars) per kilogram of heavy metal. It was therefore conservative to conclude that CRBRP fuel should be able to be reprocessed at a cost of \$1,000 per kilogram of heavy metal. Since the average plutonium content of discharged CRBRP fuel is about 17.7 percent, the cost of plutonium from reprocessing would therefore be about \$5.65 per gram of plutonium containing 19 percent plutonium-240, or \$7 per gram of fissile plutonium recovered.

The analysis ignores the fact that DOE is developing and testing advanced reprocessing concepts to demonstrate less expensive and more reliable reprocessing. This development program should make a significant contribution to improving the economics of breeder reactors and to improving the economics of the CRBRP fuel cycle. It is reasonable to project that over the life of the CRBRP, the cost of reprocessing plutonium from the CRBRP should improve significantly.

In the 25-year post-demonstration period, plutonium should be in plentiful supply on the world market. This is based on projections of the availability of reprocessing capability. The reprocessing plant capacity, currently operating or being constructed, is about 3,000 tonnes per year (Reference 1). This could increase substantially as suggested by recent French analyses showing projections of the growth rate of reprocessing capacity (Reference 2). Previous studies by the Working Groups of the International Nuclear Fuel Cycle Evaluation (Reference 3) also provide analysis supporting a projected growth in reprocessing sufficient to provide plentiful plutonium. By 1996 reprocessing activities throughout the world should produce substantial quantities of plutonium every year.

A plutonium market exists (Reference 4). In 1982 plutonium was selling at \$6 to \$9 per gram fissile. The current and predicted market price through 1984 is \$4 to \$6 per gram fissile. Current and planned reprocessing activities will result in a substantial amount of plutonium being made available. The future price of plutonium will be determined by market forces that will result from factors such as the price of uranium ore, the rate of growth of breeder reactors, and the extent of use of plutonium recycle in LWR's. For conservatism, no benefit was included in the analysis for expected improvements in the economics of reprocessing, of potential credits from sale of plutonium bred in the CRBRP or for recovering and selling the plutonium contained in CRBRP spent fuel and blanket assemblies at the end of the 30-year operating life.

The CRBRP core design has a number of parameters that can be varied to meet the cost variables produced by the marketplace. No such optimization was performed for this analysis. The operation of the blanket assemblies and the breeding performance will be demonstrated in the 5-year demonstration period. For subsequent operation, when the objective would be to maximize revenues, consideration has been given to not reprocessing the radial blanket assemblies during the post demonstration 25-year operation. These assemblies could either be discharged to a waste repository or nickel reflector assemblies could be substituted for the radial blanket assemblies. Therefore, at any time after the 5-year demonstration phase, the optimal economic decisions for the blanket can be determined based on the market price of plutonium and reprocessing costs at that time.

For purposes of this study, the total costs of plutonium for the 25-year post-demonstration period were projected to be about \$150 million (1983 dollars) or about \$6 million per year (1983 dollars). This is higher than the expected cost of either reprocessing or purchases at the current market price.

In summary, a basis exists for confidence that sufficient plutonium will be available to provide fuel for CRBRP at a reasonable cost.

Fuel Fabrication

Fuel for the CRBRP will initially be fabricated at the Secure Automated Fuel (SAF) line in Richland, Washington. This fuel line will be operated to supply the developmental fuel needs of FFTF and the breeder reactor program regardless of CRBRP needs. The fabrication costs of CRBRP fuel will be based on the actual operating and materials costs at the facility.

The goal of the breeder reactor fuels development program is to extend the lifetime of fuel and to reduce the fuel fabrication costs. This program has been, and continues to be extremely successful. Current results provide a strong basis for confidence that this program will continue to achieve its goals. The fuel for the CRBRP is quite similar to the FFTF fuel. The key difference is that the CRBRP fuel assembly is 14 feet long as compared to 12 feet in the FFTF. The CRBRP can directly use the results of FFTF experience in the fabrication of fuel and fuel performance. This provides a firm understanding of the costs of producing fuel and of ways to reduce this cost, based on considerable experience fabricating FFTF fuel. The base technology program includes a number of fuel development activities that are currently demonstrating the achievement of increased fuel lifetime and performance.

Breeder reactor development activities that are expected to reduce fuel fabrication costs and to benefit the initial and subsequent cores required for the 25-year post-demonstration period include:

- o improvements in the fuel fabrication process
- o development of means to achieve improved efficiency and increase reliability
- o optimization of specification requirements based on operating experience

Examination of the fabrication costs and process parameters show that it is reasonable to project that the initial fabrication costs should be reduced by at least 20 percent by the time it is necessary to fabricate the fuel for the fourth core loading (1993 to 1994). Use of a 20 to 30 metric tonne per year mixed oxide fabrication plant operating at or near capacity would reduce the fabrication cost to a level that is 40 percent of the initial fuel fabrication costs due to the economics of scale by 2005. It was assumed that the need for breeder reactor fuel and plutonium

recycle could reasonably be expected to support construction and operation of such a plant in the year 2005. This capacity would be sufficient to fuel the CRBRP, a large scale breeder, and to provide a modest amount of plutonium recycle fuel to LWR's.

Worldwide experience in advanced breeder fuels strongly suggests the advanced fuels capable of higher burnups will be available. These fuels are currently under active development and should be available after the end of the 5-year demonstration period.

The average annual fuel fabrication costs are about \$12 million (1983 dollars) per year. This includes the fuel, blankets, reflectors, and other replaceable core components.

Fresh Fuel Shipping

The costs of shipping fresh fuel from the fabrication facility and return of the empty casks were examined. Experience allows the costs of shipping to be predicted from experience with fresh fuel for other plants.

The costs are based on shipment of fresh fuel from Richland, Washington, to Oak Ridge, Tennessee, a distance of approximately 2,400 miles.

The fresh fuel shipping costs were conservatively calculated to be about \$3,400 per fuel assembly (1983 \$). In addition, about 10 casks costing \$30,000 each will be required. The fresh fuel shipping costs are projected to be about \$180,000 per year.

These costs are higher than present day costs for shipping LWR fuel assemblies. Since breeder reactor fuel contains over 20 percent reactor grade plutonium, Safe Secure Transport (SST) type services will be used.

The costs for shipping each assembly represents less than 2 percent of the cost of the assembly itself.

Reprocessing CRBRP Spent Fuel

The program plan for the CRBRP is to reprocess CRBRP fuel for recycle back to the plant. However, for the purposes of this study, several possible alternatives for the reprocessing of breeder reactor fuel were identified and the associated costs were examined.

Among the possible alternatives are the following:

- o Reprocessing using a research and development system to perform engineering tests of reprocessing breeder reactor fuel. The breeder reactor fuel reprocessing research and

development program has designed and fabricated equipment to conduct "cold" tests of reprocessing of breeder reactor fuel in a small integrated reprocessing plant. This "cold" test plant is being used to perfect the equipment design and obtain operating and maintenance information using non-radioactive material. This experience provides the basis for the design of a "hot" installation that would conduct engineering test by reprocessing fully irradiated fast breeder fuels. The system being considered would handle about 15 metric tonnes per year. The purpose is the testing of a small integrated reprocessing plant that includes provisions for equipment maintenance, waste management, and the most advanced state of the art effluent control and safeguards and security in an environment approaching that expected in commercial practice. This system represents a natural progression in the fuel cycle program. Program results to date on activities such as the cold tests provide a good basis for estimating the cost of building and operating this system. The system is required for the breeder reactor reprocessing program and is independent of the future of the CRBRP. The reprocessing costs of this option are based on the actual operating costs that are projected to be \$15 million per year. Since the capacity is 15 metric tonnes, the cost of reprocessing would be \$1,000 per kilogram of heavy metal processed or about \$7 per gram of fissile plutonium recovered.

- o Reprocessing in a commercial LWR reprocessing plant. Various types of plants were considered (Reference 5). In the lowest cost plant the reprocessing cost could be as low as \$250 per kilogram of heavy metal, or about \$1.80 per gram of fissile plutonium recovered. This is based on a plant design and cost study made by Exxon (The Economics of Reprocessing Alternative Nuclear Fuels, September 1979). In the most expensive case the cost could be \$500 to \$700 per kilogram of heavy metal reprocessed or about \$3.50 to \$5.00 per gram of fissile plutonium recovered. This is based on a 1978 DuPont study (Design Integration Study--Spent LWR Fuel Recycle complex, September 1979). The upper end assumes private ownership. Reprocessing of breeder fuel in these facilities could entail a somewhat higher cost than reprocessing LWR fuel.
- o Reprocessing in foreign nations. The cost of this option based on the world trend should be less than \$7 per gram fissile.

The costs for the reprocessing of breeder reactor fuel varied between less than \$500 per kilogram to \$1,000 per kilogram of

heavy metal. That equates to a cost of between less than \$3 and \$7 per gram of fissile plutonium recovered, respectively.

Research and development activities underway could result in reduction in these costs. As commercial use of breeder reactors increases, it is reasonable to assume that commercial facilities to reprocess breeder reactor fuel will be available at a price that should be less than the cost used in this examination. For conservatism these potential cost benefits were ignored.

Based on this examination a cost of \$7 per gram of fissile plutonium was used to project the cost of a variety of options for plutonium supply including reprocessing.

Waste Management

Waste disposal will be provided at reasonable cost irrespective of the actual fuel cycle used for the CRBRP. The Nuclear Waste Policy Act provides for all spent fuel and blanket shipping and storage, beginning in 1998, as well as for the storage of high level waste that would result from reprocessing CRBRP fuel or blanket material. The cost is 1 mil per kilowatt hour of electricity sold pursuant to the Act.

The first three cores used in the CRBRP will be a part of the demonstration period. The fourth core will be the first post-demonstration period core. This core and subsequent cores will be removed after 1998, and thus are immediately provided for by the Nuclear Waste Policy Act. The on-site facilities that are a part of the CRBRP include provision to store two cores, plus a portion of a third core.

Currently available spent fuel shipping casks could be modified to ship CRBRP fuel. This assumes that the fuel is cleaned of sodium prior to shipment. The largest shipping cost that can be envisioned would be if the spent fuel were shipped to Richland, Washington. The costs of such shipment would be about \$4,000 (1983 dollars) per assembly. The costs of shipment to the Savannah River Plant would be about \$1,000 (1983 dollars) per assembly. These costs are between about 0.5 percent and 2 percent of the fuel assembly costs and would apply at a maximum to the first three cores.

Description of Key Analytic Assumptions

From the foregoing, the analysis assumed:

- o An average price of \$7 per gram of plutonium fissile from plutonium reprocessing or purchase

- o Fabrication of fuel in SAF-line to the year 2005
- o Fabrication of fuel in a commercial facility after the year 2005
- o Improvement in the fuel life time from 550 full power days to 825 full power days after the completion of the demonstration period.

The potential cost benefits that might be achieved by taking advantage of beneficial changes in reprocessing prices and plutonium price changes were not used.

The analysis ignored a number of factors that could result in lowered fuel cycle costs and does not consider the implementation of certain options that could result in lower costs.

The costs in 1983 dollars resulting from this analysis are:

- o Plutonium supply--\$150 million total, or an average of about \$6 million per year.
- o Fuel fabrication--\$300 million total or an average of about \$12 million per year.
- o Fresh fuel shipment--\$4 million total or about \$180,000 per year.
- o Reprocessing cost--zero, all costs of reprocessing are allocated to plutonium supply.
- o Waste Management--This cost will be 1 mill per kilowatt hour and is provided by the Nuclear Waste Policy Act after 1998.

Generally conservative assumptions that were used in this analysis are:

- o Commercial fabrication of fuel assemblies is not available until the year 2005.
- o No credits are taken for bred plutonium or recovery of any of the plutonium used, or produced, in the 25-year post demonstration period.
- o No credit is taken for the development of the market conditions that would favor the commercial introduction of breeder reactors in the United States, and improve the economics of the CRBRP fuel cycle.

Summary and Conclusions

The fuel cycle analysis indicates:

- o A viable fuel cycle for the CRBRP will be available over the life of the plant.
- o There is therefore a basis for confidence that the actual CRBRP fuel cycle cost should not be significantly different than projected, and that the fuel cycle costs uncertainties will not adversely affect the economics of long term operation of the CRBRP.

REFERENCES

1. The International Nuclear Fuel Cycle Fact Book, PNL-3594, Rev. 1, Pacific Northwest Laboratory, February 1982.
2. Castaing Report--"Report of the Working Group on Spent Fuel Management", dated December 1982.
3. The Reports of The Working Groups on the International Nuclear Fuel Cycle Evaluation, dated January 1980.
4. Nuclear Assurance Corporation Report, Near-Term Plutonium Market, March 1983.
5. "Nuclear Energy Cost Data Base," DOE/NE-0044, Version 1, dated October 1982.

APPENDIX C

Project Reliability

I. Plant Availability/Capacity Factor

1. Introduction

An independent assessment of the CRBRP availability program was conducted by the Technology for Energy Corporation (TEC). TEC has verified the conclusion that the CRBRP availability goal of 82 percent is achievable after the initial shakedown period and that specifically a 75 percent capacity factor after the first few years of operation is reasonable and realistic. The CRBRP availability program was judged to be unique among U.S. reactors in that high availability was a design basis from the inception of the Project. Each system was allocated an availability target and each system design was assessed against the target to identify and correct the unavailability drivers. All major critical CRBRP components have been extensively tested at and beyond the design basis with full life cycle testing on major key components.

The activities reported in this paper are those that TEC considers above and beyond industry standard practices.

The DOE and TEC summary conclusions are based on the following findings:

- a. The CRBRP goal of an average 20 days per year of refueling should result in at least an improvement of .05 in availability factor over previous LMFBR's and LWR's. A high confidence level is placed on the current projection of slightly over 17 days per year average refueling time.
- b. One of the largest unknowns in a first-of-a-kind nuclear plant is fuel reliability. The CRBRP fuel will have undergone years of in-core testing in test reactors at conditions representative of CRBRP operation.
- c. Balance of Plant (BOP) scheduled maintenance and inspection are not on the critical path for any scheduled outages.
- d. A Westinghouse availability assessment for CRBRP resulted in an average 25 days per year (7 percent unavailability) for all scheduled outages including refueling, inspection, surveillance, and preventive maintenance requirements. Several conservatisms are built into this number. Recent

plant design changes should result in an improvement of this number.

- e. CRBRP's incorporation of known, and in some cases anticipated, NRC requirements into the plant design should produce improved regulatory stability and minimize backfit requirements on the plant.
- f. The CANDU reactors have demonstrated a capacity of 85.2 percent post-TMI. The Canadians attribute this success to the detailed design attention to availability. CRBRP availability should be comparable to that of the CANDU reactors because the CRBRP program for achieving high availability is consistent with the essential elements of the Canadian CANDU Program. CANDU reactors have achieved availability factors and capacity factors that equal or exceed the CRBRP goals. Consequently, the CRBRP availability and capacity factor goals are considered realistic and achievable.
- g. Regulatory-induced impacts on CRBRP are expected to be minimal due to the fact that all post-TMI fixes have been incorporated in the design, and many of the ongoing unresolved safety issues, such as station blackout and Anticipated Transients Without Scram (ATWS) have been addressed in the CRBRP design.

Further, an independent systems availability assessment of the entire plant is being conducted by System Development Corporation, and Daniel, Mann, Johnson & Mendenhall (SDC/DMJM), to verify that the systems will function as intended and that the design basis availability and capacity are met.

SHAKEDOWN PERIOD CAPACITY FACTOR

20% - First 7 months of operation

36% - Following 6 months

40% - Following 12 months

55% - Following 12 months

75% - Thereafter

For purposes of a conservative revenue projection, a capacity factor of 65 percent has been assumed while sensitivity of the capacity factor will be identified by also calculating revenues assuming a 75 percent capacity factor following the shakedown period.

2. CRBRP Availability

An overall plant availability goal of 82 percent and capacity factor goal of 75 percent were established in the original requirements for CRBRP. Initial emphasis was placed on refueling time as the most fixed contributor of scheduled plant unavailability. The original requirement for refueling time was established at 20 days per year (5.5 percent unavailability) as compared to 37 days greater than 10 percent unavailability for refueling of LWRs).

3. Design To Meet Availability Goal

3.1 Design Discipline

The system design descriptions include operations and maintenance aspects of each system down to mean-time-to-repair and the required plant status for repair of each individual component. The majority of specifications for component design and fabrication contains requirements for each component's reliability and availability, including vendor proof of component reliability through testing or analysis.

3.2 Modeling

CRBRP has made extensive use of modeling and mockups. The emphasis placed on modeling during the plant design to improve operations and maintenance characteristics of CRBRP should favorably affect the plant construction costs and plant availability.

Full-scale mockups of specific areas of the plant, such as the main control panel, reactor upper internals, and head access area (refueling area above the reactor vessel) have been constructed for fabrication, maintenance, and operations reviews. In addition, functional and proof testing of the reactor vessel closure head, through which the nuclear fuel is loaded and unloaded, has been performed to ensure high availability during refueling and to demonstrate short refueling times.

3.3 Design Features For Availability

Important design features/considerations utilized in the CRBRP design to enhance plant availability/capacity factor are listed below:

- a. Design and development of fuels to accommodate 2-year refueling interval initially and 3-year refueling interval after the demonstration period.

- b. Component design temperatures and pressures that are conservatively selected with respect to operating conditions. The lower operating pressures of 200 psi for CRBRP relative to those for LWR plants (1500-2200 psi) allow use of simplified sealing systems to enhance availability. LWR sealing systems represent a significant maintenance/repair problem.
- c. Key plant components, e.g., control rods, pump seals, blanket assemblies, are designed to be readily replaceable during refueling outages to support plant availability goals.
- d. A steam generator design that includes features to enhance the reliability of the unit, including:
 - the use of a welded versus bolted steam head design to eliminate seal leakage problems; and
 - the use of a sensitive leak detection system to alert the operators to small leaks to minimize the potential for a large sodium-water reaction and the associated significant repair and clean-up efforts.
- e. A heavily compartmentalized plant design to ensure structural separation between components of redundant fluid systems, thus enhancing availability by limiting the damage from a single component failure to a single fluid process loop.
- f. The use of an in-vessel fuel handling machine that is removed from the reactor vessel after refueling is completed. This permits complete checkout and functional testing of the machine prior to refueling shutdown and increases the chances for completion of the outage on schedule.
- g. The capability of operating on two of three loops has been designed into CRBRP. This will allow continued operation with maintenance on the shutdown loop.

TEC considers these design features to represent a significant commitment on the part of CRBRP designers to ensure that plant availability is maximized.

3.4 Verification

CRBRP is unique among nuclear powerplants in its front-end concern for systems engineering with specific emphasis on reliability, availability, and maintainability (RAM). A

detailed RAM program has been under way at CRBRP for several years and has the following features:

- a. An allocation of availability to each system in the plant has been made and viewed as a design target;
- b. Assessments of system hardware availability have been made by Westinghouse for Nuclear Island and by Holmes and Narver for Balance of Plant. An independent SDC/DMJM assessment for the total plant is ongoing;
- c. A detailed independent systems analysis of CRBRP is in the early stages of completion (conducted by SDC/DMJM); and
- d. An independently performed probabilistic risk assessment is providing availability analyses of select (e.g., safety) systems (Phase I--completed) and common-cause effects (Phase II--underway).

The initial balance of plant availability study (Holmes and Narver) concluded that CRBRP availability would most resemble PWR availability. Its assessment indicated an availability of 95 percent for the Balance of Plant and allocated availability targets for each Balance of Plant system.

The Westinghouse analysis of the Nuclear Island in April 1981 assessed availability for all but Balance of Plant systems resulting in an overall plant availability of 0.78. The unavailability drivers leading to the 78 percent Nuclear Island assessment were identified and five design changes were identified to raise the Nuclear Island availability to 85 percent, yielding a combined overall plant assessment of 82 percent.

As part of the design verification program, the ongoing Systems Interactive Analysis, SDC/DMJM, includes the following tasks:

- a. Provide an independent assessment of all plant system availabilities;
- b. Standardize and update a CRBRP RAM data base;
- c. Identify specific areas where availability enhancement can be reasonably expected;
- d. Reassess the system-wide availability allocation and change where appropriate;

- e. Formally document availability allocation and change where appropriate;
- f. Formally document availability improvements; and
- g. Develop a plant functional analysis that will model each system and all system interactions.

This entire independent CRBRP systems design assessment effort will be complete in CY 1983.

3.5 Testing

Construction of prototypes was undertaken for those major components where proof-of-design and comprehensive testing were crucial to the demonstration of safety and reliability. Prototype development also provides a demonstration of constructibility.

A program of testing has been developed for all safety-related components for CRBRP. Tests were designed not only for proof-of-design and operability, but also for maintainability and demonstration of selected plant procedures where appropriate. Test results have already led to several improvements in design and operating procedures that will directly increase component reliability and maintainability for plant operation. Notable test program applications include:

- a. A full-scale prototype test of the CRBRP steam generator;
- b. A full-scale prototype test sodium pump and pump drive/control system;
- c. A prototype test of the 200-400 gpm electromagnetic pumps;
- d. Mechanical life cycle testing of liquid metal valves under prototypic and seismic loading conditions;
- e. Life cycle and seismic testing of prototypes of the Primary Control Rod System;
- f. Life cycle and seismic testing of prototypes of the Secondary Control Rod System;
- g. Reliability testing of the Plant Protection System (PPS); and
- h. Extensive tests of CRBRP Fuel and Blanket Assemblies at CRBRP Conditions.

4. Operating Experience Comparison

The following table provides a comparison of the CRBRP availability goal to that of other reactors and also illustrates the impact of refueling time variations. Of particular note is the Phenix LMFBR, achieving a plant availability of 80 percent for the 2 years following the first 4 years of operation.

COMPARISON OF PLANT AVAILABILITIES

Plants	Availability (Capacity Factor)	Refueling Unavailability
CRBRP (Goal)	82% (75%)	5.5%
CANDU (8 units)	(79%)	0%
PHENIX LMFBR 5/78 - 3/80	80% (80%)	15.6% (Scheduled Outages)
EBR-II LMFBR 1974 - 1981	74%	14%
MATURE U.S. LWR (Greater than 4 years old) 1977 - 1979 (Median)	80%	10.7% 15.5%
MATURE U.S. LWR (Greater than 1 year old) through 1976 (Median)	72% (60%)	10.7% 15.5%

In comparing CRBRP's availability goal to CANDU operating experience, an availability similar to CRBRP's goal has been attained in practice. For the post-TMI period, CANDU's plants have averaged 85.2 percent capacity factor, much higher than U.S. LWR averages. The eight CANDU plants have averaged a 79 percent capacity factor after 4 to 11 years in service. The Canadians attribute reaching these capacity factors more to the detailed design reviews for availability that they conducted than to the on-line refueling capability of their reactor. CANDU designers are given specific

reliability and maintenance target goals at the preliminary engineering phase. Significant attention is given to availability from design through operation. The design review methodology that the Canadians use includes availability aspects similar to the availability program being used at CRBRP.

Notable exceptions to the U.S. LWR average capacity factors are the Point Beach PWRs of Wisconsin Electric Power. Point Beach Units 1 and 2 have gross capacity factors of 78.0 percent to 70.1 percent, respectively, since initial operation in 1970 and 1972. Wisconsin Electric attributes much of this success to a competent staff in plant construction commissioning and operation, and the Point Beach units were designed with maintenance in mind. This has also been the case with the CRBRP.

II. CRBRP Power Generation Capability and Useful Life

The initial operational level of the CRBRP will be at a maximum of 375 Mw or 85 percent of the design gross capacity of 430 Mw. During this initial operating period at 375 Mw gross, the net power available for sale will be 330 Mw. This determination is based on a detailed auxiliary or hotel load study which resulted in an upper limit of 45 Mw auxiliary load for operation at the 375 Mw level. After extended operation at 375 Mw(e) gross, the plant power level will be raised to the level of 430 Mw. The total gross CRBRP power level of 430 Mw is assumed to be achieved in year 10 of operation and thereafter for the 30-year design life of the plant.

The net power available to sell during operation at full design power will be 380 Mw, with an auxiliary load of 50 Mw. This 15 percent increase in power above the initial power level will be achieved by maintaining a constant temperature differential across the core and increasing the flow by 15 percent. The steam generators, sodium pumps, pump drive motors, intermediate heat exchanger (IHx), condensate pumps, feedwater pumps, turbine generator, and the electrical system including the main transformers, buses and transmission lines have sufficient margin for the 430 Mw(e) gross power level.

The Clinch River Breeder Reactor is designed to have a 30-year life. This lifetime is based upon an 82 percent availability factor and a 75 percent capacity factor for the lifetime of the plant with the exception of the first 3 years. Any decrease in availability and load factor would result in an increase in a number of calendar years of lifetime of the reactor.

The CRBRP design life for structures, systems, and components is based on judicious selection of materials, protective finishes, and/or protective practices chosen to satisfy the 30-year design life by means of preventive maintenance or redundancy to assure that, (1) the design life is achieved and (2) that plant availability is not affected.

The life of all primary and intermediate heat transport system components is based upon a very conservatively determined design duty cycle that postulates a very large number of anticipated, upset, and emergency events in addition to a high temperature steady-state hold. Since both the number and magnitude of the transients are extremely conservative, in all likelihood, the lifetime of this plant could be extended even beyond 30 years. The basic plant is designed using austenitic stainless steels which are less susceptible to radiation damage and other material problems characteristic of light water reactors which largely use ferritic steels.

Those components that cannot achieve 30 years without degradation, such as the seals in the pumps are designed to be easily replaceable and have a replacement schedule during regular maintenance periods.

In summary, a very conservative analysis is used to assure that the lifetime of the plant is at least 30 years. In all likelihood one could find it stretching well beyond 30 years. EBR-II experience indicates that the lifetime of a liquid metal plant is significantly beyond the design lifetime based on detailed examination (in-service inspection) of equipment after 20 years of service.

APPENDIX D

CRBRP Revenue Projections

Previous projections of the revenues derived from CRBRP electricity production have been based on the current contract with TVA to purchase CRBRP electricity at TVA's avoided cost.* The TVA/CRBRP contract identifies the last 100 MWe of TVA generated electricity as the basis for estimating TVA's avoided cost. TVA's forecast of this cost implies that electricity from existing coal plants will be displaced during the project demonstration period of FY 1991-FY 1995.

Electricity may logically be sold at an avoided energy cost that recovers only marginal operating costs with no amortization of capital if the power is being supplied on a nonfirm, interruptible basis. For the purposes of this study, however, it is clear that private investors would intend to sell power on a firm basis, operating the plant as a baseload station as it has been designed.

A survey of 25 utilities in the southeastern United States indicated that as of FY 1993 and thereafter, new baseload capacity would be required by a majority of the utilities surveyed in order to maintain a reserve capacity of 20 percent.⁽¹⁾ In addition, analysis of data provided by the Southeastern Electric Reliability Council (SERC) and the Oak Ridge National Laboratory (ORNL) confirms the need for new baseload capacity in the southeastern United States before FY 1995.

The SERC includes Tennessee, the Carolinas, Alabama, Georgia, Florida and portions of Virginia, Kentucky and Mississippi. Except for Florida, all SERC utilities are within an efficient transmission distance of CRBRP. Today, SERC has much more power than it needs to serve electric demand reliably. Also, SERC anticipates enough new capacity to serve projected demand through 1995.⁽²⁾ However, SERC's plans for 1990 (as of 12/31/81) include three coal units which are not yet under construction and three nuclear units whose construction is less than one-tenth complete. There are seven coal units that are planned for Florida which have not been accounted for since Florida is outside the assumed transmission range of CRBRP. If these plants are included,

*In the Public Utility Regulatory Policies Act of 1978, avoided cost is defined as "the incremental costs to an electric utility of electric energy or capacity or both, which, but for the purchase from the qualifying facility or qualifying facilities would generate itself or purchase from another source."

SERC's plans include ten coal units not yet under construction and three nuclear units whose construction is less than one-tenth complete. One of these nuclear plants (North Anna 3) has been subsequently cancelled.

Therefore, SERC's planned capacity of 153,320 MWe in 1990 is, in actuality, only 149,113 MWe of committed capacity beyond 1990.⁽³⁾ Unless SERC actually constructs the planned but not committed capacity, SERC's projected peak demand in 1995 would only be served by a 5 percent reserve margin. In order to serve SERC's projected 1995 peak demand of 141,841 MWe with a 20 percent reserve margin, approximately 16,000 MWe of additional capacity (excluding Florida) will be required. CRBRP power (provided on a firm contract commitment) would only displace 2 percent of these projected 1995 capacity requirements.

It is well recognized that electricity demand forecasts have been revised downward over the last several years. It is also recognized that econometric models are not capable of predicting the underlying structural changes in the use of electricity. These changes, such as improved end-use efficiency, are largely responsible for the need to reevaluate electricity demand forecasts. In order to evaluate the impact of these factors on the required incremental baseload capacity in the CRBRP market area, the Oak Ridge National Laboratory has provided an assessment of power needs in this service area⁽⁴⁾. Two models were employed by ORNL. One model was econometric, while the other model was an integrated end use model. The latter model is explicitly sensitive to the structural changes which have resulted in lower electric power demand forecasts.

The models provided forecasts for a geographic area roughly equivalent to the SERC market area. Four sets of input assumptions were used. These input assumptions correspond to low, medium, and high world oil price cases and to a Southern Regional Growth Case. See reference 4 for details. The range of forecasted peak electricity demand for the SERC market area in 1995 was 143,000-153,000 MWe from the structural end use model and 194,000-203,000 MWe from the econometric model (see Table D-1). The lowest forecast (143,000 MWe) is slightly higher than the recent SERC forecast discussed above (141,841 MWe (see reference (2))). Therefore, our independent analysis of the need for power indicates that at least 17,000 MWe of additional capacity will be required to serve SERC in 1995 with a 20 percent reserve capacity (excluding Florida). If the highest forecast from the structural end use model were used, 27,000 MWe of capacity would be required by 1995. The econometric model forecasts imply much higher required capacities.

The survey of utilities indicated that new coal-fired baseload units are the appropriate alternatives displaced by firm power

supply contracts. Several studies indicated that the most economical increment of this type of capacity is represented by twin 600 MWe coal-fired plants (5, 6). If the revenue requirements of such a plant were used to negotiate CRBRP contracts, utilities would have the advantage and opportunity of purchasing smaller increments of baseload capacity (30 to 330 MWe) at the same cost per MWe as provided by a 1,200 MWe plant. This provides a substantial benefit to utilities since they may avoid construction of less economic units, underutilization of larger units, joint development of larger plants with other utilities, or periods of inadequate reserve capacity. This economic advantage is particularly beneficial to smaller utilities, e.g., municipal utilities.

The revenue requirements of a two-unit coal station (each unit = 600 MWe) were developed for the region by ORNL (6). The capital cost for this plant (scheduled for commercial operation in 1991) is estimated at \$1,250/MWe (1984 \$). If this plant investment is prorated to a smaller 330 MWe plant (equivalent to CRBRP), the plant investment at 1991 commercial operation would be \$412.5 million (1984 \$). This capital cost estimate was used to develop the revenue requirements of a baseload plant displaced by CRBRP. A single coal-fired 350 MWe plant would require a \$584 million investment. (7) Two avoided cost estimates were developed using different coal price projections derived from the 1981 Annual Report to Congress by the U.S. DOE. (8) The low coal price forecast assumes no real rate of inflation in the price of coal while the high coal price forecast assumes a 2 percent annual real rate of inflation. The low coal price forecast results in a revenue requirement of \$97/MWhr (1984 \$) in FY 1991 while the high coal price forecast increased the revenue requirement to \$104/MWhr. These data are displayed in Tables D-2 and D-3 as Case 1 (low coal cost) and Case 2 (high coal cost). CRBRP is estimated to achieve a capacity factor of 75 percent after the initial shakedown period (see Appendix C). However, in order to provide a conservative estimate of future revenues, a 65 percent capacity factor was used instead.

TABLE D-2

AVOIDED COST

CRBRP Electricity Price Projections

FY 1991
Electricity Price
(1984 \$/MWhr)

Avoided Energy and Capacity Cost
(Baseload Capacity Displaced)

1 (Low Coal Cost):	\$ 97
2 (High Coal Cost):	\$104

TABLE D-3

CRBRP Electricity Price Projections
(Year of Expenditure \$/MWhr)

<u>Fiscal</u> <u>Year</u>	<u>Case*</u>	
	<u>1</u>	<u>2</u>
1991	146	157
1995	151	173
2000	165	206
2005	189	261
2015	292	488
2020	374	690

*See Table D-2 for case definitions

NOTES

1. S. M. Stoller Corp., Projections of Revenues from CRBRP Operation, March 8, 1983.
2. North American Reliability Council, Electric Power Supply and Demand (1982-1991), August 1982.
3. The estimate of 149,113 MWe of committed capacity does not account for the planned coal plants in Florida (outside of CRBRP market area) and therefore assumes that these plants are constructed. If all of the planned powerplants in SERC are subtracted from SERC's estimate of 1990 capacity, only 144,998 MWe is committed capacity
4. Oak Ridge National Laboratory, "Initial Phase Draft Report, Clinch River Breeder Reactor: Assessment of Need for Power and Service Area," February 28, 1983.
5. U.S. Department of Energy, Energy Information Administration, Projected Costs of Electricity from Nuclear and Coal-Fired Power Plants, DOE/EA-0356, August 1982.
6. U.S. Department of Energy, Nuclear Cost Data Base, A Reference Data Base for Nuclear and Coal-Fired Power Plant Power Generation Cost Analysis, DOE/NE-0044, October 1982.
7. J. G. Delene, G. R. Sanders, H. I. Bowers, Engineering Economic Analysis of Utility Alternatives to the Clinch River Breeder Reactor, Oak Ridge National Laboratory, March 1, 1983.
8. U.S. Department of Energy, Energy Information Administration, 1981 Annual Report to Congress, February 1982.