MASTER

STUDY OF THE POTENTIAL USES
OF THE BARNWELL NUCLEAR FUEL PLANT (BNFP)

FINAL REPORT

Prepared for

The U.S. Department of Energy

By

International Energy Associates Limited

25

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25 March 1980

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INTRODUCTION

Study Purpose

The purpose of this study is to provide an evaluation of possible international and domestic uses for the Barnwell Nuclear Fuel Plant (BNFP), located in South Carolina, at the conclusion of the International Nuclear Fuel Cycle Evaluation (INFCE).

The Department of Energy was directed by Congress to provide such a study to the Congress by April 1980; and the Congress provided specific guidance for topics to be addressed in the study.

Study Approach

The approach used in the preparation of this study was to begin with the 1978 BNFP Utilization Study as a basis for the definition, elaboration, and evaluation of technical and institutional options for Barnwell. In doing so, the analysis incorporated data and information made available since publication of the earlier study, but did not generate new data through independent investigation.

A major purpose of the present study was to consider how changes in the energy, nonproliferation, and regulatory "environment," within which any use of Barnwell must be considered, might influence the nature, and advantages and disadvantages of the use and institutional options for BNFP. The findings of NASAP (Nonproliferation Alternative Systems Assessment Program) and INFCE, in particular, are factors of major importance to the analyses presented in this study. These findings were not available when the first study was completed.

The report establishes a set of guidelines relating to energy, nonproliferation, cost-effectiveness, and local acceptability concerns, among others, which provide a basis for evaluation of the alternatives.

Preparation of this report encompassed three basic steps:

- The establishment of the "environment" from the energy security, nonproliferation, and regulatory standpoints within which the potential uses of Barnwell should be viewed; and the establishment of the criteria or guidelines that should be employed in assessing the potential uses of Barnwell.
- The identification of the generic use options for Barnwell in sufficient detail to provide a basis for judging the efficacy of the use, technical status, and feasibility, and related costs; and the identification of the generic institutional options in sufficient detail to provide a basis for developing optional arrangements for particular uses of Barnwell.
- In light of the assessment guidelines, the development of realistic possibilities, based upon an integration of appropriate institutional and use options for the use of Barnwell in the near, mid, and long term, including time phased combinations.

In carrying out this evaluation, priority has been given to presenting the advantages and disadvantages of alternative uses for BNFP. The study explicitly did not seek to reach conclusions as to the optimal uses, or to present policy recommendations. It has, however, confined itself to defining and evaluating realistic alternatives for Barnwell.

1.0 THE CHANGING ENVIRONMENT

The purpose of this section is to examine the energy security, non-proliferation, and regulatory environment within which potential uses of Barnwell must be viewed and considered. It is instructive, however, before examining the current situation and its dynamics, to review past events for an historical perspective of the origins both of Barnwell and this study.

The reprocessing of spent nuclear fuel from commercial nuclear power plants to recover the fuel value of the residual uranium and plutonium for recycle in light water reactors or breeder reactors was, until the mid-1970s, an accepted tenet of the development of commercial nuclear power in the United States and abroad. Government policies and programs supported, both directly and indirectly, the development of commercial reprocessing. The first commercial reprocessing plant* in the U.S. was dedicated in 1966.

In the late 1960s the Atomic Energy Commission, in its regulatory capacity, approved the construction of facilities that were to be part of the first large-scale reprocessing plant in the U.S., the Barnwell Nuclear Fuel Plant. The plant, designed to reprocess 1,500 metric tons of spent fuel per year, is located on a site contiguous to the Government's Savannah River installation, which had been deeded to the State for industrial development by the Atomic Energy Commission and, subsequently sold to Allied-General Nuclear Services (AGNS).

The Barnwell plant, as designed, would consist of facilities to:
(1) store 400 metric tons of spent fuel; (2) separate plutonium and

*This small reprocessing plant, at West Valley, New York, operated from 1966 to 1972. The plant was shut down in 1972 for clean-out and expansion. The plant did not resume operations because new licensing regulations required modifications that the owner, Nuclear Fuel Services, Inc., could not justify economically.

uranium from spent fuel using the PUREX process technology; (3) convert the aqueous uranyl nitrate from the separations facility to uranium hexafluoride available for feed to a uranium enrichment plant; (4) convert the aqueous plutonium nitrate to plutonium oxide available for feed to a fuel fabrication plant; and (5) solidify and package the high-level liquid wastes in a form suitable for storage.

By 1975, the first three facilities had been constructed and preliminary designs completed for the two remaining facilities, and licensing proceedings were in process. The AGNS investment by this time approximated \$250 million. On April 7, 1977, the President announced his policy decision to defer indefinitely the commercial reprocessing of spent fuel and the recycling of plutonium in the U.S.; additionally, breeder reactor development programs would be restructured and slowed. The conclusion was that a viable and economic nuclear power program could be sustained with the light water reactor without recycle and that the time of need for the breeder reactor was uncertain at best. The policy decision was also rooted in the concern for the risks of further proliferation of nuclear weapons from the spread of reprocessing technology and the resultant stockpiling and use of weapons-useable plutonium.

As part of the decision to defer commercial reprocessing, the policy precluded either Federal funding or support to the Barnwell Nuclear Fuel Plant. In consideration of the policy, the Nuclear Regulatory Commission suspended all licensing proceedings relative to Barnwell.

In support of its effort to encourage other nations to pause in their development and deployment of nuclear power technologies employing separated plutonium and to examine alternative means, the U.S. proposed an international examination of alternative fuel cycles. As a result, the International Fuel Cycle Evaluation was launched, in October 1977, as a two-year technical and analytical study of all aspects of the fuel cycle with the objective of evaluating measures to reduce the risks of weapons proliferation without jeopardizing energy supplies or the development of nuclear energy for peaceful

purposes. This 66-nation effort concluded its work in February 1980. The U.S. also undertook a domestic effort to analyze the proliferation resistance and economic potential of fuel cycle alternatives. The Nonproliferation Alternative Systems Assessment Program (NASAP) covered a similar time span.

The position of AGNS, reflecting on these events in 1977, was that they saw no current prospect for their operation of Barnwell as a commercial venture and, therefore, would not invest further capital at Barnwell for reprocessing; and that they had no commercial interest in using the facility for spent fuel storage. If the facility was to be maintained awaiting the conclusion of the INFCE and NASAP efforts, then the Government would have to share, in some manner, the costs of doing so.

Congress moved to provide such support in August 1977, when it directed the Department of Energy (DOE) to spend \$13 million of its FY-1978 appropriation at Barnwell for activities in support of INFCE, including research, evaluation, and assessments. This level of funding was apparently sufficient to maintain the then current staffing levels at Barnwell through the fiscal year.

Additionally, Congress directed the DOE to conduct a study to determine if the BNFP could be utilized in support of the nonproliferation objectives of the United States. The Barnwell Nuclear Fuels Plant Applicability Study included evaluation of multinational and international management options for Barnwell, possible roles for the IAEA in utilizing Barnwell for international nonproliferation programs, use of Barnwell for demonstration of improved safeguards equipment, possible use of Barnwell to support nonproliferation research also underway at Tokai Mura and Windscale, whether and how ownership of Barnwell might be transferred to the Federal government, and the impact of these options on efficient resource utilization and national security.

This study was conducted against a background of nonproliferation policy that inevitably influenced both the choice of criteria for

assessment of the options and the relative weights assigned to the criteria, the interpretation of the results of the evaluation, and the extent to which the DOE could make statements of a committal nature regarding the future utilization of Barnwell. The study was issued in April 1978.

Congress continued the program at Barnwell at a level of \$18.5 million in FY-1979. The increase in funding was due largely to an increase in nuclear safeguards work and extended cold uranium runs to verify alternative fuel cycles and safeguards hardware. The FY-1980 appropriation continues the program at Barnwell at a level of \$11.5 million. Continued federal funding of short-term research activities at least until the end of INFCE has been accepted by the Administration and the activities are seen as contributing to U.S. nonproliferation efforts.

While the Administration has sought to terminate the Clinch River Breeder Reactor (CRBR) project in furtherance of its policy decisions of April 1977, it has continued a strong technology development program for the liquid metal breeder reactor. The program objective is to maintain the breeder technology base for future use when required, "consistent with U.S. nonproliferation objectives and anticipated electric power requirements."

Similarly, in support of U.S. basic nonproliferation objectives, the DOE has pursued research and development programs to significantly improve the fuel utilization efficiency of today's light water reactors and to develop still more resource-efficient light water reactor fuel. In parallel are programs to develop and demonstrate the technical and economic performance of advanced isotope separation processes that would significantly extend the uranium resource base. The National Uranium Resource Evaluation (NURE) Program has continued with the objective of reducing the uncertainties as to the extent and availability of uranium fuel resources both here and abroad.

Implicit in the Congressional mandate for the current study of possible uses of Barnwell is the premise that the "conclusion of INFCE"

and relatedly of NASAP provides the opportunity for the U.S. to revise its nuclear policy of April 1977. In terms of the physical facility, Barnwell remains essentially as it was in 1977 -- a partially completed nuclear fuels reprocessing complex. While staff and the facility have been maintained during this period, the views of AGNS regarding the operation of the facility as a private commercial venture or the use of the facility for spent fuel storage remain unaltered. For the section that follows, significant developments both in the U.S. and abroad regarding energy supply, nonproliferation, and the regulation of nuclear activities are identified and their implications for the utilization of Barnwell are examined.

1.1 THE ENERGY/NUCLEAR ENVIRONMENT

1.1.1 Background

Major developments have taken place in the national energy outlook and policies since preparation of the 1978 BNFP utilization study. The political and economic unacceptability of continued excessive dependence on imported oil has been dramatically reaffirmed by events in Iran and elsewhere in the Middle East and Persian Gulf, and by the rapid resumption of oil price increases that had remained relatively stable in constant dollars since 1974. As a consequence, the vital role of nuclear power in helping meet U.S. energy needs has become increasingly apparent, and has been reaffirmed at the highest level, most recently in President Carter's statement of December 7, 1979, in which he said:

The recent events in Iran have shown us the clear, stark dangers that excessive dependence on imported oil holds for our nation. We must make every effort to lead this country to energy security. Every domestic energy source, including nuclear power, is critical if we are to be free as a country from our present over-dependence on unstable and uncertain sources of high priced foreign oil.

We do not have the luxury of abandoning nuclear power or imposing a lengthy moratorium on its further use....

This strong reaffirmation of the need for nuclear power was made after full consideration of the implications of the most serious U.S. commercial power reactor accident to date. Despite the seriousness of Three Mile Island (TMI), the official position, as the President's statement makes clear is that the accident provided an important and timely lesson on the deficiencies of existing safety practices, without invalidating earlier judgments that, when proper care is exercised, nuclear energy is an acceptably safe means of generating electric power.

Nuclear power is also regarded by many other nations, including the United States's closest allies, as of key importance in their efforts to reduce excessive dependence on imported oil. This is reflected in the official Communiques of the Economic Summit Meetings of the Western industrial powers including the United States, such as that of 1978, which stated: "The further development of nuclear energy is indispensable and the slippage of nuclear power programs must be reversed."

The energy security of these nations is recognized as of importance not only to each of them individually, but to their collective security including that of the United States itself.

The important contribution of nuclear power to United States energy security is, thus, firmly established in national energy policy, and its contribution has already reached substantial levels, despite repeated major reductions in attained and forecast nuclear power growth. In 1979, nuclear power provided close to 14% of total electric power generation, corresponding to 1.4 million barrels per day of oil equivalent (MBDOE). By 1990, this contribution is expected to grow to 25-27% of electric power generation, equivalent to 4 MBDOE, or 11% of total energy consumption.

Despite the recognized importance of nuclear power, ordering of new units is currently at a standstill, as a result of low electric power

growth rates in most regions, serious financial difficulties, including the reluctance of state regulatory bodies to adjust rate structures, high interest rates, and regulatory uncertainties exacerbated by TMI. As reserve generating capacity is depleted and utilities find it necessary to order additional units, the basic choice is between coal and nuclear, and there is a growing tendency by utilities to force state regulatory commissions to participate in this choice. The proportion of the market supplied by nuclear will be dependent on a complex of factors, which are undergoing constant change. Even without new orders, however, units already on order or under construction will result in major growth by 1990, as noted above. While substantial growth beyond this level cannot be assured, prudent planning would seem to require an assumption of renewed ordering at an early date.

Though the importance of nuclear power is clearly established, the corresponding need for reprocessing and other fuel cycle services, and, thus, the relationship between nuclear power requirements and possible use options for BNFP raises more complex issues. Despite long-standing assumptions as to the desirability of reprocessing in the light water reactor (LWR) fuel cycle, the once-through use of fuel has become the de facto fuel cycle in nearly every country employing LWRs outside the Soviet Bloc. With the rapidly increasing costs of oil and other alternative energy sources, which have outpaced even the sharp increases in nuclear generation costs, the economic margin favoring nuclear power has generally been preserved, even without the contribution from the energy values of recovered plutonium and residual uranium once thought as important contributions to the economics of nuclear power generation from LWRs. At the same time, disproportionate increases in the estimated cost of reprocessing and related services have reduced earlier estimates of the economic benefits of recycle to the point that there is a general consensus that current economic benefits of recycling are marginal at best.

While earlier expectations of the economic benefit of reprocessing and recycle have not been borne out, other concerns have remained. Even with the reduced forecasts for nuclear power growth now considered probable, the long-term adequacy of uranium supply at acceptable prices has remained problematical and sharp increases in uranium prices, to some extent now moderated, have already been experienced. The concern over the general adequacy long term of uranium supply has been augmented by the concern of many nations as to their access to such supplies as are available. This has led several nations to argue for reprocessing on energy security grounds despite the indications of reduced economic benefits from recycling. Reprocessing had also been viewed in several countries, notably Sweden and the Federal Republic of Germany, as an important if not essential step in the safe disposal of nuclear wastes, but these countries are now planning an extended interim storage at away-from-reactor (AFR) storage facilities.

Increasingly, the need for reprocessing has come to be viewed as related to the long-term viability of the nuclear option. As uranium availability declines, uranium prices may come to exceed the level necessary to justify economically the expansion of LWR capacity. If this tendency takes effect, economics will increasingly come to favor introduction of the breeder reactor in countries with large nuclear power programs. While there is broad agreement that this will require reprocessing and the use of plutonium, most probably in breeders of the light metal fast breeder reactor (LMFBR) type, estimates vary widely as to when breeders are likely to be required.

There is, however, agreement that before the commercial introduction of breeder reactors on any substantial scale, the requirements of plutonium for breeder reactor development and demonstration will require reprocessing on a significant scale. Additionally, the decision to commercialize the breeder will in itself require an assurance of the availability of an industrially viable reprocessing technology, which is an integral part of the breeder fuel cycle. The rate of breeder installation following initial commercialization may

well be controlled by the availability of reprocessing capacity. However, despite qualitative agreement on the sequence of steps necessary to assure the availability of a breeder option and its effective deployment, differences persist on the estimated time required for these steps, as a result of differing opinions on nuclear power growth rates, uranium resources and producibility, and, to a substantial degree, the lead-times required for the development and demonstration of breeder technology.

In a few countries, notably France, reprocessing for the production of plutonium required for breeder development and demonstration and the establishment of a commercial reprocessing capability is already underway. U.S. policies are based on a judgment that a longer time-scale is appropriate for the U.S., and that there is no immediate need for spent fuel reprocessing to meet breeder development and demonstration needs. Other sectors of the U.S. nuclear community continue to question this conclusion, both on the basis of less optimistic forecasts of uranium availability and of the long lead time associated with breeder development. Some in the nuclear industry believe that proceeding with construction of a breeder prototype is necessary now, if a viable breeder option is to be available by the turn of the century, and that early operation of BNFP is an important element in assuring the success of an overall breeder development strategy.

Less tangible factors also play a role in perceptions of the required time schedule for reprocessing. The need to maintain the momentum of nuclear power programs and to avoid departing from generally held expectations, particularly as they relate to the disposal of nuclear wastes, are cited by some as reasons to proceed with planned reprocessing activities. A number of foreign nuclear experts have suggested that U.S. participation in the development and demonstration of breeder technology, including the operation of large scale reprocessing facilities is important to the achievement of these goals outside the U.S., both because U.S. policies tend to affect

public attitudes elsewhere and because the U.S. technical capabilities can make a highly important contribution to the successful development of these difficult technologies. The U.S. government, on the other hand, believes that in light of the proliferation risks of plutonium, reprocessing, and breeder demonstration or commercialization should not be initiated in advance of well-defined needs.

INFCE, as intended, has shed considerable light on the economic, energy security, and waste management aspects of reprocessing, plutonium recycle, and the breeder, leading to a narrowing of differences and, as indicated earlier, a degree of consensus on the sequence of steps required to ensure the long-term viability of the nuclear option, although not their time schedule. In the following sections, these issues are explored in quantitative terms, proceeding from overall prospects for increased electricity demand to the role of nuclear power in meeting these requirements and, finally, the consequences of the demand for nuclear power on the need for reprocessing as a function of a range of nuclear power growth rates and possible uranium reserves.

1.1.2 Utility Fuel Use and Supply Outlook

Since 1974, the annual growth rate of electricity consumption has dropped from 7% to 3%. Projections of future annual growth rate range between 3% and 5%. The present situation is that of: a slackening of projected baseload requirements due to high fuel prices; progressive implementation of conservation measures due to higher electric power costs; and, to the extent possible, utility postponement of long-term commitments pending the resolution of major financial, fuel supply, environmental, and technological uncertainties.¹⁻⁶ Despite these low projected growth rates, which reflect estimates of the increase in demand resulting from general economic factors, some believe that electric power growth should be vigorously encouraged to take advantage of the ability of electric power to displace oil and gas with domestically abundant coal and nuclear energy sources.

Against this background, key legal and policy directives have been taken in the past two years to redirect historical patterns of energy supply and use in the U.S. economy. The major actions include: The National Energy Act (NEA) of 1978, the National Energy Plan II (NEP II) of 1979, the President's New Energy Initiatives (NEI) announced on July 15 of last year, and last December's Presidential decision on nuclear energy following the report of the President's Commission on the Accident at Three Mile Island. Building on this legal and policy framework, the most significant requirements to be faced by electric utilities between now and 1990 are as follows:

- Electric utility consumption of oil to be reduced by 50% to 750,000 barrels per day by 1990.
- No natural gas to be burned by electric utilities by 1990.
- Coal consumption to increase from 620 million tons per year to 1500 million of which 65% is for electric generation, and 17% for synfuels (which in part would also supply the electric utility sector).
- The balance of baseload requirements satisfied by nuclear power.^{1, 2, 7}

In light of the above, the moderate growth rate for baseload power at the national level does not significantly reduce the pressure placed on utilities to switch fuels in a limited time frame, nor does it adequately represent regional disparities, and physical limits to achieving the above. Assuming an annual growth of 3% per year, an additional 1.3 trillion KWh would be required by 1990.³ This would be roughly the equivalent of 145 additional GWe power plants if the current structure and operating experience of the utility sector were taken as a reference (e.g., based on the average 1979 availability of the NERC bulk power system). Using an annual growth rate of 5%, an additional 2.4 trillion KWh would be required by 1990; this would roughly correspond to two hundred sixty-five 1,000 MWe power plants, respectively, using the same assumptions as above.^{1-3, 5, 6}

Fuel supply for generating plants remains one of the greatest uncertainties confronting utility management today.⁴⁻⁶ Since electrical power uses 29% of the Nation's primary fuel supply,⁷ and provides 14% of all energy requirements,³ a dependable and assured primary fuel supply for the electric utility sector is of critical economic importance. Moreover, in some energy scenarios, electric power will continue to increase considerably faster than overall energy growth, particularly if energy is used to displace other fuels in transportation and other uses. Therefore, attention should be placed on the primary fuel mix feeding the electric contribution and the fuel shifts necessary to eliminate natural gas totally and reduce oil burning by half. The alternatives for base load bulk power generation are coal, nuclear, and synthetic fuels. For all practical purposes only coal and nuclear remain available as major utility fuels within the 1990 time frame.^{2, 3, 8} Moreover, unlike fossil fuels, which have important uses as chemical raw materials, nuclear fuel is valuable only as an energy resource.

Conservation has a vital and undisputed role to play in relieving short-term and medium-term energy requirements, and its contribution is already a substantial one. Since 1973, energy savings estimated at 7 MBDOE below otherwise probable consumption, equivalent to nearly 15% of present energy consumption, have been realized through conservation and demand restraint. Nevertheless, with U.S. population expected to increase by 40 million by the end of the century and with the evident need to continue economic growth in the United States, energy growth, even though at considerably lower rate than in the past, appears unavoidable. Gains from conservation will also become more difficult to achieve as the most readily available opportunities are exploited. The requirements of energy security also strongly favor a transition in the supply mix from heavy dependence on oil to increased dependence on the most abundant domestic fuels, coal and nuclear. The traditionally higher growth rate of electric energy than overall energy demand is likely to continue, and may even be magnified by the substitutability of electric energy for gas and oil

in end uses based on developments such as the heat pump and the electric car.

An additional consideration is the relative merits of using coal and nuclear fuels for bulk power generation. Recent studies and testimony have supported opposite views; some conclude that coal fired plants have now become more cost-effective than their nuclear counterparts,^{9, 10} others document a lower incremental production cost* for nuclear power units than for coal-fired power plants.¹¹

The issue is a complex one. First, comparative advantages can only be conclusive if site-specific; studies relying on "composites"** are bound to be inaccurate and potentially misleading.⁹ The larger the aggregation, the smaller is the confidence interval for determining relative economic advantages.

Second, "composite studies" generally compare "nuclear composites" with "coal composites" including scrubbers. In the process they necessarily compare actual costs to cost estimates since the reliability, capital, and operations and maintenance costs of scrubbers are still under question for the nameplate plant capacities typically selected for their investigation.⁹ At any rate, the sample statistic for scrubbers is narrow at best when compared to the nuclear situation.

* Production costs are fuel cost plus operating and maintenance costs. For utilities, a power plant is "cut in" or "cut out" of service on the basis of whether its incremental generating costs compare favorably with the incremental generating costs of other units in the system. Incremental costs determinations can be made on a utility system, and site-specific basis only.

** Composites are generally national cross-sections of all installed plants in terms of plant location, size, cooling systems, and so forth.

Third, results are sensitive to such variables as load factors and fuel cycle. It has been shown recently that changing assumptions regarding plant capacity factors can have significant although not large impacts on the economics of the nuclear option (i.e., Reference 11). If capacity factors were increased from 70% to 80%, nuclear costs would decrease by 0.37 mills/KWh. Similarly, nuclear costs would increase by 0.50 mills/KWh for a capacity factor reduction of 70% to 60%. These estimates apply to existing nuclear units many of which were built at capital costs well below present levels. The effects of capacity factor changes would be considerably higher for new units.

Finally, the dramatic capital cost increases in the past ten years for both nuclear and coal power plants are the result of many factors of which added complexity and delay due to increased statutory and regulatory requirements are of considerable importance. In the process, however, nuclear power plants have been more affected than coal power units due to a comparatively higher capital-intensiveness and the compounding effects of construction lead times twice as long as for coal power plants on the average, although there is considerable evidence that delays in coal fired units are beginning to be comparable to those of nuclear plants.^{6, 9, 11} In 1979, interest charges and cost escalations during construction accompanying the longer lead times for nuclear units accounted for approximately 70% of the cost differences between coal and nuclear plant investments of comparable capacity.¹¹

In summary, the facts relating to investment costs and incremental production costs appear to justify the following observations in view of current utility fuel switching policies and requirements:

- The cost of electricity for both future nuclear and coal plants will be substantially higher due to regulation and escalation. Meaningful costs comparisons, however, can only be made on a utility system and site-specific basis.
- The cost of electricity generated from existing nuclear units is well below fossil-fired generation on the same utility system.

- On a site-specific, incremental basis, future nuclear electric generation is still cheaper than coal-based electric generation for most utility system situations, but coal-fired units become cheaper at sites offering special characteristics such as mine-mouth plant situations.
- Nuclear plant investment costs are higher but nuclear fuel costs are lower than comparable costs for coal-fired plants. Construction delays due to increased statutory and regulatory requirements correspondingly penalize nuclear plants vis-a-vis coal-fired plants.
- For the ten years to come, an orderly, cost effective utility fuel switch policy at the national level implies that coal and nuclear fuels be the primary sources of new baseload electricity. Neither nuclear nor coal alone can do the job in a cost-effective manner.
- However, just because nuclear and fossil-fired plants are economic, reliable, and commercially available, does not assure utility commitment for building the required additional capacity. Agreed, stable safety and environmental standards as well as a suitable financial climate are the prerequisites to coal and nuclear becoming dependable primary fuel supplies for the utility industry.

1.1.3 Nuclear Baseload Generation: Status and Potential Contribution to Bulk Power Generation and Oil Displacement

In 1979, seventy-one nuclear power plants provided close to 14% of the total (NERC) electric power generation with 0.48 trillion KWh.^{3, 4} This compares with 1.7 trillion KWh from coal-fired units, or 48% of the NERC total. Yet, installed coal-fired capacity is almost 7 times larger than installed nuclear capacity (350,000 and 53,700 MWe, respectively). Thus, in 1979, nuclear power units delivered almost twice as much electrical power than their coal-fired counterparts on a nameplate capacity basis.³ The above discrepancy stems in large part from 1978-1979 coal strikes and resulting impaired coal deliveries in 1979. This highlights the positive and dynamic interplay between nuclear and coal baseload systems, as well as the economic advantages (i.e., reliability, flexibility, risk

spreading) of relying on distinct, independent primary fuels for baseload power.

If the construction schedule for planned nuclear power plants could be maintained, nuclear energy could provide between 25% and 27% of the total NERC forecast power generation demand in 1990. This would correspond to 11% of total U.S. energy demand in 1990, as compared to 3.6% in 1979. Most of the new nuclear capacity planned to be in service by 1983 is in an advanced stage of construction, but about 60% of the capacity planned for the 1984-1988 period has not yet started.^{3, 4, 9}

For 1980, construction scheduling can be further characterized. There are currently 91 nuclear power plants under construction (with NRC construction permits but without operating licenses), totalling close to 100,000 MWe of additional capacity. Of these, 13 nuclear power plants are more than 80% completed (11,662 MWe representing about 22% of existing capacity); 19 nuclear power plants are over 40% completed (20,079 MWe capacity); 12 nuclear power plants are over 20% completed (13,400 MWe capacity); the balance of 47 power plants represents a rounded capacity of 55,000 MWe.^{3, 9, 13}

By the end of 1981, fifteen new nuclear power plants could be brought on line, if licenses are granted.¹² This would add 15,450 MWe of nameplate capacity, or one-third of the total estimated new requirement for the 1980-1981 period.³ To the extent that these units would otherwise have been oil-fired, a savings of 10 million barrels of oil would be saved annually for each 1000 MWe of nuclear capacity.

Existing nuclear generating capacity represents an investment of some \$80 billion (1980 dollars). Yet, the financial capability of most investor-owned and public utilities to construct new facilities is presently, and for some acutely, strained. Since the early 1970s when many utilities held favorable bond ratings, there has been a

steady general decline to the point where the common stock of many companies are now selling below book value. The net effect of the current financial posture is increased costs for financing capital projects, and substantial postponements in nuclear construction scheduling, with an adverse impact on the reliability and adequacy of the future bulk power supply system.^{3, 5, 13}

The present situation represents a slow, but chronic erosion of financial ratings and capabilities of the electric utility sector due to an increasingly complex and uncertain regulatory environment, and is not a mere transitory reverberation of the Three Mile Island Accident.*

On the other hand, the Three Mile Island Accident has temporarily, if marginally, affected the market for utility stocks. By mid-June 1979, utility stocks were just 1.5% below their March 29 level and only 1.3% below their level relative to Standard and Poors' industrial index at the time of the TMI accident, a very modest change given the looseness of the basic relationship between utility and stock prices. Also, by mid-June, the only imprint of the TMI accident on security values was moderately higher utility stock yields relative to corporate bond yields.^{13, 14}

* From a total of 4 statutory and regulatory requirements in 1969, the number of Nuclear Regulatory Guides and revisions of Guides plus Nuclear Regulatory Technical Branch Positions and revisions of Positions that must be factored into the design, construction and operation of nuclear power plants has increased to a cumulative total of 323 in 1978, not counting environmental requirements.^{5, 11}

Over the next 10-year period, the utility industry will require substantial financing to support the construction of both coal and nuclear power plants necessary to meet even the lowest projected load requirements.^{3, 11} As an example, a new generating unit to be installed in the mid-1980s is expected to cost approximately 3 to 4 times as much as a generating unit installed in the mid-1970s.^{3, 5} The electric utility industry's capital requirements for new facilities are estimated to average \$50 billion per year over the next decade, with roughly 50% going to nuclear installations.^{3, 14} This roughly doubles current capital requirements, and could necessitate overall outside financing of up to \$40 billion per year.^{3, 5, 14} This represents at least one-third of all corporate financing requirements, excluding financial and real estate institutions.

As a result, any policy decision aimed at streamlining the present regulatory system, and at resolving issues over the back end of the fuel cycle, would have significant impacts on the financing and economics of nuclear power plants. Given the present financial situation of utilities, and their current financing commitments for nuclear plant construction, any decision conducive to decreased project financing costs for utilities would benefit both nuclear and coal plant projects. Finally, structuring a viable solution for the back end of the fuel cycle would consolidate the coal-nuclear tandem. Because the coal system alone cannot physically provide the desired fuel policy results 10 years hence,^{2, 3, 4; 14} a strengthened nuclear alternative is mandatory to allow utility management to proceed and cost effectively allocate resources within this time frame.

On the other hand, the nuclear industry providing fuel support services to the utility sector is generally thriving -- nationally and internationally. While the U.S. nuclear service industry is tapping the "front end" of the U.S. and other markets, Europeans are now building an international business focusing on back-end fuel cycle services.¹⁵ Despite the halt of new developments in nuclear power plant projects in the U.S., the nuclear service business is expected to expand at a rate of 25% a year, with a \$120 million business base

in 1979.¹⁹ Similarly, the worldwide slowdown in construction is not affecting the newborn fuel cycle industry in Europe, which expects the turnover for back-end fuel cycle services to reach \$1.0 billion in 1985, and \$1.5 billion in 1988. Whereas the European position is to view the steady expansion of nuclear capacity as one of the major ways of preventing further unacceptable rises in oil imports and of ensuring supplies, European Community members are developing an international service that will make a sizeable contribution to financing their oil balance-of-payments deficits.^{14, 15, 16}

1.1.4 Possible Contributions of the Barnwell Plant to the Nuclear Power Option

Given the importance of nuclear power in the energy supply equation, the question then becomes: Are there uses for which Barnwell is needed in support of nuclear power? Two possible contributions suggest themselves: an expansion of the uranium resource base, and an option for Away-from-reactor (AFR) spent fuel storage.^{18, 19} This section will review the issues of domestic uranium adequacy and AFR storage needs. At this point, the assumption is that neither of these potential contributions is necessarily exclusive of the other.

The Adequacy of the Uranium Resource Base: The Background for Thermal Recycle and Breeder RD&D Decisions

It has been estimated that uranium and plutonium recycle could reduce future uranium requirements by as much as 33%, and commercial deployment of the breeder reactor could eventually almost eliminate demand for new uranium supply.¹⁹⁻²¹ The significance of these potential contributions is, of course, heavily dependent on their economic competitiveness. This competitiveness is, in turn, dependent on the costs of recycle and the breeder, on the one hand, and balance between uranium and enrichment costs, on the other. Current indications are that the economic benefits of plutonium recycle in LWRs at present

day uranium and enrichment costs are marginal, while breeder reactors are likely to become competitive only at uranium prices considerably above present levels. The cross-over prices at which breeders become competitive are dependent on assumptions of the differential between breeder and LWR capital costs. It has been estimated by DOE that for a 50% capital cost differential, the transition could occur as early as 2007 for high uranium costs and high nuclear power growth rates, but later than 2025 for intermediate costs and low growth rates.

In addition to plutonium recycle in LWRs and the breeder, other means are available to extend the uranium resource base. Among these are the development and deployment of more efficient converter reactors and the improvement in fuel utilization of current and future LWRs. Both INFCE and NASAP suggest that improvements in uranium utilization efficiency of the order of 15% should be achievable relatively easily, and that these could be applicable to existing LWRs. This uranium savings would also be accompanied by a reduction on the order of 30% in spent fuel arisings when the improvements are applied to all LWRs. Further improvements of an additional 15% may also be possible, but these would be more difficult to achieve, and not necessarily applicable to existing reactors. Advanced Isotope Separation (AIS) technologies by stripping the tails of the uranium enrichment plants, could further reduce uranium consumption rates by another 20%. AIS technologies, however, are unlikely to be deployed until the mid-1990s at the earliest.

Extension of the uranium resource base through improvement of LWR fuel utilization efficiency has obvious advantages over LWR Pu recycle from a nonproliferation viewpoint, and probably from an economic standpoint as well. At the same time, since the extension of resources through LWR reprocessing and recycle is to some extent an additive improvement. A resource incentive will still remain for recycle, which might or might not be economically justified.

Assuming reprocessing would begin in 1990 at the Barnwell plant, and capability will be added by 2010 to serve all domestic operating

LWRs, recycle could provide about ten years of added fuel.¹⁹ This might be valuable time if the U.S. had to rely on the nuclear option more heavily than currently projected; if supply capability were lower than currently speculated projections; if LWR improvements proved to be difficult to achieve; or if the commercialization of the breeder took longer than anticipated. In light of this, it is appropriate to weigh decision making and implementation lead times -- the time required from a decision on a large scale demonstration plant to operation of the first commercial unit -- against available evidence as to the existence of adequate and exploitable uranium resources.

The overall adequacy of the uranium resource base is, of course, not the only, or even necessarily the principal, consideration in each nation's assessment of its own energy security needs. Of particular importance is each nation's estimate of its access to such uranium resources as may be available. To the extent that resources are located outside of national control, countries will, in general, continue to see energy security advantages in maximizing the use of assured sources of supply through improvements in utilization efficiency, LWR recycle and the breeder. The desire to minimize foreign exchange expenditures also provides an incentive for efficiency in the use of imported fuel and maximum use of indigenous resources.

From a supply and demand balance standpoint, the U.S. is in a favorable position in comparison to other uranium consuming countries, insofar as it represents about 40% of world demand over the next 25 years or so, and has identified about one-third of the world reserves.²⁰⁻²¹ A clear distinction between uranium reserves* and

*Uranium reserves are the drill-delineated quantities of uranium that occur in known deposits of such grade, quantity, configuration, and depth that they can be recovered at, or less than, a specified cost with state-of-the-art mining and processing technologies.

potential uranium resources* should be made. Some agreement can be reached for pegging domestic uranium reserves at, or below, \$30/lb forward costs** at about 690,000 ST U₃O₈.^{21,22} There is, however, a wide spectrum of views as to the extent of the nation's potential resources.^{18, 19, 20} Before addressing the point of uranium resources adequacy, a brief review of the current state of knowledge about such resources is therefore in order. For example:

- The 1979 NASAP Draft Report states that there remains a wide divergence of opinion as to what future availability of uranium from domestic sources may be. The views range from prediction of adequacy of supply well into the next century to warnings of shortages well before the end of this century. There are three principal reasons for this uncertainty: (1) lack of differentiation between estimated resources "in the ground" and predictable supplies; (2) differences in degree, if any, to which practical constraints and uncertainty factors are taken into account; and (3) different and constantly changing perceptions of future uranium demand.¹⁸

* Uranium resources are estimates of the quantity of uranium believed to be present in deposits that are incompletely defined or undiscovered. Resources can only be potential and are divided into three categories in order of their decreasing reliability:

- "probable" resources are undiscovered deposits estimated as extensions of known deposits and new deposits within known geologic formations.
- "possible" resources are undiscovered deposits estimated for geologic settings elsewhere within productive geologic formations.
- "speculative" resources are undiscovered deposits estimated for geologic settings not previously within productive geologic formations.

**The costs used to assign the uranium reserves and resources in cost categories covering the range of current economic interest (e.g., \$15,300, and 50 per lb U₃O₈ are called "forward costs", in present dollars, that will be incurred in the production of a particular reserve/resource category when market (marginal costs) conditions will reach the cost level of that particular category.

- The Uranium Resource Group of the Committee on Nuclear and Alternative Energy Systems (CONAES), National Research Council (1978 report) concluded that the best estimate of domestic reserves at \$30 forward cost was in the range of 480,000 to 640,000 ST U₃O₈, that the best estimate of potential resources was 1.06 million ST U₃O₈, that reliance be limited to a reserve and resource total of 1.80 million ST U₃O₈, and that the probability that the real resource was less than 1.80 million ST U₃O₈ was 33%.²³ The Resource Group did acknowledge that the information base available for appraisal of domestic resources was inadequate for precise quantitative assessment. As a result, the report supported the view that only those uranium deposits considered technically "reserves" or "probable" additional "resources" should be taken as a basis for prudent planning, the cut off point being \$30/lb forward costs: "The availability of uranium ore at estimated forward costs of more than \$30/lb, is known with such little certainty that it cannot be used for planning."
- The 1979 Draft Report of the Committee on Nuclear and Alternative Energy Systems (CONAES) refers to CONAES' Uranium Resource Group Report,²⁸ but departs from the recommendations of its Uranium Resource Subpanel in extending the relevant basis of uranium deposits for planning purposes: "This Committee believes that estimates of 'reserves' and 'probable' additional resources at forward costs of up to \$50/lb are reliable enough to plan on; the quantity of uranium in these categories at this forward cost is about 2.4 million ST U₃O₈."²³
- In its "Generic Environmental Statement on the Use of Mixed-Oxide Fuel in LWRs" (GESMO, 1976), the Nuclear Regulatory Commission took a view that was not dissimilar to that of the NASAP Report and concluded that there are enough uranium resources minable at reasonable costs to last well into the next century, but acknowledged that this conclusion was based largely on supposition, unsupported by adequate hard data.²⁹
- An April 1977 Industry Survey²⁴ indicated that industry felt the 780,000 ST U₃O₈ reserve was a reasonably valid estimate for ore which has actually been delineated by drilling and, therefore, known to exist; industry emphasized the view that the probable potential estimates are largely educated judgment as to what might exist, since they had not been drill delineated, and that only actual exploratory drilling by the private sector would convert them to reserves; that views were mixed and without consensus as to DOE estimates of the

1.9 million ST U₃O₈ of possible-plus-speculative potential resources; industry felt that the domestic uranium resource base was equal to or greater than 1.8 million ST U₃O₈. The industry response came from 16 companies representing 70% of the domestic reserves and two-thirds of production.

Because of the large number of uncertainties in present knowledge, a systematic appraisal of domestic uranium resources is being conducted through the National Uranium Resource Evaluation (NURE) program. This effort is designed to lay an adequate foundation for future fuel cycle decisions and domestic utility planning.¹⁷ At this point in time, however, the present state of knowledge can be characterized as follows:

- the reliability of reserve and resource estimates decreases with forward cost;
- the under \$30 forward cost reserves estimate is estimated to be reliable to within 16%, based on a property by property subjective evaluation;
- the reliability of the \$30 to \$50 forward cost reserves considered reliable to within 20%.
- the reliability of the potential resource estimates is not known beyond the fact that they are less certain than the reserve estimates to which they correspond and upon which their estimation is subjectively and questionably based; and
- possible and speculative potential resource estimates, which represent about half of the reserve and resource total, are defined as "occurring in undiscovered or partly defined deposits."²⁵

Few data are available on the additional uranium resources that would become available at forward costs in excess of \$50 per pound. On the basis of some geological models, however, such resources could be large. Depending on costs of reprocessing, plutonium handling, and breeder construction, uranium well in excess of current prices could

be utilized in the LWR once-through cycle, before the break-even prices for the breeder or LWR recycle are reached.

In order to put U.S. uranium resource adequacy into perspective, it is, therefore, appropriate to consider it in its institutional context. The utility industry, the mining industry, and government will each have different general and specific views as to uranium resource adequacy, depending upon respective responsibilities and objectives. For example:

Utility Companies individually seek to be assured of supplies of natural uranium at reasonable cost to support operating, committed, and planned nuclear units throughout their projected operating lifetime, even though contractual commitment may only be entered into for some portion of projected lifetime.²⁰

U.S. currently estimated reserves at up to \$30 forward cost may support 124 GWe of nuclear power for 30 years; this assumes a 1 GWe requirement of 5,000 ST U₃O₈ for 30 years and a uranium mill average recovery factor of 90%.²⁰

U.S. reserves and probable potential resources at up to \$30 forward cost may support about 300 GWe for 30 years.²⁰

U.S. reserves and probable potential resources (if real) at up to \$50 forward cost could support about 400 GWe for 30 years.^{20, 23}

In view of current nuclear power plant commitments through 1990, the issues of uranium resource reliability and economics, as well as the long lead times required to find and develop resources, the utility industry may not perceive that the uranium reserve and reasonably assured resource base is adequate.

Mining Companies individually seek to find and exploit uranium ore reserves through contracted arrangements within minimum risk time frames in order to obtain at least a reasonable return on investment;

the supply industry is concerned with delineating ore reserves in the current and near-term sense as opposed to reserves and resources that might someday become ore reserves. Under current market conditions only about 400,000 ST U₃O₈ may qualify as U.S. ore reserves; this base would sustain about 70 GWe of nuclear capacity for 30 years or alternately would meet currently projected requirements through about 1991.^{20, 21}

Except to the extent that either long-term contracts are entered into or specific discoveries are made, the mining industry does not as a policy seek to establish reserves and resources over long-term horizons, since such a policy would not be commercially sound. The mining industry would likely take a conservative and pragmatic view of world resource adequacy and perceive that, from an investment standpoint, while resources currently appear as adequate, they will not remain so for very long in view of the projected contractual demand.

The U.S. Government is currently seeking to estimate the extent of uranium reserves and resources based on the best available information usually input by the private sector, in order to implement policies perceived to be in accord with the national interest. The disparate views about U.S. uranium resources presented earlier in this section highlight the paradoxical fact that though programs such as NURE can be initiated and accelerated in order to aid in expanding the national uranium resource base, concurrent national-level options are being delineated on the basis of still intuitive estimates. However, domestic uranium resources are adequate only if they meet established and forecast requirements until such time as assured alternative energy sources become available. For example, if the demonstration lead time for alternative sources is projected as 20 years, and a further 20 years of commercial substitution time is assumed, then the uranium resource base is adequate only if it will sustain conventional nuclear plants through the various contingency demands of the next 40 to 50 years.¹⁹⁻²¹

The significance of these data for the time schedule on which breeders may be required is subject to varying interpretations and a number of possible models have been studied by the DOE and others. In its report entitled "Nuclear Strategy of the Department of Energy," (February 15, 1979) DOE has considered two models:

- The "finite ore" model, in which a fixed and finite amount of uranium is assumed to be available up to a stated cost, with no additional amount available at costs above this level.
- The "economics" model, in which uranium is assumed to become available in increasing quantities with increasing price.

Clearly, each of these models may have many subcases, in which differing uranium ore bases or differing price-availability relationships are assumed. In general, the finite model is more conservative, and tends to result in earlier dates for assumed breeder need. In addition to its dependence on the resource base, the timing of breeder need for this model is dependent on the growth of nuclear generating capacity, the relative costs of operation in breeders and LWRs, and uranium utilization efficiency. A graphical depiction of the lifetime uranium requirements of unimproved LWRs based on DOE's mid-case projections of October 1979 is shown in Figure 1-1. This figure also illustrates, for convenience, estimated domestic uranium reserves and probable resources on the basis of several assumptions.

DOE has estimated that if the resource base is only 1.8 million tons (close to the current estimate of \$30 reserves and probable resources) the breeder could be required as early as 2000, but that if the ore base is 3.6 million tons, breeder introduction could be delayed until 2010-2030, dependent on LWR growth rate and efficiency. For this case, LWR improvements would delay breeder introduction a further 5 to 7 years.

In the "economics" model, which assumes increasing uranium price with increased consumption, the date of breeder need is heavily dependent

FIGURE 1-1: Ideal and Optimistic 1980 Projections (Assuming 100% Exploitation of DOE's January 1979 Uranium Reserves and Probable Resources Estimates) of Possible U_3O_8 Supply Capability for DOE/EIA's Mid-Case Nuclear Capacity Projections (as of October 1979).*

REFERENCES: [21, 22, 26, 28]

* DOE-RA Long-Range Assessment Program Series C and Mid-Range Energy Marketing Model Estimates for Low Capacity Projections After Year 2000.

** A larger resource base assumption would yield the following:

- \$50 reserves (proven) and probable resources (unproven), and possible resources (unproven), could amount to 3.6×10^6 ST U_3O_8 and support over 700 GWe;
- \$50 reserves (proven) and probable resources (unproven), and possible resources (unproven), and speculative resources (unproven) could amount to 4.1×10^6 ST U_3O_8 and support over 800 GWe.

on the relative costs of breeders and LWRs. DOE has estimated that for a breeder/LWR cost factor of 1.25, the breeder could become economic as early as 1997, or as late as 2025, dependent on uranium cost and nuclear growth rate.²⁵ For a capital cost ratio of 1.50, the corresponding transition dates would occur in 2007 and beyond 2025. For a capital cost ratio of 1.75, there is virtually no set of assumptions of uranium supply and nuclear power growth that would lead to an economic transition date earlier than 2025.

The DOE study notes that the majority of cases in the economics model, transition dates occur after 2025, but there are a number of significant situations in which the transitions would be advantageous between 2010 and 2025. Similar conclusions were reached in the NASAP study.

The wide variations in the required dates for breeder introduction reflected in these estimates, and the fact that they are dependent on assumptions in which there is large inherent uncertainty has led to a broad consensus that the prudent strategy is one that involves development of the breeder option, with a deferral of any decision to deploy breeders until the various factors that affect breeder timing are known with greater certainty. However, because of present uncertainties, there is considerable disagreement on the pace and extent of the breeder development effort that is required or desirable. DOE's conclusion is that:

A strategy to delay the decision to build a breeder demonstration reactor is the most consistent with the largest space of future events analyzed in this study. However, because of the number of situations wherein a breeder would be needed between 2010 and 2025, it is prudent to pursue a strategy that continues extensive development of breeder design and components. Strategies to move forward rapidly with breeder development are not supported by this analysis.

On the other hand, the private nuclear community generally supports a more aggressive breeder development program, including the completion of the Clinch River Breeder Reactor (CRBR) or at least an early decision

to proceed with a breeder demonstration. This view is reflected in the following conclusions of the CONAES study, Energy in Transition 1985- 2010, conducted in response to a U.S. ERDA request of 1976, by a Committee of the National Academies of Science and Engineering:

- The growth of conventional nuclear power (today's light water reactors) will be limited by the producibility of domestic uranium resources. With today's once-through fuel cycle and no change in the prevailing policy against reprocessing, a maximum nuclear capacity of about 400 GWe could be reached. This contribution could be extended to about 600 GWe with reprocessing of fuel in light water reactors....
- Several different breeder reactors could serve in principle as candidates for an indefinitely sustainable source of energy. Only the liquid-metal fast breeder reactor could be built and operated by the year 2000.
- For this reason, the CONAES Committee recommends continued development of the LMFBR, so that it can be deployed early in the next century if necessary.

The differing views on the urgency and, thus, the nature of the breeder reactor development program reflect both differences in assumptions and differing levels of optimism or conservatism on a variety of factors, such as the rate of which even proven uranium resources can be produced and the time at which various developmental steps must take place in order to have an assured breeder option by any specific time. In general, the private sector places high importance on the need for large scale prototypes and full-scale demonstration units, a view that has generally been adopted by other countries actively engaged in breeder development. Utility industry concerns over the adequacy of uranium resource base are reflected in the following views of the Edison Electric Institute:

- Prudent judgments made on the future availability of uranium by utility managers in committing to billion dollar nuclear power plants will undoubtedly differ from the judgments made by persons not responsible for such major financial commitments.

- The projection of a plentiful resource base is of little comfort. What is more important is whether the uranium will, in fact, be produced at a reasonable price over the lifetime of the plant. Once a utility has committed to a billion dollar plant, it effectively becomes a captive buyer of uranium, even if the price were to reach hundreds of dollars per pound.
- Much of the available reserves may never reach the market place. Among the inhibiting factors are: (1) Indian tribal claims or ownership affect at least half of the uranium bearing lands in the U.S., and could reduce commercial access to ore reserves; and (2) Licensing delays and high capital costs associated with increasingly stringent environmental requirements will make some reserves uneconomical or impossible to mine.

Given foreseeable technical, economic, and social constraints put on the exploitation of domestic uranium resources, both industry and the scientific community expect the future uranium demand/supply situation to remain tight logistically.^{18, 20, 22, 23, 27}

The Breeder Option and Reprocessing Requirements

Breeder research, development, and demonstration will require plutonium as well as suitable technology for plutonium recovery from breeder fuel:

- Breeder development and demonstration require substantial amounts of plutonium, for which a number of supply options are possible. These include LWR fuel reprocessing, recovery from existing or future breeder research and development projects, such as the fast-flux test facility (FFTF) and the zero power prototype reactor (ZPPR), reprocessing of production reactor (including N reactor) fuel, withdrawal from weapons stockpile, or procurement from abroad.
- Unlike the case of LWRs, where reprocessing is optional, and a commercial reactor capability could be and, in fact, was created without a corresponding reprocessing capability, reprocessing is an integral part of LMFBR technology. Accordingly, a decision to commercialize the LMFBR cannot be made in the absence of knowledge that a viable industrial reprocessing

technology is available. This requires development and demonstration for reprocessing of LMFBR fuels on a schedule commensurate with that of the reactor technology itself.

While there is a range of views on the development and demonstration lead-times required before a commercially viable LMFBR option can be said to exist, there is agreement that this lead-time is very long and is measured in decades. DOE, for example, in the study cited earlier, considers alternate breeder development periods of 26 and 36 years from decision date of the first demonstration plant to operation of the first commercial breeder. These two cases are considered to bound the realistic time frames for breeder development and demonstration, with the latter including a full-scale commercial prototype. The desired date of breeder introduction and the development time schedule determine when a decision on construction of a breeder demonstration plant should be made. For cases which result in a breeder introduction need by 2010 or earlier, development and demonstration on the shorter time scale would be called for. For later dates of introduction, a more extended development schedule, with correspondingly reduced technological risk, would be possible.

The time at which a breeder demonstration plant is required is of direct relevance in determining the timing of the requirement for substantial quantities of plutonium, and of at least indirect relevance in determining the desirable schedule for the development and demonstration of a reprocessing capability that is suitable in terms of safety, costs, reliability, and licensability for use in the civilian LMFBR power industry, without implication as to whether the reprocessing facilities would be privately or publicly owned or operated.

A full scale (1000 MWe) demonstration breeder reactor is estimated to require an initial fuel investment of 5.5 metric tons (MT) of plutonium and up to twice that amount before recovery begins to reduce the net requirements. According to DOE, there are presently 3.5 MT of separated plutonium available for civilian use and not already in

such use. However, this quantity of material will be absorbed by the requirements of the Fast Flux Test Facility (FFTF) by about 1991. Other estimates of plutonium availability for breeder R&D, including the estimate of 11 MT provided to INFCE, include quantities already in use, such as the 4 MT in ZPPR and 3 MT allocated to the needs of the FFTF up to 1984. Some portion of this material could conceivably be made available for higher priority breeder R&D programs, including a demonstration plant. To meet prudent schedules, plutonium for a breeder demonstration should be available about 3 1/2 years before operation or about 3-4 years following the decision to proceed with the demonstration.

While tonnage quantities of plutonium for a breeder demonstration reactor are clearly required if such a reactor is to be built, full operation of a plant as large as BNFP for this purpose would lead to the production of larger quantities of plutonium than would be required for several years until initiation of a sizeable breeder deployment effort. This plutonium surplus could be avoided by reduced operation of a reprocessing plant of the capacity of BNFP, but at a substantial penalty in unit separation cost. Alternatives to reduced operation would include storage of surplus plutonium or recycle of surplus in LWRs, with its attendant undesirable nonproliferation implications. Alternative sources of supply for the plutonium that would be required for a breeder demonstration were noted on page 31.

Activation of a full-scale reprocessing plant on the schedule required to meet demonstration reactor plutonium requirements, preceded by design, construction, and testing would afford a demonstration of reprocessing technology concurrent with similar demonstration of the breeder technology itself. This reprocessing experience would, of course, have to be supplemented by the development and demonstration of the modifications necessary to handle breeder reactor fuel of considerably higher plutonium and fission product concentration than the LWR fuel initially processed. The planned Hot Engineering Facility at the Oak Ridge National Laboratory is designed to fulfill this need.

LWR Recycle

Recycle of LWR fuel can reduce uranium requirements by some 30%, extending uranium reserves by about 10 years under feasible assumptions as to nuclear power capacity and growth. However, LWR recycle has marginal, if any, economic benefits under current economic conditions. In the U.S. government's view, this resource extension could only be of importance if improvements in the LWR fuel cycle and other factors extending the availability of uranium resources were not able to sustain economic operation of LWR's on a once-through basis. Thus, timely breeder development and demonstration can reduce incentives for LWR Pu recycle.

At the same time, LWR Pu recycle, is viewed by some as a useful stage in developing assured availability of a commercially viable mixed oxide (MOX) fuel fabrication technology and capability. While LWR and breeder MOX fuel element composition and configuration differ substantially, the basic LWR MOX fuel technology and experience would have relevance to technology for the fabrication of breeder fuel. However, this technology can also be developed in the course of breeder research and development and demonstration programs.

Barnwell and the AFR Spent Fuel Storage Situation

The potential contribution of Barnwell as an AFR for spent fuel storage requires fewer planning assumptions than in the case of uranium resource adequacy. There is general agreement for placing the need for an AFR in the near term, possibly the early part of the 1980s.

The magnitude of storage requirements, however, is the major uncertainty. Since February 1979, five reports and updates have been published all presenting different estimates for the U.S.^{18, 28, 31} The reasons for such differences are manifold. AFR storage requirements are influenced by such factors as plans for onsite storage capacity

expansion, transshipment of spent fuel between reactors, and management optimization schemes for maintaining full core reserve in the storage pools.

Depending upon the assumptions made on utility actions and NRC approvals, a reasonable range of AFR requirements can, however, be defined. Based on DOE's completed May 1979 update of utilities' requirement estimates, and on the following assumptions, early AFR requirements can be estimated:

- Upper bound estimates assumption: only May 1979 utility plans for reracking and transshipment are approved and carried out.
- Planning base estimate assumption: maximum pool reracking with only transshipments planned by utilities as of May 1979.
- Lower bound estimate assumption: maximum fuel pool reracking and one transshipment of fuel within a utility system whenever possible.³¹

The above assumptions lead to the following range requirements for 1983, with full core reserve maintained at reactor sites and reactor capacity factor of 70%:

- Upper bound: 620 MTU of cumulative U.S. fuel AFR requirements.
- Planning base: 380 MTU of cumulative U.S. fuel AFR requirements.
- Lower bound: 170 MTU of cumulative U.S. fuel AFR requirements.³¹

Figure 1-2 compares DOE's latest AFR requirement estimates for 1983, 1985, 1990, and 1993-1995, respectively, with previous estimates made by GAO and NRC.^{28, 31} DOE's latest base case for planning purposes,³¹

FIGURE 1-2: Comparison of Latest AFR Requirement Estimates

* Base Case

** DOE 1980 Base Case with international fuel (DOE/ET foreign estimate)

REFERENCES: [19, 30, 31, 32, 33]

differs from previous estimates: First, the current base case assumes maximum reracking of the reactor basins and no transshipment between reactor basins, unless specifically stated. Previous estimates assumed reracking according to utility plans and transshipment between reactors in the same utility system.^{28, 30} The latest DOE and GAO assumptions more correctly reflect the data from the utilities and the current regulatory and institutional climate.^{29, 31}

Second, some utilities have changed their reracking plans since last year to avoid transshipment.^{29, 31} However, since the current base case assumes maximum reracking at each reactor, changes in reracking plans by the utilities should not cause significant changes in the base case projections presented.

Figure 1-3 is taken from DOE's latest update,³¹ and presents the amount of spent fuel discharged by U.S. reactors and the amount that could be stored under various options. Reactor growth assumptions are based on DOE-EIA's July 1979 median growth projections.²⁶ Curve I shows the total cumulative amount of U.S. fuel discharged. Curve II represents the storage that is possible with maximum reracking. Curve III is the amount of storage available if the utilities rerack according to their current plans. Curve IV represents the existing basin storage capacity. The areas between Curve I and each of the respective lines is the amount of fuel that would have to be shipped off site. DOE has assumed maximum reracking within existing AR storage capacity (Curve IV) for its planning base estimate.³¹

Thus, under ideal conditions where utilities could actually rerack to a maximum within existing AR capacity, a spent fuel discharge/storage imbalance could start as early as 1983. The actual magnitude of the imbalance would depend on the ability of the utility sector to carry out its plans on a timely basis. Under such conditions, the potential, upper-limit contribution of the existing Barnwell plant (e.g., possible 2,350 MTU AFR capacity with double-tier densification and new racking system) could be filled up with U.S. fuel by 1990 under the base case plan.³¹ If the Barnwell plant were to be expanded to

FIGURE 1-3: Comparison of Requirements and Fuel Stored at Reactors

ASSUMPTIONS: . All cases at 70% reactor capacity factor
 . Full core reserve maintained
 . Nuclear power growth; DOE/EIA July 1979 median estimate (latest available)

REFERENCE: [32]

5,000 MTU, the new AFR basins could be filled by 1995 with U.S. fuel only.

The storage of foreign spent fuel represents another potential use of BNFP as an AFR storage site. Reactors in several foreign countries have already experienced exhaustion of onsite storage capacity, after allowance for the full-core reserve policy followed in most countries, and U.S. approval has been given for transfer of U.S.-origin fuel to reprocessing sites in the United Kingdom and France for this reason. However, reracking programs in most of the countries where these storage limitations have been reached are proceeding (Germany is an exception due to licensing obstacles to reracking), and the resulting new storage capacity will, in general, probably extend the date AFR storage will be needed abroad to about the same time as in the U.S.

U.S. policy provides for the storage of limited amounts of foreign spent fuel in the U.S. when this will support U.S. nonproliferation policy objectives. This policy, however, has not to date been implemented, and provisions of the Nuclear Non-Proliferation Act of 1978 (NNPA), as well as the DOE Authorization Act of 1978, require submission of any plan for the storage of foreign power reactor spent fuel in the U.S. to the Congress for review, except in case of emergency entry.

Given the policy and statutory restraints on U.S. storage of foreign spent fuel, storage of significant amounts of this material at BNFP or elsewhere in the U.S. appears unlikely, and the amounts involved, if any, would thus have only a small impact on the BNFP storage potential for U.S. spent fuel outlined above. However, even limited storage of foreign spent fuel could have important policy implications that are described in later sections of this report.

1.2 NON-PROLIFERATION

1.2.1 General

Major changes have occurred in the nonproliferation environment since issuance of the first Barnwell Applicability Study in April 1978. These changes have involved both the evolution and detailed application of U.S. nonproliferation policy, although not its basic thrust and objectives, and the policies of other nations, particularly in terms of their relationship to U.S. policy. The changes include major events that while they do not in themselves define the nonproliferation environment, have been important milestones in the ongoing process of further defining nonproliferation policy and, thus, provide a convenient framework for examining this environment. Principal among these events are the passage, in March 1978, of the Nuclear Non-Proliferation Act of 1978 (after the preparation and essentially concurrent with the issuance of the first Barnwell report); the issuance, in January 1980, of the report of the Nonproliferation Alternative Systems Assessment Program (NASAP), and the completion in February 1980 of the International Nuclear Fuel Cycle Evaluation (INFCE).

Additionally, both the occurrence and the absence of events that help gauge the extent to which proliferation or trends toward proliferation are taking place must be noted. In a positive vein, since 1978 there has been no further definitive change in the number of countries which have demonstrated a nuclear explosive capability, although there is suspicion that a nuclear explosion of unexplained origin took place in the southern hemisphere, and no additional countries have embarked upon nuclear power fuel cycle activities that would significantly enhance their capability for acquiring nuclear explosive material. Moreover, the expected acquisition by one country -- Pakistan -- of a civilian spent fuel reprocessing facility has been greatly delayed if not reversed by the decision of the supplier

not to proceed with the supply and erection of the plant, a development of uncertain effects in view of the efforts of Pakistan to construct a centrifuge development plant. Nuclear power activities have slowed world-wide. While this slow down has been largely a consequence of economic and environmental considerations, it has included the deferral of some sensitive activities and thus has considerable relevance to the nonproliferation environment.

On the other hand, disturbing events have taken place. Satellite evidence of a possible atmospheric nuclear explosion in the South Indian Ocean raises at the least the possibility that an additional nation has tested a nuclear explosive. Any evaluation of this evidence is beyond the scope of this report, and its significance for the issue of nuclear power fuel reprocessing, if any, remains unclear. The suggested explanations, however, do not include any indication that safeguarded materials or facilities supposedly dedicated to the civil nuclear power fuel cycle have been abused.

Another important development has been the disclosure that the same country planning to acquire a spent fuel reprocessing plant -- Pakistan -- may be engaged in an effort to build a covert enrichment plant, making use of information and equipment obtained from other countries without notice of its intended use. Iraq has continued with its plans to acquire a large research reactor, with at least its original core consisting of highly enriched uranium. Argentina plans to construct an additional heavy water moderated power reactor and a heavy water production plant while refusing to accept full-scope safeguards.

These and other developments are described and discussed in the remainder of this section, with particular attention to their relationship to the nonproliferation implications of possible Barnwell use and institutional options. Of paramount importance from the standpoint of this study is the relevance of these developments to and

their impact on the principle that U.S. nuclear power programs, particularly U.S. involvement in sensitive activities, may affect the course of these developments elsewhere in the world.

The issue is a complex one, on which definitive conclusions can not be easily reached. Many in the U.S. believe that notwithstanding the continuation of reprocessing programs by other nations, there is an important distinction between the existence of such programs and their endorsement through the conduct of similar activities in the U.S. Others place greater emphasis on the factual situation, and view the continuation of foreign reprocessing programs as an indication of the lack of success of U.S. policy.

The definition of U.S. policy is in itself a complex task. While some feel that it has changed considerably since the first announcements of the present policy in April 1977, others believe that the policy was misunderstood originally, and that such changes as have occurred are largely of an evolutionary nature.

1.2.2 Nuclear Non-Proliferation Act of 1978 (NNPA)

The NNPA contains several provisions directly applicable to reprocessing and thus is clearly relevant to any consideration of BNFP use and institutional options. These provisions include:

1. A requirement for a U.S. right of approval over reprocessing of U.S.-supplied nuclear fuel as a condition of the export of such material. (Section 305)
2. A requirement that the U.S. seek in renegotiating agreements for cooperation a broader right of approval of reprocessing, which would extend to material irradiated in U.S.-supplied reactors, or through the use of U.S.-supplied equipment or materials, as well as U.S.-supplied fuel itself. (Section 401)

3. A requirement that the U.S. discontinue peaceful nuclear cooperation with any country which hereafter supplies or accepts a reprocessing facility (but not, apparently, a country that develops and installs such a facility through its own efforts) unless the transfers occurs under an international arrangement supported by the U.S. (Section 307)
4. A requirement that, two years after enactment (i.e., by March 1980) the U.S. may export nuclear materials or equipment only to countries in which all peaceful nuclear facilities and materials are under IAEA safeguards. (Section 306)
5. Of particular importance, the establishment of criteria to govern U.S. approval of reprocessing by other countries, including a finding that such reprocessing would not significantly increase the risk of proliferation, and the requirement that, in reaching this determination, "foremost" consideration be given to whether there would be "timely warning" of any diversion before transformation of diverted material to a nuclear explosive device. (Section 303)
6. A provision calling for U.S. action to help strengthen IAEA safeguards, including those applicable to the possible diversion of weapons useable material. (Section 201)
7. Several provisions which call on the U.S. to seek limitation of reprocessing to facilities "under effective international auspices and inspection" including the placement of existing facilities under such auspices. (Section 403)
8. Despite the numerous restrictions on reprocessing reflected in the above points, an affirmation that the Act is not intended to prohibit permanently or unconditionally reprocessing of U.S.-supplied material or material otherwise coming under U.S. reprocessing approval, to limit the consideration

by INFCE of reprocessing, or to prejudice open and objective consideration of the results of INFCE. (Section 303)

The provisions of the NNPA relating to reprocessing identified above are, of course, cited in simplified, non-statutory language and are in reality much more complex than indicated. In particular, many of the restrictive provisions and criteria of the NNPA include authority for their waiver by the President under appropriate circumstances, usually coupled with an opportunity for Congressional review and override of any such waiver.

The complexity of the NNPA, including its provisions relating to reprocessing, and its legislative history make it difficult to summarize the Act's impact on overall U.S. reprocessing policy.

1. The Act restricts, but does not prohibit, reprocessing abroad of materials subject to U.S. reprocessing approval rights, and a number of requests by foreign governments for reprocessing approval have been approved. A general prohibition of reprocessing is explicitly rejected.
2. Reprocessing is deemed acceptable only when it does not result in a significant increase of the risk of proliferation beyond that present in the absence of reprocessing.
3. The strong emphasis given the criterion of "timely warning" constitutes an expression of preference for reprocessing technologies or modes which avoid the separation of pure plutonium.
4. When reprocessing does occur, the Act expresses strong preference for its performance "under effective international auspices." Although not explicitly defined in the Act or its legislative history, it is clear that this term means a degree of international or multinational control of sensitive materials which extends beyond safeguards.

An area of particular importance in the evaluation of U.S. nonproliferation policy has involved the administration of the provisions of the NNPA governing the exercise of U.S. approval rights over reprocessing. This activity involves both the provisions of the NNPA itself and Executive Branch policy relating to such approvals, the requirement for which was present in Agreements for Cooperation long before passage of the NNPA. Because those aspects relating to Administration policy have been of greater significance in defining the current nonproliferation policy environment, the subject of U.S. reprocessing approvals will be discussed in the section on U.S. Policy, Section 1.2.5.

1.2.3 INFCE

While it is difficult to isolate the impact of INFCE itself from the respective policies of its participants, including the United States, it seems clear that INFCE has played a significant role in affecting the nonproliferation environment since its inception in October 1977. In a pragmatic sense, its very existence has, as intended, afforded a period during which participating countries could continue cooperation under existing arrangements, while examining the merits of alternative policies without prejudice to their current individual policies.

At the same time, while INFCE has not been a negotiation, there is evidence that it has led to some convergence of national policies that at the time of issuance of the first Barnwell report, appeared still to be far apart. This consequence has considerable relevance to reprocessing and, thus, potentially to use and institutional options for the BNFP. It includes, for example, as reflected in the statement of the U.S. representative to the IAEA at the IAEA General Conference of December 1979, a growing recognition that... "Since INFCE apparently will not foreshadow major technical fixes, we should press for institutional measures to provide both greater supply and nonproliferation assurance. Indeed, such an evolution is contemplated by U.S. law and policy."

One INFCE finding of major importance to reprocessing was the conclusion that the uranium industry would be able to achieve supply levels adequate to support even the once-through fuel cycle, at INFCE's lower reactor growth projections, through 2025, but that it could not meet post-2000 requirements for the once-through cycle and some recycle strategies at INFCE's high growth projections. Another INFCE conclusion of importance was that the economic advantage of LWR plutonium recycle is likely to be relatively marginal. INFCE also concluded that economies of scale favor reprocessing in a small number of large facilities. At the same time, INFCE reaffirms the importance of the LMFBR as a means of assuring the adequacy of nuclear fuel supply, and concluded that its proliferation risks are not unacceptable.

INFCE also concluded that given the evolutionary nature of safeguards and institutional improvements, no single judgment about the risk of diversion from the different fuel cycles can be made that is valid both now and for the future. The decline in radioactivity of spent fuel over time also makes this material an increasingly attractive target for diversion. On the other hand, INFCE notes: "Once such [spent] fuel were reprocessed, and separated plutonium used on a large scale, these physical barriers [radiation from spent fuel] would to a large extent disappear...." Thus, INFCE concluded that the relative proliferation risks of reprocessing and once-through fuel cycles with spent fuel storage are not fixed, but change over time.

A prominent characteristic of INFCE is the highly qualified nature of virtually all of its findings and conclusions. Accordingly, the significance of these conclusions and the degree of consensus that they represent have important limitations.

While not carried out directly under INFCE auspices, the overall INFCE process has also included an intensifying international dialogue conducted principally through IAEA Expert Groups on both international storage of plutonium and international management of spent

fuel. International support has grown for the implementation of the IAEA's authority, under Article XII.A.5 of the Statute, to act as a depository of plutonium in excess of current programmatic needs.

While the establishment of international depositories for plutonium is seen by some as presenting risks of giving premature encouragement to reprocessing, U.S. policy now encompasses active participation in the IAEA's examination of international storage, in recognition of the need to establish effective international controls over excess plutonium already in existence or produced in the future.

Discussions on international spent fuel management are at an earlier stage, but are also experiencing greater international support than had earlier seemed likely. In one respect, these discussions parallel those on international plutonium storage; they reflect an acknowledgement that, regardless of the course of nonproliferation policy, or fuel cycle developments, just as considerable amounts of separated plutonium continue to be accumulated, so will large amounts of spent fuel be accumulated. However, interest in international or multinational spent fuel storage as either a nonproliferation measure or a practical solution to growing spent fuel inventories continues to be limited. Instead, the focus of international discussions to date has been principally on ways in which the countries can, either individually or collectively, be of help to each other in alleviating the spent fuel storage problem.

The future course of this discussion will depend heavily on U.S. initiatives and could have a significant impact on the assessment of Barnwell use and institutional options.

1.2.4 Policies and Programs of Other Countries

Although the changes in nonproliferation policies and programs of other countries since issuance of the 1978 BNFP report⁴¹ have, in general, not been dramatic, several trends of importance have been evident, and several specific events of significance have occurred.

While the Pakistan situation has characteristics that set it somewhat apart from general nonproliferation trends, the possibility that events there will influence policies elsewhere cannot be ignored. The decision by France to refrain from further implementation of the arrangement to supply Pakistan with reprocessing know-how and hardware represents a reaffirmation and extension of French policy not to engage for the time being in the supply of this technology. At present, no countries with the capability of supplying reprocessing technology or equipment appear to be prepared to enter into new arrangements to do so.

The reported effort by Pakistan to build a centrifuge enrichment plant has important nonproliferation implications. It reflects once again the sensitivity of technologies that can produce weapons useable material, and the possibility that their acquisition will be justified on the basis of a civil nuclear power requirement, as Pakistan has reportedly sought to do in the present case. On the other hand, Pakistan's reported efforts, in the opinion of some, lend support to the view that small, dedicated non-commercial facilities represent a more likely route to explosive material manufacture than do commercial fuel cycle facilities.

There is no evidence that the denial to Pakistan of safeguarded reprocessing facilities led to its reported efforts to secure enrichment technology on an unsafeguarded basis. On the contrary, the efforts were apparently undertaken in parallel and long preceded the termination of the reprocessing arrangement.

At the time of issuance of the 1978 BNFP report, active reprocessing programs were underway in four industrialized countries: the United Kingdom; France; Japan; and the Federal Republic of Germany. Shortly before that time, the U.K. intent to construct a large uranium oxide fuel reprocessing plant for both U.K. and third-country fuels had been reaffirmed following a public inquiry that concluded the program should go forward. France's program to continue and expand its reprocessing activities has also gone forward without change.

In Japan, the U.S.-Japan agreement allowing limited operation of the Tokai-Mura pilot reprocessing plant on spent fuel of U.S. origin has remained in effect, as a result of an extension to April 30, 1980. This extension reflects both a recognition of the fact that the plant has been operable for only a short period of time during the original agreement, and a mutual desire to postpone a substantive review of the issues pending the conclusion of INFCE.

Additionally, Japan has recently adopted legislation authorizing private participation in reprocessing, and a company to undertake the construction and operation of a privately-owned, commercial reprocessing plant, to be in operation by the 1990s, has been formed. While no site has been announced and no actual construction activities have begun or are anticipated for some time, the step constitutes confirmation of Japanese plans to proceed with reprocessing. Japan has also indicated its willingness to study with the U.S. the feasibility of spent fuel storage in the Pacific Basin.

In the Federal Republic of Germany, a somewhat opposite development has occurred, with deferral until the mid-1980s of a decision on whether to proceed with a large-scale reprocessing plant and waste disposal facility at Gorleben. As a corollary, a decision has been adopted to employ interim storage of spent fuel in AFRs as an acceptable means of managing spent fuel for some time to come. While these decisions were apparently based primarily on political considerations and local opposition to the construction of the reprocessing plant and waste disposal facility, the effect is nevertheless to confirm interim spent fuel storage as an acceptable alternative to early reprocessing for management of high level wastes. It also tends to support other indications that plutonium recycle in LWRs provides little or no economic benefit, although political considerations were paramount in the German decision to defer.

While Sweden has had no plans for national reprocessing, a somewhat similar development has occurred with respect to waste management. Earlier Swedish emphasis on reprocessing as the preferred approach to

high level waste management has been replaced by a readiness to accept interim storage of spent fuel, and Sweden is further advanced than any nation toward the establishment of a national AFR. In Belgium, plans to proceed with reactivation of the former Eurochemic pilot reprocessing plant on a national basis, are still in effect, but have moved more slowly than earlier anticipated. Brazil's plans to install a small reprocessing plant of German design also remain in effect.

The developments outlined above indicate that reprocessing activities underway or planned at the time of the 1978 BNFP report are still generally proceeding (with the German plans for Gorleben a notable exception), although the pace of these activities has to some extent slowed. Additionally, an important qualitative change has occurred, with support for and interest in plutonium recycle substantially reduced, and reprocessing increasingly viewed as an adjunct of breeder reactor development and demonstration rather than a necessary near-term step toward acceptable management of high level waste. This evolution in views is reflected in the important case of Japan in a recent privately sponsored study of U.S.-Japan nuclear cooperation that states: "...a reasonable compromise of the reprocessing issue would be to agree now that reprocessing would occur as an integral part of breeder reactor research, development and demonstration...a decision on commercial plutonium recycle in light water reactors would be deferred...." This approach is also reflected more generally in the INFCE findings.

Accompanying the developments specifically related to reprocessing has been a general decline in the rate of growth in nuclear power in both developed and developing countries. This decline has been induced by low and often zero growth in electric power demand, rising nuclear power costs, intensive financial pressure on utilities, and continued problems of public acceptance heightened by the TMI accident. While those factors are not of direct nonproliferation relevance, their indirect consequence is to reduce pressure on uranium demand and to impose problems on all sectors of the nuclear power

industry which detract from the ability and readiness of the industry to initiate costly new fuel cycle ventures.

The overall impact of the development described above would appear to increase the prospects for at least a rather broad de facto international consensus on a lengthy deferral of plutonium recycle in LWRs, on the suitability of interim spent fuel storage as an acceptable means of high level waste management, and of the limitation of reprocessing to the needs of breeder reactor development and demonstration. It must, however, be emphasized that while the prospects for such a consensus has improved, there is no certainty that it can be achieved, particularly on anything more than a de facto basis.

1.2.5 U.S. Policy

Through the INFCE process, the administration of the NNPA, the conclusion of NASAP, and other means, U.S. policy has also undergone evolution and more precise definition in the two years since the 1978 BNFP report. This evolution and definition have affected U.S. practices with respect to reprocessing.

Both immediately before and immediately after the U.S. policy statement of April 1977, the U.S. policy was to approve requests for reprocessing only when a physical need for reprocessing, evidenced by lack of space for additional spent fuel storage, was present. An important feature of these approaches has been the requirement that recovered plutonium is to remain at the reprocessing sites, unless or until U.S. approval for its transfer and use is given. This policy was later broadened to permit, on a case-by-case basis, consideration of approval where reprocessing was to take place under contracts entered into prior to the April 1977 policy statement. These conditions, of course, are in addition to, and not in replacement for, the criteria specified by the NNPA. While this modification has broadened the circumstances under which reprocessing may be approved, it has not affected the underlying policy that reprocessing per se is to be avoided to the extent possible, and that approval should be

justified on the basis of mitigating circumstances beyond the reasonable control of the party seeking approval.

The policy governing U.S. approval outlined above has been identified as an interim one, to be reviewed upon conclusion of INFCE. Thus, there has been no public expression of the policy likely to be adopted in the future, although indications of U.S. Government thinking have been made known in recent statements by U.S. officials. These include a speech by the Deputy Assistant Secretary of State for Nuclear Energy Affairs on September 10, 1979, in which he stated:

In the post-INFCE era, I expect that spent fuel storage congestion and pre-existing reprocessing contracts will continue to influence our response to requests for the reprocessing of spent fuel subject to U.S. control. As provided in our laws, we must be reasonably assured that such approval will not result in a significant increase in the risk proliferation. A big element in this consideration, of course, will be the timeliness of the warning provided to minimize opportunity for successful diversion of nuclear materials into nuclear explosives. In addition, I believe that we would consider a number of factors including: (1) the non-proliferation commitment of both the state requesting the reprocessing and the state where the reprocessing would take place; (2) the technical and institutional arrangements associated with the reprocessing, including the effectiveness of safeguards and stabilizing factors such as multinational participation; (3) the need for reprocessing, including alternatives available for the disposition of the spent fuel and the intended use of the separated plutonium; (4) the adequacy of physical protection and safeguards arrangements both for the spent fuel prior to reprocessing and for any separated or easily separable plutonium at all points in the fuel cycle; and, (5) adequacy of arrangements to ensure that the U.S. has the right to prior approval of any return or retransfer of the separated plutonium.

We recognize that our recent case-by-case consideration of each request places a heavy burden of uncertainty and delay on both requesting and reprocessing states and makes it difficult for them to develop long-term fuel cycle plans. We hope that we can reach mutually acceptable understandings with our cooperating partners on the situations in which U.S. approval can be expected on a more regular and routine basis.

U.S. policy concerning the uses for which reprocessing will be regarded as acceptable, one of the suggested criteria, has also been the subject of more precise definition in several recent U.S. policy statements. For example, in his address to the IAEA General Conference of December 1979, the U.S. Representative stated:

The long-term growth of nuclear power will also eventually require more advanced reactor systems. Since fuel utilization improvements can be achieved in thermal reactors, nuclear power could proceed in such a once through mode for a considerable time. Plutonium recycle appears to us as unnecessary, marginally economic at best, and imprudent at this time from a nonproliferation standpoint.

Although some nations are proceeding with breeder research and development (which requires reprocessing), we believe there are compelling economic and nonproliferation reasons for limiting the number of reprocessing plants to a few large-scale facilities and gearing reprocessing capacity to near-term plutonium demand for R&D on advanced reactors.

This more concise definition is a prominent feature of Administration policy as it has evolved on the basis of the April 1977 policy statement, which stated that the U.S. would "defer indefinitely the commercial reprocessing and recycling of the plutonium produced in the U.S. nuclear power programs." Avoidance of plutonium recycle, as foreshadowed by this statement, has remained the priority U.S. objective, in light of its potential for the rapid and widespread distribution of plutonium to a number of countries. Several recent policy statements, including that cited above, have made it clear that reprocessing for breeder R&D, while it will not receive U.S. encouragement, is viewed as justifiable, if limited for some time to come to a few countries, and undertaken under appropriate nonproliferation conditions. However, the means for deciding on the specific circumstances in which reprocessing for breeder R&D would be appropriate remain undetermined.

The distinction made in U.S. policy between reprocessing alone and subsequent use of recovered plutonium has also been apparent in U.S.

approvals of reprocessing of U.S.-origin spent fuel. These approvals have, without exception, been based on the understanding that separated plutonium would remain at the reprocessing facility, with any later transfer and use subject to further U.S. approval. Congressional reaction to these approvals has also made it clear that the Congress attaches key importance to plutonium utilization, insisting that any such use should be subject to separate assessment and determination of consistency with the statutory criteria governing sensitive subsequent arrangements.

Similarly, NASAP concluded that all nuclear fuel cycles entail some proliferation risks and that there is no technical fix. Nevertheless, LWR once-through fuel cycle is more proliferation resistant than fuel cycles that involve highly enriched uranium or pure plutonium. At the same time, NASAP concluded that U.S. uranium supply and demand could be in unbalance as early as 2010, and that the most promising approaches to the extension of resources are improvements in LWR uranium utilization efficiency and continued development of the plutonium-fueled breeder. Recognizing the even greater attraction of breeder reactors to other nations, NASAP further concluded that the U.S. should continue to urge others to refrain from developing reprocessing capability until it is clearly needed, and that there would be less proliferation risk if services were to be provided by a few large facilities, and on schedules driven by economically and technically justified fast breeder and advanced reactor research and development needs.

The above discussion indicates that while U.S. policy continues to favor the deferral of reprocessing and plutonium recycle, the policy has received more precise definition, which recognizes the need for reprocessing limited amounts of spent fuel in keeping with the requirements of breeder and other advanced reactor R&D programs. Moreover, since it is impractical to ensure that separated plutonium will be immediately placed in such uses, U.S. policy, in the words of the U.S. Representative to the IAEA General Conference, foresees that "as such reprocessing takes place, it will

become highly important to assure that the resultant plutonium is subject to rigorous international controls."

While U.S. policy, as outlined above, accepts the need for limited amounts of reprocessing, the important issue for purposes of this study is the relationship of this limited acceptance of the need for reprocessing to the acceptability or desirability of power reactor fuel reprocessing in the United States.

Fundamental to the U.S. policy of deferral of commercial reprocessing and plutonium recycle in the U.S. -- itself a nuclear weapons state -- has been the recognition that U.S. nuclear power policies and activities may influence the policies and activities of other nations, as well as the U.S. capacity to affect these policies and activities. This "linkage," particularly in relation to reprocessing, was first enunciated in the October 28, 1976 nuclear policy statement, in which President Ford stated: "We must ensure that our domestic policies and programs are compatible with our international position on reprocessing and that we work closely with other nations in evaluating nuclear fuel reprocessing." Similar considerations were apparent in the April 7, 1977 policy statement, in which President Carter stated: "We have concluded that the serious consequences of proliferation...require: ... a major change in U.S. domestic nuclear energy policies and programs;...."

Although often so described, the concept of "linkage" is not simply, or even primarily, one of "good intentions" -- the assumption that other nations will follow a good example set by the United States. Rather, the policy finds its basis in the principle that U.S. advocacy of policies of restraint could be less effective if its own program includes the activities it seeks to restrain.

The concept also has a juridical basis. Article IV (1) of the NPT states:

Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with Articles I and II of this Treaty.

U.S. policy does not question the right of NPT signatories to undertake any peaceful nuclear activities, including reprocessing, so long as these take place under NPT safeguards. Nevertheless, some states have complained that policies that seek to limit their opportunities to undertake sensitive activities are inconsistent at least in spirit with the NPT, and these complaints are voiced even more sharply when the restraint concerned an activity, such as reprocessing, in which others are engaging.

The events of the past two years have provided additional evidence concerning the nature and strength of the linkage between U.S. reprocessing activity and the policies and programs of other countries.

In the preceding discussion of the reprocessing policies and programs of other countries, it was noted that while the number of reprocessing facilities in operation or firmly planned has not expanded, there has been no general reversal in national programs or plans to engage in reprocessing. While a general tendency to slow down such programs is evident, this trend appears to be related more to economic and political than to nonproliferation considerations. In light of this background and the conclusions of INFCE, many have questioned the effectiveness of U.S. self-denial in affecting the reprocessing policies and programs of other nations. The fact that the reprocessing programs already projected have not been reversed suggests that the linkage between U.S. policies and those of other countries is limited. On the other hand, the fact that what had appeared to be an inexorable trend toward a further spread of reprocessing has not occurred may have been influenced by U.S. policy as well as by economic, demand, and internal political considerations.

The concept of linkage has another aspect. To the extent that the availability of reprocessing services may meet the needs or desires of other countries for these services, reprocessing by the U.S. and other nuclear advanced nations may help moderate both the justification and desires of others to acquire their own capabilities. The effectiveness of this consideration can be gauged by the relatively limited spread of enrichment technology and capabilities, which has been generally attributed to the availability of enrichment services from initially one, and later, a small number of large, efficient suppliers.

The widespread interest in the successful development of breeder reactor technology, even on the part of countries that have no near-term aspirations to deploy breeders themselves, also creates a demand for the development and demonstration of reprocessing technology on a sufficient scale to ensure its availability when needed for breeder reactor development, demonstration, and deployment. The possibility that this demand can be met with less overall proliferation risk if reprocessing is confined to the few countries best able to develop and demonstrate a commercially viable reprocessing technology must be considered. Because of U.S. pre-eminence in nuclear technology, a number of countries have urged that the U.S. continue to develop a reprocessing capability.

The foregoing considerations suggest that the concept of linkage is more complex and less certain in both its strength and direction than earlier assumed. This is a factor that should be taken into account in considering BNFP use and institutional options.

Another important development since issuance of the first BNFP report is the growing emphasis in both U.S. policy and that of other countries on institutional means for the reduction of proliferation risks. This emphasis is reflected in the U.S. statement at the 1979 IAEA General Conference, already cited, that "we should press for institutional measures to provide both greater supply and nonproliferation assurance."

Thus, among the issues in considering use and institutional options for BNFP is the extent to which such options may provide opportunities for important institutional initiatives, and the balance between the nonproliferation benefits of these initiatives and any nonproliferation disadvantages of the use involved.

It was concluded in the 1978 BNFP study that:

Various international, multinational, and national ownership/management options present possibilities for the future use of this facility. In no case considered did the attractions of such options appear to constitute, in themselves, a basis for future use which would not otherwise be justified by technical, economic, and nonproliferation policy considerations.

While the balance between the weights accorded institutional and use-related considerations reached at that time may not have changed, the increased emphasis in U.S. nonproliferation policy on progress in institutional arrangements requires careful reexamination of this balance with respect to each specific use and institutional option. The need for this reexamination is reinforced by the fact that, with INFCE concluded, less time now remains to take institutional initiatives before opportunities to do so may be lost irreversibly.

1.3 ENVIRONMENTAL AND REGULATORY CONSIDERATIONS

This section discusses a wide range of factors that must be considered in assessing use and institutional options for BNFP. They are, primarily, of a regulatory or public acceptance nature. For the purposes of discussion, these factors may be divided into five categories:

- Health, Safety, and Environment (HS&E)
- Regulatory Environment

- National Spent Fuel Policy
- Waste Management
- Public Acceptance

1.3.1 Health, Safety, and Environment (HS&E)

Health, safety, and environment (HS&E) issues are an important parameter of evaluating Barnwell use and institutional options. Since the first BNFP study was completed, three studies have been released that provide valuable information for consideration by decision-makers.

GESMO

The first of these is the Health, Safety, and Environmental portion of GESMO -- the Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors (NUREG-0002) -- which discusses mixed oxide fuels of the type that would have been produced at BNFP had work continued. At least three commercial reactors have been licensed in the past to use such fuel, and other utilities have considered applying for similar amendments for their licenses. The Atomic Energy Commission decided, in 1974, that an Environmental Impact Statement (EIS) would have to be prepared prior to the widescale use of mixed oxide fuel because of the possible broad impacts on the physical and social environment (39 FR 5356). Several years of proceedings followed, but the Presidential decision to defer reprocessing prompted the NRC to suspend the GESMO proceedings, although the possibility of reactivating the proceedings following the conclusion of INFCE was suggested (42 FR 65334). Although there is no requirement that they be done successively, it would be impractical to proceed with the licensing of BNFP as designed, or for any reprocessing function, without the completion of a GESMO-like activity, which would likely take several years (plus any time for litigation).

It seems likely that any future proceeding would have to begin anew. Nevertheless, the GESMO findings regarding the safety and environmental aspects of plutonium recycle are instructive. They were:

- The safety of reactors and fuel cycle facilities is not affected significantly by recycle of fissile material.
- Nonradiological environmental impacts resulting from recycle of fissile materials from spent fuel are slightly smaller than those from a fuel cycle that does not reclaim residual fuel values.
- Differences in health effects attributable to recycle provide no significant basis for selection of a fuel cycle option.
- No waste management considerations were identified that would bar recycle of uranium and plutonium.

In light of the early suspension of the GESMO proceedings, there is no indication that utilities have reacted to their findings.

INFCE Summary Report

The second document, which bears on the issue of HS&E, is the final summary report of the International Nuclear Fuel Cycle Evaluation (INFCE). Its conclusions are quite similar to those of GESMO. According to the report "... (T)he difference in the impacts of waste management and disposal among the reference fuel cycles does not constitute a decisive factor among them... (T)he radioactive wastes from any of the fuel cycles studied can be managed and disposed of with a high degree of safety and without undue risk to man or the environment."

With specific regard to plutonium recycle in either thermal reactors or breeders, INFCE reported that "reprocessing, mixed oxide fuel fabrication, plutonium handling and recycle can all be carried out in conformity with ICRP [International Commission on Radiation Protection] recommendations." In addition, INFCE concluded that a

breeder economy would result in lower thermal and radiological impacts from reactor operation than either U/Pu recycle in LWRs or the throw-away options.

In addition to HS&E issues, the INFCE report assessed the technical and economic ramifications of various fuel cycles. No one cycle was found to have an advantage in all cases, but under certain assumptions regarding uranium supply over the long term, recycle in thermal reactors or FBRs is necessary. Wet storage of spent fuel was found to be a proven (i.e., safe) technology.

Draft NASAP Report

Volume VI of the Draft Nonproliferation Alternate System Assessment Program (NASAP) Report assesses the safety and environmental considerations that would arise on licensing the principal alternative nuclear reactors and fuel cycles in the United States for large-scale commercial nuclear power uses. Included are descriptions of the principal unresolved technical issues and estimates of the time required for licensing each of the alternatives. Since the potential uses of BNFP involve fuel cycle activities, these NASAP findings are of interest.

The NASAP Report addresses safety and environment issues on both a generic and specific basis. From the generic standpoint, the Report states that the principal safety issues yet to be addressed relate to the prevention of radiation exposures to the facility operating staff and the general public, which would result from unplanned events or accidents (equipment failures, operator error, or external forces), thus implying that normal operation would not present a risk. Environmental issues include commitment of land and water resources, heat disposal, radiation exposure, proliferation risk, and social and direct costs, and are outside the scope of this discussion. In addition to safety and environment considerations, NASAP identifies five areas of public concern that must be addressed in the licensing process: probability and severity of accidents;

disposal of high level wastes; radiation exposure from normal operation; nuclear proliferation; and the competency and preparedness of federal agencies and utilities to oversee and operate nuclear reactors.

With regard to specific fuel cycles and activities, NASAP presents the following findings:

Once-through LWR cycle with interim spent fuel storage. Licensing of mills, conversion facilities, fabrication plants, and transportation is already well established. Mining operations do not require licensing, and licensing requirements for commercial enrichment facilities are not needed in the short term. Licensing of away-from-reactor (AFR) spent fuel storage facilities has not been established, but NASAP estimates that a new AFR could be operating within seven years of a decision to proceed. Utilization of a pre-existing facility like BNFP was estimated as shortening this timetable by two years.

Alternative fuel cycles. No safety or environmental issues were identified that would prevent the eventual licensing of any of the candidate fuel cycles. However, it was estimated that a minimum of ten years would be necessary for the implementation of any alternative fuel cycle:

- 10-14 years for retrievable geologic disposal of spent fuel.
- 15-20 years for U/Pu recycle in LWRs; reduced to 10-20 years if BNFP can be used without major design revision.
- 20 or more years for U/Pu or U/Th recycle to FBRs.

In summary, NASAP concludes that any safety obstacles to the licensing of any of the alternative fuel cycles could be overcome given a sufficient expenditure of time and funds, and that environmental considerations do not provide a clear preference toward one cycle.

1.3.2 Regulatory Climate

A profound change has occurred in the climate of nuclear regulation as a result of TMI. Although initiated by, and so far only directly relevant to, reactor regulation and licensing, these changes are implicitly applicable to the licensing of any major facility. In short, the consequence of the TMI-initiated reexaminations of regulatory policy and practices is to increase uncertainty as to when and under what conditions licensing of any major facility can go forward. As applied to BNFP, since no licensing proceedings are active (although the licensing proceeding for the Fuel Receiving and Storage Station legally still remains open), the issue certainly has no immediate practical significance.

In the long run, more stringent regulation, especially as it applies to operation of all major nuclear facilities, is likely. Although it is conceivable that the original design for BNFP could have been licensed if the original proceeding had been carried through to completion under earlier circumstances, under present conditions, design changes will undoubtedly be necessary.

Licensing procedures can be expected, moreover, to take a long period of time. Detailed discussion of implementation schedules are to be found in the relevant sections on utilization options, but reasonable estimates are highlighted below:

AFR option. The estimated licensing schedule is four years without any allowance for likely litigation. One year is allowed for preparation of license application, followed by another year for NRC to amend (or prepare anew if necessary) the Safety Evaluation Report (SER) and Environmental Impact Statement (EIS). The NRC must also conclude its rulemaking for AFRs (10 CFR 72) proceeding, which is expected to be accomplished in the first half of 1980. The actual hearing process before the NRC would take an estimated two years, thus providing an estimated licensing schedule of four years. Importantly, this does not include any allowance for litigation. Also,

there is no allowance for design and construction (if re-racking is desired).

Recycle options. Due to the necessity to reinstate and complete a GESMO proceeding, as well as a licensing proceeding (including an EIS) for BNFP itself, and construction of the Separation and Waste Solidification facilities, a lengthy implementation schedule would be experienced. Estimates are included in the discussion of this use option. If an alternative fuel cycle is selected, additional time must be allowed for design and modification of the BNFP facilities.

1.3.3 National Spent Fuel Policy

In October 1977, a policy for the interim storage of spent fuel was announced by the U.S. government, whereby it would accept and take title to spent nuclear fuel from utilities upon payment of a one-time storage fee. This policy was intended to provide a means whereby utilities could plan for the disposition of their spent fuel arisings, since an earlier Presidential decision in April had indefinitely deferred the reprocessing of commercial spent fuel. At the same time, the U.S. announced that it would accept and take title to limited quantities of foreign spent fuel for nonproliferation purposes.

Since the publication of the 1978 BNFP Applicability Study, three draft environmental impact statements (EIS) have been prepared by the Department of Energy to aid in the decision making necessary to implement these policies:

- Storage of U.S. Spent Power Reactor Fuel (DOE/EIS-0015-D), August 1978.
- Storage of Foreign Spent Power Reactor Fuel (DOE/EIS-0040-D), December 1978.
- Charge For Spent Fuel Storage (DOE/EIS-0041-D), December 1978.

In addition, studies have been conducted of the institutional and technical factors governing the return of foreign spent fuel to the U.S., and Congress has passed legislation requiring any such plan to be Congressionally approved before implementation.

Until the 1977 announcements, U.S. utilities had assumed that spent fuel from power reactors would be cooled at the reactor site for several years and then shipped to a reprocessing plant for separation of the useful uranium and plutonium, followed by solidification and disposal of the final wastes, and had planned accordingly. At-reactor storage (ARS) pools were designed to have a relatively small capacity in comparison to lifetime arisings from a reactor because of the presumed short-term nature of the storage. Now, however, ARS pools are filling, and the utilities are searching for a means to relieve the pressure on their storage capacities. A recent DOE analysis of AFR requirements (DOE/NT-0002 Update - January 1980) shows a need for AFR storage capacity of 186 MTU in 1981, 755 MTU in 1985, and 3,277 MTU in 1990. Congress has before it several proposals for the purchase, construction, or both, of an AFR.

The Nuclear Regulatory Commission issued an EIS on Handling and Storage of Spent Light Water Power Reactor Fuel (NUREG-0575) in August 1979, in preparation for final rule-making of a proposed 10 CFR 72, "Storage of Spent Fuel in an Independent Spent Fuel Storage Installation." Prior to this, AFR facilities were licensed under 10 CFR 70, "Domestic Licensing of Special Nuclear Material," and 10 CFR 50, "Domestic Licensing of Production and Utilization Facilities." NUREG-0575 reaches the following conclusions:

- The storage of LWR spent fuels in water pools has an insignificant impact on the environment, whether in ARS or AFR storage sites.
- The storage of spent fuel in AFRs is economically and environmentally acceptable.
- There is an increasing need for AFR storage in the early to mid-1980s.

As outlined in the section on Public Acceptance, many anti-nuclear groups are opposed to the operation of an AFR for reasons that range from a concern for the effects on the environment to a hope that preventing AFRs will force the shutdown of nuclear power plants, a fear that AFR storage is simply a stalking horse for a return to reprocessing, or a belief that it is inequitable for certain states to be forced to accept spent fuel from which they have derived no benefit.

1.3.4 Waste Management

The deferral of commercial reprocessing has led to the institution of government programs designed to provide interim and long-term waste management strategies, including spent fuel storage. The first of these is planning for an Independent Spent Fuel Storage Facility (ISFSF). DOE is investigating the purchase of several existing spent fuel storage facilities for use as interim away-from-reactor (AFR) storage. These potential sites are the Fuel Receiving and Storage Stations (FRSS) at the West Valley, Morris, and Barnwell reprocessing plants. At the same time, NRC is engaged in a rule-making for a proposed 10 CFR 72, "Storage of Spent Fuel in an Independent Spent Fuel Storage Facility" and has published a Final Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel (NUREG-0575), which analyzes the alternatives for disposing of spent fuel. Congress may provide funds for the purchase and operation by DOE of such a facility.

With regard to long-term, permanent disposal of spent fuel elements, which was implied by the President's deferral of reprocessing, DOE had intended to proceed immediately with the construction of a Waste Isolation Pilot Plant (WIPP) in New Mexico, which would have served as a repository for defense TRU wastes and 1,000 commercial spent fuel elements, under NRC licensing requirements. Congressional opposition to the NRC licensing of a defense site, and to the large degree of state involvement in decision making, prompted DOE to drop

plans to store commercial spent fuel at the WIPP site. The NRC, on the other hand, favors another five years for site selection and qualification of several different types of media for geologic disposal.

Attempting to relieve the uncertainties that the utilities faced, and as a natural follow-on to his 1977 policy, President Carter appointed an Interagency Review Group (IRG) on Nuclear Waste Management, which was to prepare a comprehensive report covering not only spent fuel (or HLW) disposal, but also low level wastes, state roles in siting, and other issues. The IRG report was submitted to the President in March 1979, and he announced a nuclear waste management policy based on that report on February 12, 1980.

The President announced an interim planning strategy based on detailed and extended site-specific evaluations leading to the identification of several alternative waste disposal sites. One of these sites would be selected in 1985, as a location for the first repository, which in turn would be licensed by the NRC. The operation of this site for permanent disposal of wastes arising from commercial reactor operations and reprocessing would commence around the mid-1990s. In addition to adopting this waste program, the President announced:

- The cancellation of the Waste Isolation Pilot Plant because it was to be an unlicensed facility.
- The formation of a State Planning Council to provide a forum for state input to siting decisions.
- Continued support for the provision of limited federal AFR storage capacity.

Despite this Presidential decision, considerable Congressional support continues to exist for a spent fuel strategy leading to earlier demonstration or operational capability. The INFCE report analyzes the current state of waste management technology, and states that

long-term disposal "can be carried out without undue risk to man or the environment." In particular, INFCE notes that vitrification has been successfully carried out on both low and high burnup fuels.

The effect of the continuing delay in waste disposal planning and demonstration is to leave without resolution the question of high level waste processing form and technology to be employed at any reprocessing facility.

1.3.5 Public Acceptance

Although the accident at the Three Mile Island nuclear power station, on March 28, 1979, focussed public attention on nuclear power safety issues, the specific context was nuclear power plants per se, and the impact of TMI on public attitudes toward reprocessing plants is far less certain. Public concern over domestic nuclear power now centers on two areas: reactor safety and the handling of radioactive wastes. It is in the latter area that can be found the public acceptance issues likely to have the greatest effect on the evaluation of use and institutional options for BNFP.

National opposition to nuclear power has generally grown in the last several years, but most public opinion polls continue to show a majority or plurality favoring nuclear energy and extreme policy shifts, such as a moratorium on nuclear power plant construction and operation, are considered unlikely. Nevertheless, there is a de facto moratorium on nuclear power plant ordering, reflecting a combination of economic, demand, regulatory, and public acceptance uncertainties. This moratorium has an obvious impact on the need, both real and perceived, for reprocessing services.

Because of its potentially strong effects on the future of nuclear power and BNFP, the role of the investment community is especially interesting. The investment community itself is subject to pressures from its stockholders in the same way that political sectors are responsive to their constituents.

In the six weeks following TMI, electric utility stock prices dropped 7.8%, compared to 3.1% for industrial stocks in general. During the same period, stock yields versus bond yields showed similar trends. Current high interest rates have generally depressed the value of fixed income investments, making it difficult to isolate any lasting effects of TMI. There has been some recovery since, but one analyst concludes, "...[U]tility dividend streams must be viewed as carrying more risk than was believed before [TMI]....This should persist until events give investors cause to have more confidence...." The recent announcement by GPU that it would not pay any dividend for the last quarter of 1979, while not unexpected, could tend to add to investor concern.

Also, at the time of TMI, several major banks announced that they would not provide loans for nuclear power plants in the future. Most have reevaluated that position, however, and reversed their decisions. The establishment on April 1 of Nuclear Assurance Ltd., a utility industry pool to share the costs of purchasing replacement power in the event of a reactor accident is designed to meet one of the major uncovered risks of TMI, and should help restore confidence in utility financing soundness.

It is also of interest that stockholders of eleven utilities will be asked to vote in 1980 on resolutions seeking to halt further planning and construction of nuclear power plants, and that two investment firms have been asked to stop financing of the Haven nuclear plant. In addition, General Electric faces two separate resolutions; one would prohibit any sale of the Morris, Illinois nuclear waste storage facility to the U.S. government and the other would halt all commercial and defense-related uranium mining and nuclear research, development, production, and sales (except that related to medical uses).

There has been continuing discussion regarding the appropriate level of involvement of local officials in decisions regarding nuclear

power facilities. At issue now is the proposal of a state "concurrency" role in the siting of AFR storage facilities and waste treatment centers. This issue has yet to be resolved, but it is safe to assume that there will be a certain degree of state control, whether de facto or de jure, over future nuclear activities. (The President's policy statement of February 12, 1980 does not provide a clear definition of the extent of that state control.) It is thus relevant to consider official attitudes toward nuclear energy in South Carolina.

The recent decision by Governor Riley to reduce the quantity of shipments to the Chem-Nuclear low level waste disposal site, is indicative of the state government's intention to exercise careful control over nuclear waste activities in South Carolina, especially in regard to wastes originating out of that State.

For its part, the South Carolina legislature is considering bills to prevent or delay DOE from establishing an AFR at BNFP. Two resolutions were introduced this year. The first calls for the President and Congress to prohibit the use of Barnwell as an AFR unless approved by the legislature and by the Governor. The second resolution calls for AFR storage on a regional basis, participation of South Carolina officials in all environmental and safety reviews, removal of the spent fuel after 40 years' cooling time, and agreement by the legislature and Governor that such sites may be explored and developed.

There are local groups in South Carolina opposed to nuclear power or further development of Barnwell. In most instances, the groups are broadly anti-nuclear and see the Barnwell plant as means of forcing the broader issue. They present several arguments against the use of BNFP as an AFR or waste disposal site in particular:

- Environment. It is felt that the Barnwell site is not appropriate as South Carolina has a high water table which could be contaminated in the event of storage failure. Concern is also expressed about the dangers in transporting spent fuel and wastes to and from the plant.

- Reprocessing. Use of BNFP as an AFR is seen as an intermediate step to the resumption of reprocessing activities and their perceived hazards.
- Interim Storage. It is believed that a) AFR storage is not needed until the 1990s; b) creation of an AFR would relieve the pressure on DOE to develop a waste disposal strategy; and c) preventing construction to an AFR may force the shutdown of operating reactors.

In a development related to the potential utilization of BNFP as either a reprocessing plant or an AFR, several transportation routes in the eastern U.S. have been closed to shipments of spent fuel, either directly or effectively. The city of New York has banned the transportation of nuclear wastes on its streets. The port of Miami has banned such shipments, and the North Carolina State Port Authority has notified at least one carrier that it may not ship nuclear wastes through the ports of that state. One lawsuit has been filed to block spent fuel transportation through Portsmouth, Virginia (Virginia Sunshine Alliance v. Hendrie). A temporary injunction was denied, but the case is still to be tried on its merits. Finally, NRC and the U.S. Department of Transportation have until recently been unable to agree on regulations for routing spent fuel shipments; DOT calls for use of interstate highways, while NRC requires use of secondary roads. A recent DOT proposed rulemaking on highway routing of radioactive materials should help overcome this problem.

REFERENCES

1. U.S. Department of Energy. December 1979. Strategy options for direct combustion technologies. U.S. DOE, Fossil Energy Division, draft paper.
2. The Engineering Societies Commission on Energy, Inc. January 1980. Coal technologies market analysis. Pamphlet.
3. National Electric Reliability Council (NERC). August 1979. 9th annual review of overall reliability and adequacy of the North American bulk power systems.
4. Exxon Company. December 1978. Energy Outlook 1979-1980. Pamphlet.
5. A dark outlook for utilities. Business Week. 28 May 1979:108-124.
6. Nagel, T.J. 1978. Operating a major electric utility today. Science. Vol. 201:985-993.
7. Hayes, E.T. January 1979. Energy resources available to the United States, 1985-2000. Science. Vol.203, No. 4377:233-239
8. Wolk, R.H. and Alpert, S.B. Paper read at Second Symposium, Coal Dilemma II on Coal Liquefaction and the Electric Utility Industry, February 1979, at Denver, CO.
9. Komanoff, C. Testimony read before the Subcommittee on Energy and the Environment of the House Interior Committee, 12 July 1979, at Washington, DC.
10. Taylor, V. Paper read to the Union of Concerned Scientists on the Easy Path Energy Plan, 30 May 1979, at Cambridge, MA.
11. Reichle, L.F.C. Paper read before the Richmond Society of Financial Analysts on the Economics of Nuclear Versus Coal, 30 October 1979, Richmond, VA.
12. World list of nuclear power plants. Nuclear News. Vol. 22, no. 2:59-66.

13. Financial news and comments. 19 July 1979. Public Utilities Fortnightly. Vol. 104, no. 2:35-39.
14. Gambs, G.C. 1979. The future of coal as a source of synthetic fuels. Paper read at the coal Dilemma II symposium, 12-13 February 1979, at Denver, CO.
15. McKenzie, N.C. 1979. Meeting the special requirements of the fuel cycle industry. Nuclear Engineering International. Vol 24, no. 285:59-68.
16. The U.S. nuclear service business; \$120 million a year and growing 25% annually. 1979. Nucleonics Week. Vol. 20, no. 5:8-9.
17. Office of the White House Press Secretary. 17 May 1979. National Energy Plan II. Press Release.
18. U.S. Department of Energy. December 1979. Nuclear proliferation and civilian nuclear power. In NASAP; Resources and fuel cycle facilities. Vol. III. DOE Draft Report. Washington, DC.
19. Steyn, J.J. 1977. The increasing costs of delay in closing the fuel cycle. paper read to the Conference on Nuclear Power Financial Considerations; Atomic Industrial Forum, 26 July 1977, at Seattle, WA.
20. Steyn, J.J. 1978. Uranium resource adequacy. Review paper for the Edison Electric Institute. November 1978.
21. U.S. Department of Energy. 1979. Statistical data of the uranium industry. Doc. no. GJO-100(79). Grand Junction, CO. 1 January 1979.
22. National Research Council, Committee on Nuclear and Alternative Energy Systems, Supply and Deliver Panel. 1978. Problems of U.S. uranium resources and supply to the year 2010. Supporting paper no. 1 of National Academy of Sciences, Washington, DC.
23. National Research Council, Committee on Nuclear and Alternative Energy Systems. Final report on Energy in Transition 1985-2000. 1979. National Academy of Sciences, Washington, DC.

24. Survey of uranium industry views concerning U.S. uranium resources and U.S. uranium production activities. 15 April 1977. Doc. no. ERDA 77-59.
25. U.S. Department of Energy. 1979. The nuclear strategy of the DOE. 25 September 1978. (revised 15 February 1979)
26. U.S. Department of Energy, Energy Information Administration. 1979. Annual report to Congress 1978. Vol. 3, sec. 12:203-223. Doc. no. DOE/EIA-0173/3.
27. U.S. Department of Energy. 1979. Nuclear proliferation and civilian nuclear power. NASAP, Executive Summary. Draft report. December 1979. Washington, DC.
28. U.S. Department of Energy. 1979. Spent fuel storage requirements--the need for away-from-reactor storage. Doc. no. DOE/ET-0075. February 1979. Washington, DC.
29. U.S. General Accounting Office. 1979. Federal facilities for storing spent nuclear fuel--are they needed? Doc. no. EMD-79-82. 27 June 1979. Washington, DC.
30. U.S. Nuclear Regulatory Commission. 1979. Final generic environmental impact statement on handling and storage of spent light water power reactor fuel. Doc. no. NUREG-0575. August 1979. Washington, DC.
31. U.S. Department of Energy. 1980. Spent fuel storage requirements--the need for away-from-reactor storage--an update. Doc. no. DOE/ET-0075. Washington, DC.
32. U.S. Department of Energy. 1979. Environmental impact statement on storage of foreign fuel. Foreign Demand Option 2 of Doc. no DOE/ET-0040-D. Draft. Washington, DC.
33. U.S. Department of Energy. 1978. Barnwell nuclear fuel plant applicability study. Doc. no. DOE/ET-0040/1/2/3. April 1978.

ADDITIONAL SOURCES

1. The Newsletter of the Engineering Societies Commission on Energy, Inc. October 1979. Synfuels briefing. Vol. 3, no. 22.
2. Booz-Allen & Hamilton, Inc., and Wharton School of Business Administration. A conference on Energy Regulation: Trends and Implications, 21 October 1976, at University of Pennsylvania, Philadelphia, PA.
3. Edison Electric Institute. 13 November 1979. Press release.
4. A.M.R. International, Inc. 1979. Paper read at Advanced Management Research Seminar on Utility Financing, 17-18 June 1979, at New York, NY.
5. Hahn, O. 1979. New investment powers of Euratom. Nuclear Engineering International. Vol. 24, no. 285:67-68.
6. U.S. Nuclear Regulatory Commission. 1976. Final generic environmental statement on the use of recycled plutonium in mixed oxide fuel in light water reactors. Vol. 5, no. NUREG-002. August 1976. Washington, DC.
7. EIA. 1979 nuclear power projections for U.S.--gigawatts. October 1979 estimates. 29 October 1979. Nuclear Fuel. Vol. 4, no. 22:9.
8. International Energy Associates Limited. 1978. Pacific basin plutonium utilization impact on spent fuel storage requirements. DOE contract no. EN-77-C-03-1583. Submitted to Boeing Engineering and Construction, 17 April 1978.
9. Cook, M.C. 1979. Testimony on uranium resource adequacy. Paper presented to Subcommittee on Energy Research and Production, Science and Technology Committee, U.S. House of Representatives, 31 May 1979, at Washington, DC. Draft.

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2.0 BARNWELL NUCLEAR FUEL PLANT EVALUATION GUIDELINES

The purpose of this chapter is to establish a set of guidelines that can be utilized to evaluate potential use and institutional options for the Barnwell plant. These guidelines encompass those specified by the DOE, but include additional elements designed to ensure the application of all important factors. They are:

- technical feasibility
- consistency with national energy policy
- consistency with U.S. nonproliferation policy
- health, safety, and environmental (HS&E)
- cost effectiveness
- organizational and financial attractiveness
- public acceptance
- institutional acceptability

Each of these guidelines is designed to emphasize the pros and cons of the use and institutional options examined. Additionally, the guidelines of economic and operational benefits and costs should, in principle and, if adequate data are available, permit quantitative estimation of differences. The guideline of technical feasibility implies, at least in the limiting cases, that some use options are not realistically possible, and this is employed for initial screening to avoid the expenditure of analytical effort on approaches that are not technically realistic.

Although none of the above criteria are specifically addressed to the issue of the need for BNFP, or the services it can provide, the issue of need is implicit in several of them. This approach to the formulation of criteria has been chosen since "need" appears to be a derivative criterion, on which judgments can be made only by consideration of the various policy objectives that might give rise to a need. Additionally, it was felt that the Congressional mandate of this study would be better served if all realistic uses were considered, with the question of need to be determined on the basis of all factors, rather than as a means of screening alternatives. In practice, the analyses should yield similar results, regardless of which step is taken first.

The compatibility of each alternative with the complete set of guidelines will be compared in an effort to isolate those alternative uses and institutional factors for Barnwell that would yield the most favorable combination for promoting energy security and nonproliferation goals in a technically feasible, safe, economic, and acceptable manner.

The following sections define each guideline and illustrate how they provide a basis for evaluating the Barnwell utilization and institutional options.

2.1 TECHNICAL FEASIBILITY OF USE OPTION

Technical feasibility guidelines call for evaluation of whether the Barnwell facility is suitable for the use option under study, or the nature, extent, and difficulty in modifying the facility to permit such an option. The following guidelines have been identified:

- Compatibility with the state of development of the materials and technologies involved; including, years of and levels of R&D activities, and years of operating experience (e.g., laboratory, field, and end-use experience).

- Transfer capability of the experience base to projected alternative use.
- Evidence of national infrastructure capability on the technical and industrial front.
- Situation of the supply of resources required for the completion and operation of the alternative use; the origin of supplies may be national or international.

2.2 CONSISTENCY WITH NATIONAL ENERGY POLICY

Among the possible elements that would ensure compatibility with United States's energy policy, the following guidelines have been identified:

- Contribution of the use and institutional option to the achievement of U.S. energy policy goals; in particular, national energy security, and for contributing to the energy security of U.S. partners and allies.
- Contribution of each option to the attainment and maintenance of desired levels of nuclear power operation.
- Costs and benefits of alternative uses for spent fuel storage requirements.
- Costs and benefits of alternative uses for possible uranium resource base expansion needs as qualified by the U.S. non-proliferation policy.

2.3 CONSISTENCY WITH U.S. NONPROLIFERATION POLICY

The extent to which alternative BNFP use and institutional options support U.S. nonproliferation policy and further the achievement of U.S. nonproliferation objectives is an important, but not exclusive, guideline for this study.

As outlined in Section 1.2, U.S. nonproliferation policy focuses on several specific aspects of the fuel cycle including sensitive nuclear facilities, plutonium use, spent fuel management, and fuel assurances. U.S. nonproliferation policy is a complex of principles and considerations, which are not defined in a single document. Among the elements of U.S. nonproliferation policy of particular importance to the consideration of BNFP use and institutional options are the following:

Sensitive Nuclear Facilities

- The development of new reprocessing facilities, or expansion of existing facilities, should be based on international plutonium needs for breeder and advanced reactor R&D only. They should not be built in order to manage spent fuel arisings or to prevent plutonium for recycle in conventional reactors.
- The creation of additional reprocessing capacity should be related to worldwide breeder and advanced reactor R&D requirements rather than to national or regional needs. In this regard, the United States supports existing reprocessing capacity as adequate for a substantial period.
- If and when new sensitive facilities are justified, they should incorporate appropriate technical and institutional barriers to proliferation.

Plutonium Use

- Some plutonium may be justifiable for fast reactor R&D in some countries where, on the basis of projected nuclear energy requirements and capabilities, breeder deployment early in the next century would be a serious option.
- In view of the marginal economic and resource benefits associated with recycle of plutonium in light water reactors compared to the substantial proliferation risk associated with the early widespread use of plutonium fuels, such recycle should be avoided.

- Consistent with concerns about LWR recycle, existing reprocessing facilities should separate plutonium at a rate corresponding with current needs for R&D breeders and advanced reactors.

Spent Fuel Management

- Spent fuel beyond that needed for plutonium for advanced reactor R&D should be stored under adequate safeguards. Reprocessing decisions should not be driven by spent fuel storage problems.
- In addition to developing means to dispose of high- and low-level wastes resulting from reprocessing, the technical basis for the permanent disposal of unprocessed spent fuel through encapsulation should also be developed so that states may choose this option in the future should they deem it appropriate.

Fuel Assurances

- Various forms of low enriched fuel assurances should be developed for states that meet basic nonproliferation criteria and that forego the development of national enrichment and reprocessing facilities.

The application of guidelines involves complex considerations.

Performance of sensitive fuel cycle activities at the BNFP may tend to legitimize the performance of nuclear operations elsewhere, and undermine U.S. ability to effectively advocate restraints. On the other hand, the availability of services in the United States could reduce perceived incentives to establish capabilities elsewhere. A major consideration in the application of nonproliferation guidelines, accordingly, would be "linkage" -- the extent to which performance of a particular fuel cycle activity in the U.S. influences the interest in and performance of the activity elsewhere.

2.4. HEALTH, SAFETY, AND ENVIRONMENT

Health, Safety, and Environmental (HS&E) guidelines will include the following:

- Evaluation of the physical effect that the facility and its selected activity has on its surroundings (e.g., physical, occupational, and public).
- Conformance of use alternatives with existing HS&E regulatory framework.
- Dependence of use alternatives on new HS&E regulatory standards.

2.5 COST-EFFECTIVENESS OF USE ALTERNATIVES FOR THE U.S. GOVERNMENT

The following guidelines have been identified for the cost-effectiveness of project alternatives; these guidelines are designed to highlight economic aspects that may be of particular interest to the government:

- Presentation of capital cost outlays on a yearly basis for completing alternative uses.
- Presentation of annual operating and maintenance (O&M) costs for operating alternative uses.
- Comparison of capital requirements and O&M costs for completing alternative uses where data was available for comparable alternatives.

2.6 ORGANIZATIONAL AND FINANCIAL ATTRACTIVENESS OF THE PROSPECTIVE PRIVATE OR FOREIGN INVESTOR

Organizational, managerial, and financial guidelines have been identified for assessment of institutional and management options. The general guidelines are as follows:

- Simplicity of the decision-making process for enterprise management.
- Clear delineation between the treatment of operational matters and policy decisions.
- Distinction between business operations and regulatory/control functions in the overall management organization.
- Technical competence and cohesiveness of staff as they relate to national composition, public confidence in facility operation, and local acceptability of multinational operations.

2.7 PUBLIC ACCEPTANCE

Whereas compatibility with health, safety, and environmental considerations may be defined specifically by laws and regulations created and administered by local, state, and federal governments, public acceptance guidelines cannot be so narrowly defined. Public acceptance of a utilization or institutional option depends on perceptions of such varied matters as the contribution to energy security, proliferation risks, economic benefits and costs, and, importantly, health, safety, and environmental effects. Therefore, public acceptance guidelines must take into account every element that affects public approval of a utilization option.

Institutional options may also elicit varying public attitudes. Foreign staffing of the facility may give rise to concern, however unjustified, that safe and reliable operation will be prejudiced. Any need for governmental financing will have predictable effects on public acceptance, while issues concerning public vs. private ownership will elicit both support and opposition in ways that will be difficult to forecast.

2.8 INSTITUTIONAL ACCEPTABILITY

Institutional acceptability guidelines involve consideration of the attitudes toward each particular institutional option of a variety of concerned groups. The owners, state and local governmental units, the federal government, and the nuclear industry are among the obvious groups with a strong and legitimate interest in the institutional arrangements to be considered. Moreover, if an option is to be a useful international or multinational institutional model that advances nonproliferation and energy security goals, it must be viewed as acceptable by as many other states as possible. Like public acceptance, institutional acceptability depends upon other guideline considerations to form the basis for approval. Organizations may accept an option based on that option's ability to satisfy combined interests such as technical feasibility; energy security needs; nonproliferation goals; participation in ownership, management, and staffing opportunities. In short, institutional acceptability considerations are important for determining which utilization option will receive approval from whom, and for which reasons.

3.0 GENERIC USE OPTIONS

In this study, four generic categories of use options for the Barnwell plant have been considered. These are:

- Storage of spent LWR fuel
- Reprocessing of LWR spent fuel
- Safeguards development and training
- Non-Use

The first of these categories, spent fuel storage, has two sub-categories: as a domestic AFR, and as an international AFR.

The second category, reprocessing, has four sub-categories: in support of a program of LWR recycle, in support of a program of breeder development, in support of the development of alternative fuel cycles, and as the U.S. contribution to an international fuel service center.

President Carter's 1977 nonproliferation policy calling for indefinite deferral of commercial reprocessing and recycling of plutonium produced in the U.S. nuclear power program put a hold on these uses for the foreseeable future. While the policy could no longer accept the BNFP for its originally intended use, at the same time it opened for consideration two other types of uses: the storage of spent fuel, and several nonproliferation-oriented activities in support of the new policy.

Although avoidance of plutonium recycle has remained the priority U.S. objective, recent policy statements have suggested that reprocessing capacity geared to near-term plutonium demand for R&D on advanced reactors would be acceptable, although not encouraged.

As utilities had previously planned on having spent fuel reprocessed, the deferral of commercial reprocessing in the U.S. created a need for away-from-reactor (AFR) storage to unload the utilities' at-reactor storage basins. The possibility of using the BNFP's completed but empty spent fuel receiving and storage facilities as an AFR for domestic fuel is, thus, a natural outgrowth of the policy of deferral of reprocessing.

The Administration's nonproliferation policies also created the incentive to examine the use of the BNFP in various activities supportive of these objectives. Of those listed above, these would be: the opening of the BNFP's basins to foreign spent fuel (international AFR); its use in support of the development of alternative (more proliferation-resistant) fuel cycles; the U.S. contribution to an international fuel service center; and as a facility for use in the development, demonstration, and training for improved safeguards equipment and techniques.

The specific use options to be analyzed are grouped into the above four generic categories, presented in detail, and evaluated in Section 4.0.

Two uses were not treated: uses requiring involvement with DOE's defense programs or facilities (specifically the reprocessing of Hanford's N-Reactor spent/target fuel or spent/target fuel from the Savannah River Plant), and the use of BNFP in support of the TMI recovery program.

4.0 ANALYSIS OF USE OPTIONS

The grouping of specific use options under the four generic categories described in Section 3.0 gives this section the following structure:

Spent Fuel Storage (4.1)

- . As a domestic AFR (4.1.1)
- . As an international AFR (4.1.2)

Reprocessing (4.2)

- . In support of a program of LWR recycle (4.2.1)
 - As a facility for development of a national capability to recover Pu & U from spent LWR fuel (4.2.1.1)
 - A facility for production of PuO_2 and UF_6 from LWR spent fuel (4.2.1.2)
 - A developmental and/or production facility for immobilization of LWR HLW (4.2.1.3)
- . In support of a program of breeder development (4.2.2)
 - A facility for development of a national capability to recover Pu from spent LWR fuel (4.2.2.1)
 - A facility for production of PuO_2 as required for research, developmental, or deployed breeders (4.2.2.2)
 - A developmental and/or production facility for immobilization of LWR HLW (4.2.2.3)
 - A facility for development of a national capability to reprocess spent breeder fuel (4.2.2.4)
 - A developmental and/or production facility for immobilization of breeder HLW (4.2.2.5)
- . In support of development of more proliferation resistant fuel cycles (4.2.3)
- . As an international fuel service center (4.2.4)
- . Technical assessment of Barnwell plant design (4.2.5)

Safeguards Development and Training (4.3)

Non-Use (4.4)

The following format was used in analyzing each of the above specific options:

1. Description (of the specific use option being analyzed)
2. Documented Indications of Need/Interest/Support
3. Sources Used in Making Analysis
4. Assumptions Used in Making Analysis
5. Schedule for Implementation of Use
6. Estimated Costs for Implementation of Use
7. Evaluation of Use
 - . Technical Feasibility
 - . Cost Effectiveness
 - . Compatibility with U.S. Energy Policies
 - . Compatibility with U.S. Nonproliferation Policies
 - . Environmental Health & Safety Factor
 - . Public Acceptance

Two possible influencing factors were not taken into account in the evaluations. These were the costs of decontamination and decommissioning and the possible availability of sensitive materials, or services, or both, from foreign sources.

Throughout this section some specific use options appear more than once, e.g., immobilization of HLW is required for both LWR recycle (4.2.1) and breeder program support (4.2.2). In these cases, where a specific use has already been presented, rather than repeating the description and analysis, reference is made to the earlier discussion.

Three exceptions were taken to a strict adherence to the above format. These were:

1. There has been some concern expressed relative to the plant design of the BNFP. These concerns are not really focused on technical feasibility (there is no question that the Purex process is technically feasible) but, rather, on the practical aspects, the maintainability of the plant. Thus, a separate section has been added (4.3), in which a review is made of the several studies done on this point and of the BNFP status and response, to date, to these observations.
2. Rather than attempting to evaluate the compatibility with U.S. nonproliferation policies of each of the separate BNFP use options supportive of a program of LWR recycle (4.2.1.1 through 4.2.1.3), an evaluation on this point was made of the whole concept of a LWR recycle program. The nonproliferation evaluation of BNFP used in a national breeder program (4.2.2.1 - 4.2.2.5) is treated similarly. (These two evaluations are presented below in this introductory section, 4.0.)
3. Similar treatment was given to the public acceptance evaluation. The subject was felt to be too complex and interrelated in nature to lend itself to making an individual evaluation of each of the specific use options. (Public acceptance of the BNFP use options is thus evaluated below, as a whole, in this introductory section, 4.0.)

Compatibility with nonproliferation of using BNFP in support of an LWR recycle program. The principal nonproliferation effects of this option would be detrimental to U.S. efforts to discourage LWR recycle in other countries and the premature and unnecessary widespread use of plutonium. It would encourage reprocessing for the same purpose abroad, with no assurance that nonproliferation measures would be as strong as for Barnwell. At the least, it might then be more difficult to confine reprocessing to a few large facilities in safe locations.

This would place a correspondingly greater burden upon early development and implementation of institutional arrangements among a larger number of possible politically and economically more diverse countries. The greater diversity of the countries might undermine the effort to devise the strongest measures possible, since agreement on effective measures might be more difficult to develop among such a group. Furthermore, the opportunity to develop a base of experience with technical and institutional measures might be limited before the demand on these measures increased.

Making provision for reprocessing and export of plutonium for foreign LWR recycle programs might provide a means by which the U.S. could influence those programs, but the nonproliferation costs might be greater than in the breeder case. Whereas the FBR support option below seeks to control those risks by limiting the quantities in circulation and distribution of plutonium, particularly to foreign countries, the less restricted purpose of this option might relieve those constraints. Limiting the plutonium to domestic recycle only would minimize the risk of foreign governmental diversion, as might a domestic breeder only option, but at potentially even greater cost.

Compatibility with nonproliferation objectives of using BNFP in support of a national breeder program. Any option involving reprocessing could entail certain risks of theft or sabotage at BNFP, itself, and anywhere else the resulting plutonium would be located, and a potential for diffusion of the technology where foreign parties might obtain access to the facility. Since safeguards, as currently practiced, would be insufficient to provide

acceptable nonproliferation assurances for bulk handling operations, adoption of this option would necessarily require development of improved technical and institutional measures to address these proliferation risks.

Confining the distribution of plutonium to support the domestic breeder program only, with no provision for even limited export, would clearly minimize the risk of diversion. (It would not, however, affect the subnational risks within the U.S.)

Making some plutonium available for foreign breeder R&D, and reprocessing foreign spent fuel for this purpose if there were a market, would create a potential for national proliferation, but might also offer several nonproliferation policy-related benefits. Current U.S. policy recognizes the existence of legitimate needs for plutonium in support of existing breeder programs, where clearly justified on energy grounds, and links the expansion of world reprocessing capacity to the servicing of those needs. It also recognizes, however, the need for strong institutional arrangements, including suitable international controls on plutonium, to accompany this option. A breeder support option for Barnwell would be consistent with this policy only insofar as need for new capacity for this purpose existed. The principal point from a nonproliferation perspective, however, is that use of BNFP for reprocessing has to be tied to a clear, well-defined need for Barnwell to support a U.S. breeder program. To do so prematurely would undermine the policy objective of discouraging reprocessing in advance of legitimate need.

Public Acceptance of BNFP Use Options. As is pointed out in Section 2.7, public acceptance guidelines take into account every element that affects public approval of use options. These elements include public perception of security; proliferation risks; economic benefits and costs; and most important, health, safety, and environmental effects. Institutional options may also affect public attitudes. For example, public confidence in the safety of operation may be adversely affected by foreign participation in ownership, management, or staffing. It is important, in considering public acceptance, to keep in mind that it is the public perception of the issues surrounding particular options that is of relevance to this criterion, and not the objective merits of these issues. For a variety of reasons, perceptions and objective reality may not always coincide.

It is also important to keep in mind that the "public" is far from homogeneous, and that different sectors of the public may hold widely differing views on the acceptability of particular use or institutional options. Moreover, in this analysis, the term "public" is used in the broad sense to include the public at large, as well as important sectors such as state and local governmental entities and various groups within the public sector.

In addition to its sectoral divisions, public acceptance has both a local and national component. In general, the local component may carry greater weight in the overall decision-making process, particularly as it related to environmental, health, and safety issues, and local economic impacts. National attitudes, on the other hand, tend to carry greater weight in the decision-making process related to such national issues as energy security and nonproliferation. There is, of course, considerable interaction between local and national public attitudes and the groups through which these are expressed. In the analysis that follows, primary attention is given to local attitudes, but an attempt is made to identify possible national attitudes whenever possible.

Finally, it must be recognized that there are few objective measurements of public opinion or acceptance, especially those that might characterize the opinion of the public at large, as contrasted with specific groups. This difficulty increases if efforts are made to assess public attitudes toward each of the various detailed sub-options. For example, there is little objective basis on which to differentiate between public attitudes toward the operation of BNFP to reprocess spent fuel in support of breeder R&D and its use in support of LWR recycle.

In general, four broad modes of use can be distinguished for the purpose of assessing public attitudes. These are:

- . Non-use
- . Non-radioactive uses (training, safeguards R&D, etc.)
- . AFR use
- . Reprocessing use

Within each of these categories, it may be possible to associate certain differences in public acceptance with particular sub-options, although such distinctions will, in most cases, be based upon informed speculation. For example, the acceptability of AFR use will almost certainly depend, in part, on whether fuel to be stored is of U.S. or foreign origin, and may even be affected, in the case of domestic origin fuel, by whether the fuel arises in the region or is gathered from distant locations.

In the following paragraphs, possible public attitudes toward these use options are identified and discussed. It should be reemphasized that, in the absence of objective data on public attitudes, this discussion necessarily rests to a considerable degree on speculations.

Non-Use

It is evident that a decision not to use Barnwell would be welcomed by that segment of the local and national public that opposed nuclear power generally or that takes particular exception to such back-end fuel cycle activities as reprocessing and AFR fuel storage.

The decision could attract considerable opposition, however, on grounds of lost economic and employment opportunities by local groups and individuals that place priority on this consideration. Since BNFP has not been put into operation, however, the effect of a non-use decision would be, principally, to frustrate expectations of future economic benefit, rather than to lead to layoffs and other economic dislocations. Accordingly, any opposition to the decision on these grounds is likely to be limited.

Such concerns would be more limited to the extent that a non-use decision would be accompanied by a substantial program to put BNFP into standby condition.

Nationally, continued non-use of BNFP would be expected to attract the opposition of the industrial nuclear community, which strongly favors nuclear power, the breeder, and closure of the nuclear fuel cycle. Continued energy supply problems, including price increases and high oil import levels, could give these views added weight in the future.

Non-Radioactive Use

This use option involves the possible use of BNFP in safeguards training and development, without the introduction of radioactive materials, other than natural uranium. Such use is already taking place or scheduled to a limited extent.

Public attitudes toward this use can be expected generally to parallel those of non-use, with the likelihood that the continued use, even though of limited economic significance, would be welcomed by those concerned with the loss of economic opportunities associated with complete suspension and viewed with some added concern by those who prefer a definitive end to the likelihood of full use of BNFP.

AFR Use

Two sub-cases of AFR use can be distinguished, although public attitudes toward these are likely to include a number of elements that are common to both sub-cases. These sub-cases are: use exclusively for storage of national spent fuel; and use in which some portion of the stored fuel is of foreign origin.

The national AFR option faces public opposition for a variety of reasons. First, an AFR poses perceived hazards to public health and safety, and to the environment. In addition, use of the BNFP as an AFR would lead to increased spent fuel transport through South Carolina from all parts of the country, leading to a perceived higher risk of accidents, sabotage, and radiation leakage.

Though all of these perceived risks would be associated with the use of the facility in its design mode as a reprocessing plant, and the latter use would also involve health, safety, and environmental risks associated with reprocessing, there is evidence that significant sectors of the local public would be more prepared to accept full use of BNFP than its partial use as an AFR.

This may reflect an attitude that the full-economic benefits may as well be enjoyed if the facility is to involve the presence of large amounts of radioactive material; or it may simply reflect the fact that the use of BNFP for its original purpose was generally accepted in the area, while AFR use involves a change in the situation, and one which is out of keeping with current general attitudes toward the presence of "nuclear waste."

An issue of particular significance affecting local and even statewide public attitudes toward AFR use is the opposition to becoming a "dumping ground" to fuel originating elsewhere. There is considerable evidence that this opposition is affected by whether BNFP would be the only such facility, or whether the burden would be shared with sites in other states, perhaps accepting fuel on a regional basis.

AFR use could also be expected to be opposed by those groups, both local and national, that oppose nuclear power generally, and particularly by those groups that oppose establishment of AFRs at this time as premature.

AFR use could be expected to be preferred to non-use by at least some who would favor full operation of BNFP because of its economic and employment benefits, particularly if AFR use were viewed as a forerunner of full plant activation. Nationally, AFR use would be likely to enjoy considerable support among the nuclear industrial sector, which would view such use as at least a step forward in the resolution of the waste and spent fuel management issue, as well as a step that might increase the chance of full utilization.

Storage of foreign spent fuel at BNFP could be expected to increase opposition arising from feelings against the use of BNFP as a dumping ground for wastes originating elsewhere, particularly if BNFP were the only U.S. facility called on to accept such material. This increased opposition might be substantial, despite the fact that foreign fuel would not affect the objective nature of any risks and hazards arising from fuel storage per se. Further concern might be present if, in addition to storage of foreign fuel, the facility management and operation were perceived to be partially in foreign hands. Receipt and transshipment of foreign spent fuel in the ports of the area might attract local opposition in these locations, which would probably be offset only in part by expectation of increased port revenues and employment.

Nationally, and perhaps even locally, there is some support, even among groups generally opposed to AFR storage, for allowing the entry and storage of limited amounts of foreign spent fuel to help relieve proliferation problems. It is unlikely, however, that this attitude will exercise a controlling influence on public attitudes at the local or state level.

Reprocessing Use

While reprocessing use of BNFP would involve the most significant potential radiation risks of any use, there is evidence, as indicated earlier, that local public opposition to this use would be less than for AFR use. In this regard, it should be recalled that BNFP enjoyed broad public acceptance when the Barnwell site was selected, and that the Savannah River Plant, which includes major reprocessing facilities, has been operating and has been fully accepted locally for nearly 30 years.

Major changes in national policy and, to some extent, underlying public attitudes have, of course, taken place since the announcement of BNFP. These changes include increased concern over proliferation and the potential risks of reprocessing and plutonium use to further proliferation, as well as increased concern over radiation health and safety, particularly in connection with the storage of high level wastes. While these concerns undoubtedly have an affect on local attitudes, their effect, especially in the case of proliferation concerns, is more pronounced at the national level, and there is little evidence that broad, local opposition to full activation of BNFP would exist, provided regulatory proceedings confirmed its safety and the absence of serious environmental effects.

Some distinctions in public attitudes might exist, dependent on whether use of BNFP was in support of breeder objectives or LWR recycle. Any such distinctions, however, would be more prominent at the national rather than the local level.

Nationally, full use of BNFP either in support of breeder R&D or of LWR recycle could be expected to have strong support in the nuclear industry. This would be reflected to some extent locally, particularly among groups that place emphasis on economic and employment benefits, to which full operation of BNFP would contribute significantly.

Use of BNFP for the reprocessing of significant amounts of foreign spent fuel, especially if this was accompanied by the establishment of an international fuel cycle center involving a degree of foreign ownership, management, and staffing, would probably attract some additional opposition, compared to the case of wholly national operation. There is little evidence on this point, however, and the extent of any such additional opposition is difficult to forecast.

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4.1 SPENT FUEL STORAGE

4.1.1 Use of BNFP Storage Basins as a Domestic (U.S. Government Owned) AFR

4.1.1.1 Description of AFR Storage Facilities and Expansion Options

The existing Fuel Receiving and Storage Station (FRSS) at Barnwell provides the ability to receive at least five MTU of spent fuel daily and store 400 MTU. (Since Volume II of Reference 1 describes and pictures the FRSS in some detail, no description is given here.) Under contract to DOE, AGNS has developed plans and concepts for expanding the capacity of the FRSS. Most of this effort has been devoted to studying techniques for increasing the capacity of the existing facility, including methods for repackaging and reracking fuel assemblies to increase the density of stored material within safety (criticality) constraints. AGNS has also completed conceptual design and cost work for constructing new pools and a connecting canal adjacent to the existing FRSS.

4.1.1.1.1 Densification

The densification concepts, which are identified in Reference 2, call for three separate modifications to the way fuel is stored in the FRSS. The first is the use of poison material (thermal neutron absorbing) between fuel assemblies to increase canister capacity. This is a proven process already licensed by NRC for utilities to increase "at-reactor" storage capacity. The second modification is to use new racking techniques in addition to new canisters to increase pool capacity. The third modification, which also increases pool capacity, is to store fuel assembly racks in double tiers in the two deepest, but smallest, of the three storage pools. References 2 and 3 describe all three techniques in detail.

Table 4-1 summarizes the expanded capacity provided by these modifications, as developed in Reference 2. The figures shown assume a 60% BWR and 40% PWR mix of fuel, and BWR fuel assemblies with 0.20 MTU and PWR fuel assemblies with 0.45 MTU.

4.1.1.1.2 New Construction

For a further expansion of the BNFP capacity, AGNS developed concepts and costs for construction of a new building adjacent to the existing one.^{3,4} The two buildings would be connected by a canal for transferring spent fuel. This concept would utilize the fuel receiving and removing equipment of the existing FRSS, and the new building would house three 1300 MTU storage pools, the canal, and support equipment. These pools and the existing FRSS, configured to be compatible with the new pools and the canal, would provide a total plant storage capacity of 5,000 MTU for a typical loading of PWR and BWR fuel.

4.1.1.1.3 Fuel Disassembly/Repackaging

AGNS is also investigating a technique that would use existing BNFP facilities to transform spent fuel into a form that permits storing greater quantities in a given space. This technique disassembles and encapsulates spent fuel, taking advantage of existing capabilities in the headend hot cells, which, in the plant's originally designed reprocessing mode, would be used for shearing the spent fuel prior to processing. AGNS describes this technique in two recent reports,^{5,6} and concludes that it can lead to more than a doubling in storage capacity.

There is no operating experience with disassembly in this country, but the FRG has done it successfully as an operation preparatory to fuel shearing. AGNS finds considerable indication that the process could

TABLE 4-1 .

SPENT FUEL STORAGE CAPACITY USING
EXISTING BARNWELL FACILITIES
AND HIGH DENSITY CANISTERS AND RACKS

	Single Tier	Double Tier
	MTU	MTU
Fuel Storage Pool	1335	1335
Cask Unloading Pool	296	592
Fuel Transfer Pool	<u>202</u>	<u>424</u>
Total	1750 - 1833*	2351

*1750 MTU is the nominal capacity. Exact capacity will depend on the BWR/PWR storage mix.

be successfully performed in the BNFP hot cells and recommends a cold test of the process. However, Reference 5 concludes that disassembly and encapsulation has economic merit only if two conditions are met. First, the storage capacity without disassembly must be greater than about 1500 MTU and, second, the objective must be to about double the existing capacity. However, if the hot cell is already included in the purchase of the plant, then the disassembly technique is economic at the 400-500 MTU level, according to BNFP officials.

4.1.1.1.4 Radwaste Facilities

Use of the BNFP as an AFR spent fuel storage facility would require meeting radwaste disposal requirements for the contaminated liquid wastes generated during the receiving and storage of spent fuel. AGNS evaluated four modes of disposal [2, Appendix A] and found that the best approach depends strongly on the future of BNFP. First, they found that the original design of concentrating the liquid radwastes and storing them in the existing LLW storage tanks prior to solidification was most cost effective, but only if BNFP were operating as a reprocessing facility at the same time as, or in the near future after, startup of the FRSS. In that way the costs of concentration, storing, and disposing of the wastes could be shared between the AFR and processing activities.

Second, they found that if only the AFR mode is activated and future storage expansion is likely, then a cost-effective approach is to use a proven, but expensive, European system called VRS, or Volume Reduction and Solidification. VRS, which vaporizes liquids and encapsulates the solids in an asphalt binder, would require construction of a new building at BNFP. AGNS reports that this disposal technique has been in use since 1965 and that VRS plants are under construction at two nuclear power plants in the U.S.

Finally, if the current uncertainty regarding plant completion and expansion of storage capacity persists, AGNS believes the existing solidification unit, which has several technical disadvantages, but little capital costs, should be used, at least until expansion plans are firm.

4.1.1.1.5 Summary of AFR Expansion Potential

Table 4-2 summarizes the storage capacity options described by AGNS. Option 7, the addition of new pools, does not include the disassembly technique. Assuming AGNS disassembly information for options 5 and 6 can be applied to the new pool option, then an additional option that would provide double the Option 7 capacity, i.e. 10,000 MTU, would result from disassembly. It should also be noted that AGNS is currently engaged in a \$2.2 million, four-part study of the use of BNFP in the AFR mode. The scope of work includes (1) design of, and licensing support for, an AFR safeguards system; (2) design modifications, encompassing 68 different jobs, necessary for start-up of a 1750 MTU AFR facility; (3) a study of seismic characteristics for a spent fuel transfer canal as well as designs for rack densification for storage of 1750 MTU; (4) licensing documentation pertinent to the above. The completion of the study in the Spring of 1981 will enable AGNS to begin the procurement and construction phase upon appropriate authorization.

4.1.1.2 Need for an AFR Capability

Several studies of the need for away from reactor (AFR) storage have occurred since the 1978 BNFP options study.¹ (See Figure 4-3).

The most recent of these (DOE/NE-0002 January, 1980, Table 4-4) indicates a requirement for an AFR by 1981. Additionally, according to DOE officials, there are six reactors currently operating without

TABLE 4-2

SUMMARY OF BNFP AFR
STORAGE CAPACITY OPTIONS

Capacity¹

<u>Option</u>	<u>MTU</u>	<u>Reference</u>
1. Status Quo	400	3
2. High Density Canisters	830	3
3. Option 2 + High Density RACKs	1,830	2
4. Option 3 + Double Tier ²	2,350	2
5. Option 3 + Disassembly ²	3,370	6
6. Option 4 + Disassembly ³	4,320	6
7. A second Fuel Storage Pool Building	5,000	3
8. Option 7 + Disassembly	10,000	6

¹These figures assume a fuel mix of 60% BWR and 40% PWR.

²Racks are in double tier form in the Fuel Storage Pool, in one Cask Unloading Pool, and in the deep portions of the Fuel Transfer Pool.

³These capacities are scaled from Reference 6 (page 28) data, which are based on a 30% BWR and 70% PWR mix.

FIGURE 4-3: COMPARISON OF LATEST AFR REQUIREMENT ESTIMATES

* Base Case

**DOE 1980 Base Case with international fuel (DOE/ET foreign estimate (401)

REFERENCES: 7,8,9,10,11

TABLE 4-4

CUMULATIVE AFR STORAGE REQUIREMENTS
(MTU)

<u>Year</u>	<u>Cumulative U.S. Reactor Discharges</u>	<u>Upper Bound</u>	<u>Domestic AFR Requirements</u>	
			<u>Planning Base</u>	<u>Lower Bound</u>
1981	9,102	210	186	22
1982	10,900	334	200	97
1983	13,103	617	377	171
1984	15,740	962	529	233
1985	18,727	1,457	755	309
1986	22,312	2,238	1,047	385
1987	26,202	3,119	1,491	465
1988	30,425	4,091	1,905	556
1989	34,836	5,147	2,532	899
1990	39,360	6,405	3,277	1,586
1991	44,105	8,080	4,271	2,367
1992	48,965	10,061	5,534	3,219
1993	53,894	12,472	7,013	4,375

ASSUMPTIONS:

- o FULL CORE RESERVE MAINTAINED FOR ALL CASES
- o UPPER BOUND-CURRENT EXPANSION PLANS-NO TRANSSHIPMENT
- o PLANNING CASE-MAXIMUM POOL EXPANSION-NO TRANSSHIPMENT
- o LOWER BOUND-MAXIMUM POOL EXPANSION-WITH TRANSSHIPMENT
- o CUMULATIVE DISCHARGES BASED ON CURRENTLY OPERATING AND PLANNED REACTORS AND INCLUDES FUEL ALREADY SENT TO STORAGE AND PROCESSING FACILITIES. THE AFR REQUIREMENTS EXCLUDE THIS FUEL.

SOURCE: Spent Fuel Storage, DOE/NE-0002, January 1980

full core reserve (FCR) while they are being reracked, thus creating a short term need for the storage of 130 MTU in 1980. A more detailed assessment of the spent fuel storage situation in the U.S., and its potential negative impact on the future availability of nuclear generated electricity is given in Section 1.1.3.

With the indefinite deferral of reprocessing, the question has been raised as to the classification of spent fuel. Many have interpreted spent fuel to be waste. The National Academy of Sciences' Committee on Nuclear and Alternative Energy Systems (CONAES) rejects this interpretation, and considers it prudent to preserve spent fuel as a possible future resource. This stance reaffirms the need for spent fuel storage in the interim until a final decision on spent fuel reprocessing has been made.

The 1978 BNFP options study¹ devoted relatively little space to the AFR question. However, the following conclusions are given:

Utilization of the BNFP as a spent fuel storage facility whether as an action to implement the U.S. spent fuel policy or eventually under some multinational or international auspices, could contribute to U.S. nonproliferation and nuclear policy objectives.

Since the BNFP capacity could be modified and made available within less than three years (plus additional time required for completion of licensing), it could help to implement U.S. policy in a timely fashion, particularly to handle critical or emergency storage problems. However, AGNS has stated that it is not interested in utilizing the BNFP solely as a spent fuel storage site. Whether and in what way the BNFP could be used to store spent fuel will depend on the future attitude of AGNS on how the U.S. spent fuel policy is implemented. If the BNFP should be used as a spent fuel storage facility, additional storage space eventually could be constructed at the site.

Given the well-established need for away-from-reactor storage, the use of BNFP as an AFR is an important and viable option. In the AFR mode, BNFP could be used to store domestic, or foreign spent LWR fuel,

or both. (See Section 4.1.2.) Fuel could be stored indefinitely as an interim measure pending resolution of the unanswered questions of permanent spent fuel storage, processing, and breeder development.

4.1.1.3 Sources Used in Determining Schedules, Costs and Evaluation

Since DOE's 1978 study, AGNS has conducted several technical and economic studies to ascertain the potential of BNFP as an AFR storage facility.²⁻⁶ These studies, which AGNS did under contract with DOE, address the modifications required to make the existing facility suitable for AFR operations, various techniques for expanding capacity, their cost and scheduling. The referenced studies form the basis for much of the information in the programmatic descriptions given above and also for most of the cost and scheduling data in Sections 4.1.1.5 and 4.1.1.6.

Reference 2 details reracking and densification modifications; Reference 3 addresses new construction as well as densification; Reference 4 provides detailed cost estimates for both options; References 5 and 6 investigate the use of the disassembly technique.

Various sources were used for the evaluation of the AFR use option. They comprise the bulk of the references found at the end of this chapter as well as several already noted above. For example, NASAP and the Nuclear Non-Proliferation Act (NNPA) provided information regarding U.S. energy policy and nonproliferation policy. The NRC's environmental impact statement¹² forms the basis for the health and safety evaluation of Barnwell. Technical feasibility and cost effectiveness evaluations are drawn from the entire range of material provided by both AGNS and the government.

4.1.1.4 Cost and Schedule Assumptions

Cost figures and milestone estimates developed by AGNS rely on several assumptions that affect each of the expansion alternatives to varying degrees. These assumptions are generally optimistic regarding the resolution of the policy issues; any decisions or events that invalidate these assumptions could alter the time and cost figures considerably. On the other hand, DOE reports and testimony reflect a longer time frame for licensing.^{13,14} Additional time for environmental impact statements (EIS) in compliance with the National Environmental Policy Act (NEPA), subsequent public comment, and financial and other negotiations with AGNS must be factored in prior to actual federal procurement of BNFP. This would naturally lengthen the time before BNFP could be operational as a government AFR.

The following assumptions reflect the construction and operating costs and schedules developed by AGNS, with licensing and preacquisition time frames based on DOE and NRC information.

The assumptions are:

1. Federal acquisition of BNFP will be based on its use as a 1750-2350 MTU AFR-only facility.
2. The purchase price of BNFP is subject to agreement between AGNS and DOE. It is assumed that this price would be in a range between (a) the recovery of AGNS's sunk costs of \$362 million, representing the maximum BNFP purchase price; (b) the market value of an existing and comparable AFR (e.g., the GE Morris plant) calculated at \$105-154 million for BNFP; this represents the lower bound of the price range.
3. The draft site-specific Environmental Impact Statement (EIS) is assumed to be completed by DOE, as required by law, prior to government acquisition. Completion of the EIS represents the starting point of the schedule.

4. Twelve months is allotted for public comment on the completed EIS and government acquisition of BNFP is assumed to occur at the end of this period.
5. Engineering design, procurement, construction and capital outlay are assumed to commence, as planned, prior to the issuance of the license by NRC.
6. NRC licensing approval for AFR storage of spent fuel will be obtained in 32-36 months using the newly promulgated 10 CFR 72 license application as a basis. BNFP could also be approved under the existing 10 CFR 70 application; the same time frame would apply as under part 72.
7. NRC will approve licensing amendments for new storage pool construction in eighteen months after the amendments are submitted. Total licensing time required for new construction would therefore be 50-54 months.
8. Time for public hearings and court proceedings is included in the schedules.
9. The legal and licensing transportation issues regarding state and local approval and NRC, DOE, and DOT working agreements will be resolved expeditiously.
10. No foreign fuel is stored, or if it is, it has no impact on costs and schedules. This topic is developed further in Section 4.1.2.
11. For expansion alternatives that include fuel disassembly, the R&D program will prove the viability of the concept and successful licensing proceedings will take place.
12. The costs are based on FY-1978 dollars unless otherwise noted.
13. The costs assume use of the presently installed radwaste systems. AGNS estimates that if the FRSS is expanded in the future, it will be cost effective to install an advanced radwaste system at a cost of \$1.9 million [Reference 2, Appendix A]. Otherwise, the capital costs for radwaste are minor.

14. Transportation costs are not included.

15. Mothballing costs for the balance of the plant, i.e., other than the FRSS, if it is not used in conjunction with or in addition to the AFR operation, are not included.

4.1.1.5 Schedule

AGNS's September 1979 report² provides a schedule for developing the 1750- and 2350-MTU AFR storage capacity at BNFP. The total construction time required would be 30 months. The critical path for completing the expansion, given approval to do so, is to: (1) complete rack design; (2) complete rack engineering; (3) design the pool modifications to the cask unloading pool; (4) complete licensing documents; (5) obtain DOE approval; and (6) obtain NRC licensing review and inspection. Reference 3, also cites the 30-month schedule for the 1750- and 2350-MTU expansion, and, in addition, estimates 51 months to construct the 5,000 MTU facility.

Time will be saved by ongoing activities. Under contract to DOE, AGNS has already begun studies and tests of some aspects of the AFR development program.

Figure 4-5 gives the schedule developed from AGNS information in Reference 3 and from DOE and NRC sources. It gives a detailed planning schedule for the densification and pool expansion options.

AGNS gives no schedule for the disassembly and encapsulation capability, but Reference 6 does give a schedule for the R&D program now underway for DOE. It is to be completed in 1983. No specific time frame is given regarding implementation. However, the AGNS study⁶ does state that if BNFP faces saturation of pool space, the disassembly process could become operational more rapidly than a new pool, assuming NRC licensing approval and the availability of equipment.

FIGURE 4-5: SCHEDULE OF AFR EXPANSION OPTIONS FOR BARNWELL

4.1.1.6 Costs

All available cost data related to the AFR option for BNFP originate either from AGNS studies or in reports that reference AGNS sources. Tables 4-6 and 4-7 give capital and O&M cost estimates for the expansion options. There are no R&D costs associated with the AFR option with the exception of the disassembly technique now under study at BNFP. The R&D costs for this program are not currently available. Capital costs were derived from information in References 2, 3, and 15.

Year by year operating and maintenance costs were available for only the 5000 MTU alternative. The same information for the other alternatives is not currently available in documented form. However, AGNS officials estimate that annual charges for the 1750 MTU alternative are approximately 80% of the costs for the 5,000 MTU alternative. Table 4-7 gives the operating costs for the 5000 MTU expansion option through the first 11 years of the project. This schedule assumes storage begins after the fourth year into the project. Table 4-8 summarizes the O&M costs for the total 30 years of the project. Many of the same operating cost components that apply to the 5000 MTU option would apply to the other expansion options described in Table 4-6.

The operating costs do not include transportation costs, which are costs that must be considered in evaluating the merits of AFR storage in general, but not necessarily in evaluating Barnwell options. Also, the costs in Table 4-8 give a \$6.6 million/year average operating expense. This figure does not include disassembly operating costs, since the 5000 MTU option concept does not use disassembly. References 5 and 6 estimate operating costs for disassembly at \$1.7 million/year.

TABLE 4-6

CAPITAL COSTS
FOR AFR EXPANSION OPTIONS
(Millions of 1978 Dollars)

Expansion Option	Year After Year After Acquisition						TOTAL	TOTAL WITH PURCHASE (1979 DOLLARS)
	1	2	3	4	5	6		
Government Purchase*	105 - 362							105 - 362
1. Existing FRSS (400 MTU)	1.5**						1.5	106.5 - 363.5
2. High Density Canisters (830 MTU)	2.0	8.1	5.9				16	121 - 378
3. High Density Racking (1750 MTU)	1.6	11.0	7.4				20	125 - 382
4. Option 3 & Double Tier (2350 MTU)	2.0	13.8	9.2				25	130 - 387
5. Option 3 & Disassembly (3770 MTU)	5.6	34.5	22.9				63	168 - 425
6. Option 4 & Disassembly (4320 MTU)	6.0	37.3	24.7				68	173 - 430
7. Option 3 & Second Fuel Storage Building (5000 MTU)	3.6	16.3	27.3	48.9	12.9		109	214 - 471

*The purchase price figure is the expected range, and is added to each option's capital cost (1979 dollars).

**1.5 million is the cost of the physical security system.

TABLE 4-7

O & M COSTS
FOR AFR EXPANSION ALTERNATIVES
(Millions of 1979 Dollars)

YEAR	1	2	3	4	5	6	7	8	9	10	11
O&M Costs for 5000 MTU	4.6	4.6	4.6	4.6	9.3	9.3	9.3	9.3	6.0	6.0	6.0
Estimated O&M Costs for 1750 MTU	3.7	3.7	3.7	3.7	7.4	7.4	7.4	7.4	4.8	4.8	4.8

TABLE 4-8

O&M COSTS FOR 5,000 MTU AFR SPENT
FUEL STORAGE AT BNFP

<u>Mode of Operation</u>	<u>Years of Operation</u>	<u>Annual Operating Expenses \$ Million</u>	<u>Cumulative Operating Expenses \$ Million</u>
Pre-operation	4	4.63	18.52
Receiving	4	9.26	37.04
Caretaker	15	6.03	90.45
Removal	4	9.26	37.04
Decommission	3	4.63	<u>13.89</u>
Approximate total for 30 years			\$197.0M
Average yearly cost for 30 years			\$ 6.6M
Total capital and operating cost for 30 years			\$306.0M

[REFERENCE 4]

4.1.1.7 Evaluation Criteria

4.1.1.7.1 Technical Feasibility

The BNFP will utilize existing and proven technology in the AFR Mode. Reracking is a technique currently used for at-reactor (AR) storage and should present no problems for use at BNFP. Even double-tier racking, which may create problems in inspection, is technically feasible for increasing storage pool capacity. The fuel disassembly and repackaging technique is still in development, however. This is discussed in Section 4.1.1.1.3. The necessary water purification and waste management techniques are also well developed.

4.1.1.7.2 Cost Effectiveness

DOE has recently issued a report, completed at the Savannah River Office,¹³ comparing the fuel storage costs of reracking, new at-reactor basins and AFR basins. The results are summarized in Table 4-9.

These are interesting relative to the cost effectiveness of AFR's in general versus the use of AR basins. To complete this comparison, one would have to get into site specific analyses since the costs of transportation and handling would have to be taken into account.

The general conclusion is that AR storage can compete economically with AFR storage only if a utility has reactor sites with spent fuel storage requirements of about 100 MTU/year or more. There are, however, very few utilities with such a large annual storage need.

The cost effectiveness of BNFP as an AFR versus other AFRs available to the government (GE Morris and NFS West Valley) must be analyzed. Of the two available only the former is large enough to be of interest

TABLE 4-9.

RERACKING, AR, AND AFR STORAGE CHARGES

<u>Mode</u>	<u>Storage Requirement MTU/Yr.</u>	<u>Basin Capacity MTU</u>	<u>Capital Cost \$ Millions</u>	<u>Unit Capital \$/kg</u>	<u>Annual Cost* \$ Millions</u>	<u>Unit Cost \$/kg</u>
Reracking	25	400	2.8	7	0.4	16**
AR						
1 reactor	25	500	40	80	8.0	320
2 reactors	56	1,100	52	47	10.4	185
3 reactors	96	1,900	66	35	13.2	137
AFR	1,000	5,000	250	50	--	130

*Assuming a 15% fixed charge rate and 5% operating except for reracking, which requires no incremental operating cost.

**The reracking plan assumes a 200 MTU basin to 400 MTU by adding poisoned racks at \$7/kg.

as a national AFR. The GE Morris plant is already licensed and is storing spent fuel. Reracking will expand its storage capacity from 350 MTU to 1100 MTU. The Morris plant is under consideration by DOE for use as a federal AFR.

While the final purchase price of GE Morris is subject to negotiations, a range of \$30-60 million, including reracking, has been estimated after conferring with GE officials. Using the higher figure of \$60 million and a capacity of 750 MTU (the uncommitted capacity available at Morris after reracking) results in a unit cost of \$80,000/MTU. Assuming a reracked capacity at BNFP of 1750 MTU, BNFP would have to be available at a price of \$154 million to be cost competitive with GE Morris. This comparison, plus an estimate for a new AFR, are shown in Table 4-10.

This cost effectiveness analysis would not be valid, of course, if the BNFP was purchased to serve any additional use(s).

4.1.1.7.3 Support of National Energy Policy

Since the nuclear option has a stated role in U.S. energy policy and since a national AFR is felt to be desirable in support of this option (see Sections 1.1.4 and 4.1.1.2) the use of BNFP as an AFR would be supportive of this policy.

Additionally, new initiatives on waste policy by the Administration further underline the possible use of BNFP as an AFR. A variety of media are to be explored for geologic storage; until successful resolution of ultimate disposal, interim storage of spent fuel will be necessary.

TABLE 4-10

COST COMPARISON OF BNFP
(1979 dollars)

<u>Possible BNFP Purchase Price</u>	<u>UNIT COST \$/MTU</u>
154,000,000 ¹	80,000
250,000,000 ²	50,000
362,000,000 ³	206,000

¹Based on \$60 million for purchase of Morris facility

²Based on construction of new 5,000 AFR MTU (Reference 13)

³Purchase price based on sunk costs by AGNS

4.1.1.7.4 Support of National Nonproliferation Policies

The nonproliferation contribution of using BNFP as a domestic AFR, would be sharply constrained if there were no provision for storage of foreign spent fuel. Unless there were such a provision, this use-option would be unable to offer any relief to congestion of spent fuel storage facilities abroad and would not provide an alternative to early foreign reprocessing where driven by spent fuel management concerns. It, furthermore, would not contribute to fulfilling the President's offer to retrieve limited amounts of foreign spent fuel for storage here.

The nonproliferation advantages of a domestic AFR option, with no storage of foreign spent fuel, would be confined to relieving pressure emanating from domestic spent fuel management concerns that might otherwise influence U.S. reprocessing decisions. Relief of such pressure would give the U.S. greater flexibility in determining the pace and purpose of reprocessing in the U.S. This option, moreover, would demonstrate that interim spent fuel storage is a viable alternative to early reprocessing. A domestic AFR also would provide a means of centralizing the location of spent fuel for the purpose of applying safeguards more effectively. Nevertheless, the nonproliferation benefits attributable to an AFR depend in part upon the strategy for ultimate disposition of the spent fuel (e.g., encapsulation and burial, reprocessing), since storage at the AFR would be of finite duration.

4.1.1.7.5 Health, Safety, and Environmental Aspects of BNFP as an AFR

The material in this section is based on the Generic Environmental Impact Statement from NRC.¹² As noted in Section 4.1.1.7.1, the storage of spent fuel in water pools is a well established technology

and represents a "low environmental impact and low potential risk to the health and safety of the public." Modifications to increase storage capacity are adequately covered by existing regulations and regulatory practices; new regulations (Part 72) are being promulgated to cover AFRs in particular.

According to Reference 12, based on existing water pool storage technology, it makes an insignificant environmental difference whether the spent fuel is stored at-reactor or at an AFR. The sintered ceramic oxide fuel pellets are sealed in zircaloy cladding tubes which have a high resistance to oxidation in water. Minor impacts to the environment may occur from the transfer of heated water or vapor to the environment; drift from cooling towers; local fogging and increased humidity. All of these impacts can be reduced at reasonable costs. NRC has precedence for the treatment of corrective solutions in various licensing measures.

The human health and safety impacts of AFR storage are mitigated considerably due to the relatively inert conditions of spent fuel in storage. Increased AFR storage normally only involves aged fuel. Volatile and non-volatile compounds containing radionuclides with short half-lives will have decayed to negligible levels. Underwater storage of aged spent fuels is an operation involving an extremely low risk of catastrophic release of radioactivity.

4.1.2 Use of BNFP as an International AFR

4.1.2.1 Description

BNFP could also be utilized as an international AFR in support of U.S. nonproliferation objectives. Its use is viewed as a subset of the domestic AFR option. The U.S. would be unable to provide storage

facilities for foreign spent fuel without having its own storage capacity as well. The term "international" as used in this section refers to spent fuel of non-U.S. origin. It does not refer to ownership or management of the BNFP. See Section 6.0, Integration of Institutional and Use Options.

In April 1977, President Carter announced that as part of his policy to defer reprocessing, the U.S. would accept limited quantities of foreign spent fuel. It was intended as a contribution towards international and national resolution of the spent fuel problem. U.S. storage of limited quantities of foreign spent fuel is designed to demonstrate the feasibility of alternatives to the premature reprocessing of spent fuel and plutonium recycle. Accepting custody of foreign spent fuel may be one of the most effective means of controlling nuclear proliferation, by introducing a degree of flexibility into international planning for the nuclear fuel cycle.¹⁶ The U.S. interest is broader, however, than just controlling spent fuel; it also hopes to further the nuclear power interests of others.

BNFP would have to be licensed and operational within the U.S. regulatory system before it could begin to receive and store foreign spent fuel. Since it would be primarily a national AFR, expansion, construction, and licensing would be under jurisdiction of the NRC while the importation of foreign spent fuel would fall under the review of various other government agencies. BNFP's use as an international AFR would entail the same expansion alternatives as set forth. Additional modifications to the plant might be necessary due to variations in foreign spent fuel and cask characteristics that may require different types of handling and storage service equipment. As much foreign spent fuel could be stored as capacity and public acceptance will allow.

Foreign fuel is projected to have a relatively small impact on domestic AFR storage requirements. Estimates of the percentage of foreign spent fuel range between 10% and 20% of total fuel in AFR storage in the U.S. by 1990, and are not expected to total any more than 1000 MTU in that time period. Therefore a reracked or expanded BNFP could accommodate a large proportion of the foreign spent fuel requirement in addition to its primary function as a domestic AFR. The amount of foreign spent fuel that is currently projected for storage in the U.S., along with domestic requirements, (the planning base currently used by DOE; requirements could be more or less)⁷ is shown in Table 4-11.

4.1.2.2 Need for an International AFR

The interest in using BNFP for storage of foreign fuel stems primarily from the potential support of such a move for U.S. nonproliferation policies. Spent fuel storage is beginning to be a problem in several countries as the storage pools at reactor sites are becoming filled. Table 4-12 indicates the amount of spent fuel discharged world-wide in 1978, and anticipated in 1980, 1985, and 2000.

4.1.2.3 Sources Used in Determining Schedules, Costs, and Evaluation

The sources used in determining schedules and costs for bringing the BNFP on-line as an AFR are discussed in Section 4.1.1.3, and cited in the reference list after Section 4.1.2.7.5.

The material utilized in evaluating the use of BNFP as an international AFR were the Nonproliferation Alternative Systems Assessment Program (NASAP),¹⁰ the International Nuclear Fuel Cycle Evaluation (INFCE),^{17,18} the Draft Environmental Impact Statement on the Storage of Foreign Spent Power Reactor Fuel,¹⁹ the Evaluation of the Administration's Proposed Nuclear Nonproliferation Strategy by the GAO,¹⁶ and questions and answers on spent fuel from the Interstate and Foreign Commerce Committee to DOE.¹⁴

TABLE 4-11

CUMULATIVE AFR STORAGE REQUIREMENTS

(MTU)

Domestic AFR Requirements

<u>Year</u>	<u>Cumulative U.S. Reactor Discharges</u>	<u>Planning Base</u>	<u>Foreign Requirements</u>	<u>Planning Base Total (U.S. & Foreign)</u>
1981	9,102	186	50	236
1982	10,900	280	100	380
1983	13,103	377	220	597
1984	15,740	529	340	869
1985	18,727	755	435	1,190
1986	22,312	1,047	575	1,622
1987	26,202	1,491	690	2,181
1988	30,425	1,985	885	2,870
1989	34,836	2,532	1,000	3,532
1990	39,368	3,277	1,000	4,277
1991	44,105	4,271	1,000	5,271
1992	48,965	5,534	1,000	6,534
1993	53,894	7,013	1,000	8,013

ASSUMPTIONS:

- o FULL CORE RESERVE MAINTAINED
- o PLANNING CASE-MAXIMUM POOL EXPANSION-NO TRANSSHIPMENT
- o FOREIGN DEMAND-OPTION 2 OF DOE/ET-0040-D-DRAFT EIS ON STORAGE OF FOREIGN FUEL
- o CUMULATIVE DISCHARGES BASED ON CURRENTLY OPERATING AND PLANNED REACTORS AND INCLUDES FUEL ALREADY SENT TO STORAGE AND PROCESSING FACILITIES. THE AFR REQUIREMENTS EXCLUDE THIS FUEL.

SOURCE: Spent Fuel Storage, DOE/NE-0002, January 1980.⁷

TABLE 4-12

Cumulative Spent-Fuel Arisings in 1978 and
Projected to 1980, 1985, and 2000
(tons of uranium)

Country	1978	1980	1985	2000
Argentina	----	620	1,890	15,290
Austria	----	----	110	440
Belgium	64	196	764	3,702
Brazil	----	----	92	7,600
Canada	2,366 ^a	2,500	8,310	65,300
Denmark	----	----	----	680
Egypt	----	----	92	373
Finland	----	56	396	2,014
France	----	----	2,900	19,000
Federal Republic of Germany	165	655	3,065	21,490
Greece	----	----	----	461
India	50	210	876	7,900 ^d
Iran	----	----	361 ^d	6,697 ^e
Italy	51	73	344	
Japan	720 ^b	1,000 ^f	3,900	30,000
South Korea	----	16	347	7,663
Mexico	----	----	80	2,740
Morocco	----	----	----	221
Netherlands	18	53	140	1,767
Philippines	----	----	33	462
Portugal	----	----	----	1,202
South Africa	----	----	72	1,592 ^e
Spain	^e	60 ^c	732	^e
Sweden	120	420	1,400	
Switzerland	252	320	787	2,164
United Kingdom	100	300	1,000	8,400
Total	3,906	6,479	27,691	207,158

^a Canada, 1976

^b Japan, 1976

^c Spain, 1977

^d Excluded from total due to uncertainty in plans

^e Not available

^f Not available; estimated

SOURCE: Vol. III, Resources and Fuel Cycle Facilities, NASAP.
Draft December 1979.

Cost and scheduling sources covering necessary modifications to BNFP in order to handle foreign spent fuel were unavailable.

4.1.2.4 Assumptions Made in Determining Schedules, Costs, and Evaluation

Assumptions made regarding the cost and scheduling of the basic AFR are treated in Section 4.1.1.4.

The following assumptions are applicable to the use of BNFP as an international AFR.

1. The use of BNFP as an international AFR is based on furthering U.S. nonproliferation objectives, not merely to alleviate foreign spent fuel storage congestion.
2. BNFP would be already licensed and operational as an AFR.
3. Any necessary modifications to BNFP to accommodate foreign spent fuel are assumed to be completed and licensed.
4. The NRC, Department of State, or other appropriate agency will approve the importation of foreign spent fuel into the U.S.
5. There are no serious technical problems introduced by the foreign fuel.

4.1.2.5 Schedule

The schedule of the expansion alternatives of the basic BNFP facility are covered in Section 4.1.1.5. The schedule for modifications, if any, required to receive and store foreign spent fuel is unavailable.

4.1.2.6 Costs

Costs for bringing BNFP on-line are described in Section 4.1.1.6. Costs associated with modifying the plant to accommodate foreign spent fuel are assumed to be recovered from the owners of the fuel and are not included here.

4.1.2.7 Evaluation

4.1.2.7.1 Technical Feasibility

According to Reference 14, no particular technical problems are anticipated in handling and storing foreign spent fuel. Foreign LWR fuel, supplied by the U.S. or geometrically similar to U.S. LWR fuel, is fully compatible with planned BNFP storage facilities.

Foreign LWR fuel of differing specifications (i.e., upper end fittings; lengths; planview envelopes) might require storage modifications at BNFP. This may, in turn, result in non-optimal use of the storage facilities from a management standpoint.

Additionally, design modifications may be required for some of the spent fuel handling facilities, cranes, etc., to accommodate diverse types of spent fuel casks. However, conversations with Barnwell officials indicate these modifications would be minor.

Non-LWR fuel presents definite problems for storage at BNFP. HWR fuel, for example, cannot be placed for long periods in storage pools as there is leakage due to water corrosion. These problems can be overcome, however, by placing the fuel in canisters at some cost in capacity.

4.1.2.7.2 Cost Effectiveness

The cost-effectiveness of BNFP as a national AFR is evaluated in Section 4.1.1.7.2.

As an international AFR, the cost of foreign spent fuel transportation will detract from the cost-effectiveness of this option. Intercontinental fuel shipment ranges from \$80,000-120,000/MTU.¹⁷

As discussed in Section 4.1.2.7.1, cost incurred in plant modification would also lessen the cost effectiveness of using BNFP as an international AFR.

DOE has stipulated¹⁴ that if foreign fuel is accepted for storage and disposal, a charge would be assessed to recover the full cost of the services. To the extent that this storage fee mitigates the transportation costs and the incremental costs incurred by the modifications required to handle foreign spent fuel, the international AFR option for BNFP becomes more cost effective (to the U.S.).

4.1.2.7.3 Support for National Energy Policies

The benefits of using BNFP as an AFR to support U.S. energy policy is described in Section 4.1.1.7.4.

As an international AFR, BNFP would continue to receive and store U.S. spent fuel and, hence, contribute to U.S. energy policy. However, as foreign spent fuel displaces the storage space available for U.S. spent fuel, it decreases the positive impact on U.S. energy policy.

4.1.2.7.4 BNFP as an International AFR in Support of U.S. Non-proliferation Objectives

An international AFR, in which foreign spent fuel was included for storage, would offer a direct means to provide relief to spent fuel storage pressures abroad that might otherwise encourage early reprocessing. In doing so, this option would ensure that spent fuel retrieved and stored at BNFP could be safeguarded to the satisfaction of the U.S. An international AFR would provide a means to carry out the President's offer to retrieve and store a limited amount of foreign spent fuel.

The actual impact of the international AFR option, however, would be constrained by the amount of fuel that could be stored. This option might be one of several available to foreign countries, including expansion of at-reactor storage, national AFRs, and reprocessing by parties other than the U.S. As the President's offer to store limited quantities of foreign spent fuel recognized, the international AFR is a complement to other spent fuel management options, and it is highly unlikely that, except in a few cases where a particular country's spent fuel was sufficiently small to be accommodated by this option, the use of the BNFP as an international AFR would offer a comprehensive alternative to other spent fuel management strategies. Not to offer this service, however, would deprive the U.S. of a potentially important instrument to influence foreign fuel cycle policies.

Discussions of spent fuel storage within INFCE indicate that the institutional and legal framework governing spent fuel storage is crucial to the effectiveness and acceptability of an international AFR. This framework would address such matters as the purpose of the AFR, who participates and how discussions are arrived at, as well as safety and environmental regulation and the application of safeguards.

The nonproliferation gains of this option must be considered in light of the ultimate disposition of the stored spent fuel. How the AFR relates to reprocessing, and the institutional and technical nonproliferation measures at that step in the fuel cycle, is of direct significance to the level and duration of the nonproliferation gains achieved through the AFR itself. This consideration is particularly relevant to the institutional arrangements governing retrieval of spent fuel from the AFR.

4.1.2.7.5 The Impact of BNFP as an International AFR on Health, Safety, and Environment

The health, safety, and environmental aspects of AFR storage are treated in Section 4.1.1.7.5.

The Draft Environmental Impact Statement (EIS) on the storage of foreign spent fuel in the U.S. concludes that for all the alternatives considered, domestic resources will be consumed and small amounts of radioactivity will be released to the environment. However, analyses show that there are no significant radiological health impacts resulting from implementation of this policy.

Some incremental environmental hazard is also involved because foreign spent fuel will introduce additional sources of radiation into this country. But in comparison to the risks involved in shipping and storing domestic spent fuel, the additional risk introduced from foreign fuel is marginal.

Environmental and safety problems due to increased spent fuel shipment may exist, but recent experience with intercontinental shipment of spent fuel to and from Europe and Asia has been favorable.

Experience has also shown with respect to safety questions that the current systems are adequate and that no problems are expected.¹⁹

REFERENCES

1. Barnwell Nuclear Fuels Plant Applicability Study, Three Volumes, U.S. Department of Energy, April 1978.
2. Converting Reprocessing Plant's Fuel Receiving and Storage Area to an Away-From-Reactor (AFR) Storage Facility, Final Report, Jim E. Cottrell et al, Allied General Nuclear Services, AGNS-35900-1.3-32, September 1979.
3. LWR Spent Fuel Storage, Frank A. Shallo, Allied General Nuclear Services, AGNS-1040-1.4-20, August 1978.
4. Life of Project Operating Expenses for Away-From Reactor (AFR) Spent Fuel Storage Facility, Final Report, Frank A. Shallo, Allied General Nuclear Services, AGNS-35900-1.3-2, September 1979.
5. Spent Fuel Disassembly and Canning Programs at the Barnwell Nuclear Fuels Plant (BNFP), G. A. Townes, et al, Allied General Nuclear Services, AGNS-35900-1.2-45, October 1979.
6. Spent Fuel Disassembly: Increasing Hot-Cell Storage Capacity at the Barnwell Nuclear Fuel Plant, Robert T. Anderson, Allied General Nuclear Services, AGNS-3590-1.3-47, October 1979.
7. Spent Fuel Storage Requirements - The Need for Away-From-Reactor Storage, U.S. Department of Energy, DOE/ET-0075, February 1979.
8. Federal Facilities for Storing Spent Nuclear Fuel - Are They Needed, U.S. General Accounting Office, EMD-79-82, June 27, 1979.
9. Spent Fuel Storage Requirements - The Need for Away-From-Reactor storage, an DOE/NE-0002, January 1980.
10. "Nuclear Proliferation and Civilian Nuclear Power" NASAP. Resources and Fuel Cycle Facilities, Volume III, DOE Draft Report, December 1979.
11. "Final Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel," U.S. Nuclear Regulatory Commission, NUREG-0575, August 1979.
12. Final Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel, U.S. Nuclear Regulatory Commission, NUREG-0575, August 1979.
13. "Spent LWR Fuel Storage Costs, Reracking, AR Basins, and AFR Basins" U.S. Department of Energy Savannah River Plant; Aiken, South Carolina, DOE-SR-SF-2002 Rev. 1, January 1980.

14. Questions and Answers regarding Spent Fuel Storage from the Interstate and Foreign Commerce Committee (Rep. Dingell) to the Department of Energy, January 1980.
15. Statement Submitted to the Subcommittee on Energy and Power of the Committee on Interstate and Foreign Commerce, U.S. House of Representatives, by L. J. Colby, Jr. of Allied Chemical Corporation and James A. Buckham of AGNS, June 26, 1979.
16. An Evaluation of the Administration's Proposed Nuclear Non-proliferation Strategy Government accounting Office, October 4, 1977.
17. International Nuclear Fuel Cycle Evaluation (INFCE) Working Group 6 Spent Fuel Management Summary, October 31, 1979.
18. INFCE Report of Working Group 6, Spent Fuel Management, November 1979.
19. Draft Environmental Impact Statement. Storage of Foreign Spent Power Reactor Fuel DOE/EIS-0040-D, December 1978.

Additional Sources

1. Spent Fuel Management Program Study Summary Option Paper, Tennessee Valley Authority, May 1979.
2. Alternatives for Water Basin Spent Fuel Storage; Five Volumes, Nuclear Assurance Corporation; SRO-1051-1,2,3,4, and 5; NAC-C-7915, 7916, 7917, 7918, and 7919, September 1979.
3. Proceedings of Workshop on the Management of Spent Fuel and Radioactive Wastes, Atomic Industrial Forum, 16-19 September 1979.
4. Energy Daily Volume 8, Number 31 February 15, 1980.
5. Nuclear Non-Proliferation Act of 1978.

4.2 REPROCESSING OPTIONS

4.2.1 Uses of BNFP In Support of a Program of LWR Recycle

This would be the use for which the plant was designed. Pu and U would be separated from the LWR fission products, and the U, in the form of UF_6 would be shipped out for re-enrichment. The PuO_2 would be sent to a MOX fuel fabrication facility, and the radioactive waste immobilized and shipped for disposal elsewhere.

There are a number of steps that would have to precede the use of the BNFP for this purpose:

- Acquisition of the plant by the U.S. government.
- Completion of the plant as designed, primarily the addition of a Pu conversion and HLW immobilization facilities.
- Licensing of the plant to operate in this mode.
- A shift in the present Administration's policy against reprocessing for LWR recycle.

There are three specific uses presented and analyzed herein for the BNFP in support of a program of LWR recycle:

- As a facility for development of a national capability to recover Pu and U from spent LWR fuel (4.2.1.1).
- A facility for production of PuO_2 and UF_6 from LWR spent fuel (4.2.1.2).
- A developmental and/or production facility for immobilization of LWR HLW (4.2.1.3).

4.2.1.1 Use of BNFP as a Facility for Development of a National Capability to Recover Pu and U from Spent LWR Fuel

4.2.1.1.1 Description of This Use Option

This section describes the configuration of the BNFP for this use, and discusses items yet to be completed. Very basically, BNFP could be utilized to accept spent fuel from current design light water reactors, produce uranium hexafluoride (UF_6) and plutonium dioxide (PuO_2) and solidified waste as output, for an additional capital outlay to complete the plant of approximately \$580 million (1978) over "sunk costs". This figure should be considered a very crude estimate. The following discussion will elaborate on the definition of, and assumptions regarding the completion and checkout of the plant, ready to start producing PuO_2 , or UF_6 , or both, and immobilizing its wastes.

BNFP was designed to reprocess spent fuel from current LWR reactors using the PUREX process. The fuel is assumed to be first cycle, low enriched uranium (LEU) fuel, irradiated to a burnup of approximately 33,000 MWD/ton, and containing approximately 1% Pu. This PUREX process involves: chopping the spent fuel into pieces; leaching the contained spent fuel from the cladding "hulls" with nitric acid (HNO_3); separating the uranium and plutonium from fission products by preferentially extracting them into an organic solvent (tributyl phosphate (TBP) and a hydrocarbon diluent); and then separating the uranium and plutonium by selective extractions. The Barnwell design performs three cycles of plutonium extraction before achieving a purified solution to concentrated plutonium nitrate as an intermediate product. There are two cycles of uranium extraction and filtration through silica gel before the intermediate uranium product, uranyl nitrate, is produced.

The facility for the PUREX process described above is part of the BNFP as it exists today. The annual design capacity of this process at BNFP is 1500 metric tons of uranium (MTU), assuming 250 operating days/year, 6 MTU daily. The fuel receiving and storage station is the other major component of the Separations Facility. It provides for the receipt, storage, and pre-separation handling of spent fuel assemblies. As built, there is capability to store 400 MTU of fuel. All loading and unloading operations on fuel assemblies are performed here under water, which acts as a radiological shield and as a cooling mechanism for removing decay heat.

There are two other major facilities currently in place at Barnwell: the UF_6 conversion plant for converting uranyl nitrate to UF_6 , and the liquid waste storage facilities. In the liquid waste storage facility, intermediate level liquid waste (ILLW) and high level liquid waste (HLLW) can be stored in storage tanks.

In addition, there exists a variety of central systems for the servicing of BNFP, including ventilation, fire protection, electrical power, and laboratory services, among others.

There are several major systems which were never constructed, and which would be needed for the operation of BNFP as an LWR fuel re-processing plant. EPA requirements expressed in 40 CFR 190 were developed subsequent to the original plant design and which imply the need for a radioactive krypton-85 ($Kr-85$) recovery and storage system. Estimated costs for this were added in this study option. Two other important additions required would be a plutonium conversion facility, and additional waste management facilities, including a waste solidification plant and three additional liquid waste storage tanks.

Transportation safety considerations preclude shipping highly radioactive liquids offsite, and there are regulatory criteria which dictate that HLLW not be stored more than five years (although lack of a decision regarding ultimate waste form has interfered with the implementation of this criteria). Thus, it is required that both the waste solidification and the plutonium conversion facilities be constructed at the BNFP site before reprocessing can be conducted over an extended period.

The waste solidification process considered here is based on a glassified waste form. In particular, the vitrification process assumed is one using in-can melting to produce a borosilicate glass which incorporates the calcined PUREX waste. The technologies involved have been demonstrated on a small engineering scale at Battelle Northwest, and are now being utilized in production of solidified HLW in France.

The Pu conversion process, as originally conceived, requires some additional development, but is nearly designed at a detailed level. It will produce a fully decontaminated, isolated PuO_2 product. To do this, the oxalate precipitation process will be used. Although it has never been used on this scale for Pu conversion, it is a demonstrated process, in the DOE facilities at Hanford, Washington. Development is required to facilitate handling of powders, to demonstrate certain remote handling techniques, to determine certain reaction rates, and to demonstrate the chemistry of a scrap recovery process on an industrial scale.

Aside from these major additions, there are miscellaneous necessities for extended hot operation. Interim solid waste storage and a non-destructive assay (NDA) facility for solid waste would be needed to complete the requirements for hot operation of the BNFP as an LWR fuel recycle plant. AGNS studies have also concluded that a need

exists for additional liquid waste storage tanks and solid waste volume reduction (compaction and incineration) capability. On the basis of their potential economies of operation and contribution to reduction of environmental impact, they have been included. Possible addition to the spent fuel storage capability was covered in the discussion of the AFR option (Section 4.1.1). Another on site construction possibility would be a fuel fabrication facility. This addition will be considered under the International Fuel Service Center option (Section 4.2.4).

To summarize, the requirements for completion of the BNFP have changed little since the 1978 study. Some regulatory developments in the areas of radwaste treatment and safeguards have affected these requirements. Additional study by AGNS staff has also affected their perception of needs for facility use. On the whole, however, the changes are not significant compared to the greater uncertainties inherent in the balance of the evaluations.

4.2.1.1.2 Indications of Need/Interest/Support for This Use of BNFP

In assessing sensitive fuel cycle activities, U.S. nonproliferation policy takes into account both proliferation risks and economic and energy security considerations. Given its marginal economic benefits and high proliferation risks, LWR recycle is viewed as an activity which should be avoided or deferred for the foreseeable future.

The economics of LWR recycle depend on three important factors -- the cost of reprocessing, the cost of virgin U_3O_8 , and the efficiency of the LWR once-through fuel cycle.

The cost of reprocessing on a commercial scale is unknown since there is no data except for a reported price from the French of 750 \$/kg.

NASAP has projected an estimate of 370 \$/kg, or \$168/lb. Although little other than educated guesses are available regarding the amount of U₃O₈ available at the \$100/lb level, several studies conclude that, in combination with the anticipated efficiencies in the LWR fuel cycle, there would be sufficient U₃O₈ available to keep the once-through cycle cost-competitive with LWR recycle at least into the next century.

The utility industry, however, still appears to be supportive of the LWR recycle concept if the economics justify its use. Additionally, others believe that any means by which domestic fuel resources can be extended is deserving of serious consideration.

However, the proliferation risks of LWR recycle, combined with the absence of a clear-cut economic advantage, appear to put the political and economic feasibility of this use option in serious doubt for the foreseeable future.

4.2.1.1.3 Sources Used in Determining Schedules, Costs, and Evaluation

The information upon which the description of this option, its schedule, and costs were based has been culled from existing sources. The sources of principal interest and utility are References 1-4 on the Reference list which appears after Section 4.2.5.2.4.

Other sources were reviewed but found not to have significant impact with respect to this case. They included the Alternative Fuel Cycle Evaluation Program (AFCEP) summary reports (Hanford Engineering Development Laboratory, 11/79), and some associated documentation from Dupont and Exxon regarding reprocessing costs. These sources were of limited utility since they dealt with cases not specifically applicable to BNFP, in some cases referred to Reference 1 above, and would,

therefore, not change the information we used, given the potential variable in the estimates we are utilizing. Additional references for this option are listed in the Reference list.

4.2.1.1.4 Assumptions Made in Determining Schedules, Costs, and Evaluation

In addition to the definition of this option outlined, the following assumptions have been made in order to bound this specific option and address specific estimates of cost and schedule:

- In order to establish a demonstrated U.S. LWR fuel reprocessing capability all of the processes must be tested at commercial scales this option would stop short of operating at that level for extended time.
- There are several assumptions that are pertinent to the development of cost and schedule data for all LWR fuel recycle cases. They are summarized here:
 1. The facility/process would be completed to the design originally intended (except as noted).
 - a. In particular, oxalate precipitation is assumed for the conversion of Pu nitrate to PuO_2 . The effect of changing this assumption would be felt not only on the Pu conversion plant, but also on the waste treatment facilities.
 2. Sunk costs were escalated to 1978 levels from early 1970 levels. Other costs were also adjusted to 1978 level. In particular mid-1979 costs were adjusted downward by 10%, as a rough inflation compensation.
 3. The plant, when complete, would operate at the full annual design capacity of 1500 MTU for the separations facility, and all other processes would be scaled accordingly.

4. Spent fuel storage basins will not require expansion. (However, see AFR option, Section 4.1.1).
5. An environmental impact statement would be completed prior to the decision to acquire BNFP for government use. Actual procurement of the facility would take place after final acceptance of the EIS, which is assumed to take one year.
6. Two years of planning and design would be required prior to the submission of an application for a construction permit (CP). Another two years would be required to process the CP.
7. The operating license (OL) would be processed in parallel with construction, and would take no longer than the construction schedule already requires.
8. Recent R&D cost estimates were unavailable from AGNS; it appears that these, and other engineering costs were included in capital cost estimates. This convention is assumed.
9. Certain portions of the schedule were adapted from several existing sources, and arbitrary but reasonable breakdowns were made of single design and construction estimates into separate design and construction figures.
10. Cost figures were allocated by IEAL in a reasonable but arbitrary fashion across years in accordance with the schedule.
11. Most of the source estimates of cost are claimed to be within a tolerance of ±25%.
12. Most recent estimates were not used for capital costs of the Pu conversion and storage facility, since they assumed some form of co-processing. We felt that lower, earlier figures were more representative of the case of LWR fuel reprocessing as originally intended. (See Section 4.2.3 for discussion of proliferation resistant fuel cycles.)

13. Only the capital costs are shown, for comparability with the 1978 applicability study. Other costs, such as owner's costs during construction, interest on the construction debt, etc., are not included. Some information relevant to these economic factors is included in the AGNS study.³
14. See Section 4.2.5 for an assessment of the BNFP design, and potential implementation difficulties.

It should be noted that large uncertainties in regulatory criteria (especially for waste management and safeguards), and economic factors cast doubt upon the ultimate validity of the foregoing assumptions, and the associated cost and schedule estimates. Major portions of the facility are not yet designed. There is no commercial scale experience in the U.S. with much of this technology. Although we attempted to adopt reasonable assumptions, this uncertainty, and its efforts, should be considered in any interpretation of the data presented. Complacency with regard to the costs and schedule is not justified.

4.2.1.1.5 Schedule

The estimated schedule is shown in Figure 4-13.

4.2.1.1.6 Costs

Based on the 1978 BNFP Applicability Study (Volume II, pps. 4-47),¹ we estimate the capital costs already expended ("sunk costs") at \$342 million (in 1978 dollars) by combining capital costs for the separations/UF₆ plant and the existing liquid waste tanks. (However, "sunk costs" may not be the basis for negotiated purchase price when the U.S. seeks to purchase BNFP from AGNS.) The 1978 study estimated \$21 million of R&D cost, which we assume is included in the capital costs estimates shown in Figure 4-14. Not included there were: the radioactive Kr-85 recovery facility; additional plant safeguards;

FIGURE 4-13

SCHEDULE FOR COMPLETION OF BNFP FOR LWR FUEL REPROCESSING

FIGURE 4-14

Note: R & D, and engineering costs are included in these totals

waste volume reduction capability; and additional liquid waste storage tanks. These items total \$226 million (1978) incremental cost additional in this configuration. When these changes are accounted for, the total cost estimated here (\$928 million [1978]) is well within 10% of that estimated in 1978 for a complete facility (\$894 million [1978], including \$260 million [1978] for a fuel fabrication facility).

4.2.1.1.7 Evaluation

In regard to technical feasibility, the PUREX process for spent uranium fuel reprocessing is a proven technology. However, the ability to reprocess commercial quantities of high burn-up LWR fuel on a continuous basis over an extended period of time has not been demonstrated. Additionally, there have been questions raised regarding the maintainability of the specific design of the BNFP. (See Section 4.2.5 for a technical assessment of the BNFP plant design.) The BNFP plant was designed on the basis of a combination of previously demonstrated elements. The French, who have designed a PUREX plant similar to BNFP, reached the same basic conclusions as AGNS in selecting the design approach for their commercial reprocessing plant. This plant has so far reprocessed only a limited amount of LWR fuel.

In regard to the cost-effectiveness of this particular option, it is noted that there are no other plants available in this country for reprocessing commercial spent fuel against which a cost-effectiveness comparison could be made.

The relationship of this use to national energy policy is discussed in Section 4.2.1.1.2, Indications of Need/Interest/Support, p. 140.

The compatibility of this use to national nonproliferation policy is discussed in Section 4.0, Analysis of Use Options, p. 87.

Health, safety, and environmental considerations for the use of BNFP in this mode would have to do primarily with: safety in transporting spent fuel to and immobilized waste from the plant; the discharge of effluents to the atmosphere during operation; the introduction of mixed oxide fuel; and the exposure received by the workers in the plant. These are addressed in the environmental impact statement,⁵ a review of which did not reveal any problems not already being dealt with safely in current situations.

The public acceptance of this use option is discussed in Section 4.0, Analysis of Use Options, p. 87.

4.2.1.2 A Facility for Production of Plutonium Oxide (PuO₂) and Uranium Hexafluoride (UF₆) from LWR Spent Fuel

4.2.1.2.1 Description of the Use Option

The use is identical to the preceding option described in Section 4.2.1.1.1 as far as the activities pursued at the BNFP site are concerned. This use option differs from the preceding one in that its objective is not to use BNFP to develop a capability for PuO₂ and UF₆ production, but rather to produce PuO₂ and UF₆ as required for LWR recycle.

In this case, the PuO₂ is transported to an LWR mixed oxide (MOX) fuel fabrication facility; the UF₆ is brought to an enrichment facility for eventual fabrication into MOX fuel for LWR utilization. Thus, we refer the reader to Section 4.2.1.1 for the pertinent descriptions, assumptions, schedules, etc.

4.2.1.2.2 Indications of Need/Interest/Support for This Option

Interest in this use option is found in Section 4.2.1.1.2, Indications of Need/Interest/Support for this Option, p. 140.

4.2.1.2.3 Sources Used in Determining Schedules, Costs, and Evaluation

The sources used in determining the schedule, cost and evaluation of this option are located in Section 4.2.1.1.3, Sources Used in Determining Schedules, Costs, and Evaluation, p. 141.

4.2.1.2.4 Assumptions Made in Determining Schedules, Costs, and Evaluation

Assumptions pertaining to this option are found in Section 4.2.1.1.4, Assumptions Made in Determining Schedules, Costs, and Evaluation, p. 142..

4.2.1.2.5 Schedule

See Section 4.2.1.1.5 and Figure 4-13 for the appropriate schedule the the potential availability of the BNFP to be used in this production mode.

4.2.1.2.6 Costs

See Figure 4-14 in Section 4.2.1.1.6 for estimated capital costs needed to arrive at operational status.

Figure 4-15 lists the O&M costs for PuO₂ and UF₆ production at BNFP given a 1500 MT spent fuel input per year.

4.2.1.2.7 Evaluation

- As is evident from the explanation above, the technical feasibility of this option is identical to that of the preceding option as discussed in Section 4.2.1.1.7.

FIGURE 4-15¹

O&M COSTS FOR LWR FUEL RECYCLE
(Millions of 1978 Dollars)

	<u>YEAR</u>	
	10 and Before*	11 and Beyond
Separations/UF ₆ Plant (includes safeguards)	0	31
Waste Management Facilities	0	16
Pu Conversion and Storage	0	9
Waste Containers	0	9
TOTALS	0	65

*Except test and maintenance costs presumed included in development.

- The cost effectiveness of using BNFP as an operational reprocessing plant in support of a program of commercial LWR recycle is, like the previous case, impossible to evaluate because of a lack of alternative production sources of PuO₂ (and recovered uranium) to compare it with.
- The question of the degree to which utilizing BNFP in this mode would be supportive of national energy policy is discussed previously in Section 4.2.1.1.2.
- The compatibility of this use option with national nonproliferation policy is discussed in Section 4.0, Analysis of Use Options, p. 87.
- As explained above, the environmental, health, safety, and safeguards concerns for this option are identical to those addressed in 4.2.1.1.7, as long as we restrict our evaluation to the direct impact of the BNFP itself, and not the entire fuel cycle implied by this option.
- The public acceptance of this use option is discussed in Section 4.0, Analysis of Use Options, p. 87.

4.2.1.3 A Development and/or Production Facility for Immobilization of LWR HLW

4.2.1.3.1 Description

If BNFP were to be used as an LWR fuel reprocessing plant, it would require facilities for the management of wastes generated during reprocessing. In this report these facilities are treated separately from the rest of the reprocessing plant because U.S. reprocessing plants constructed in the past have not included facilities for HLW immobilization, nor has BNFP to date. AGNS has developed design concepts for such facilities.^{4,6} Required waste management facilities would include:

- Liquid Waste Storage
- HLW Immobilization
- Solid Waste Storage
- Solid Waste Assay
- Solid Waste Volume Reduction
- Onsite Handling and Transportation

The Liquid Waste Storage and HLW Immobilization Facilities are designed to handle 5 MTU equivalents of HLLW and ILLW per day of operation. Spent LWR fuel entering the reprocessing plant is assumed to be three years old with a burnup of 29000 MWd/MTU. Five-tenths of one percent of the uranium, plutonium, and iodine isotopes in the spent fuel are assumed to be associated with each of the liquid waste streams, and all of the tritium is assumed to be released during reprocessing. The Spray Calcination/In-Can Melting Process developed by Battelle Northwest Laboratories would be used to solidify the HLW.

Acceptance criteria for the solidified waste canisters at the Federal Repository have not yet been developed. These criteria will have a significant impact on the eventual capital and operating costs associated with waste solidification at the BNFP.

The Solid Waste Storage Area would provide interim storage for five categories of waste: hulls, high-level general process trash, low-level general process trash, uranium scrap, and failed equipment. An area has been allocated with the capacity to store wastes generated from processing 7000 MTU, or approximately five years of operation.

The Solid Waste Assay Facility (SWAF) is used to assay the waste containers non-destructively prior to interim storage or offsite shipment in order to prevent the diversion of SNM. The SWAF will be able to process up to 70 drums of waste per day, which is sufficient

to service a 1500 MTU/yr Separations Facility and the associated Product Conversion plants and the Liquid Waste Solidification Plant. Passive gamma, passive neutron and active neutron assay techniques would be used.

The Solid Waste Volume Reduction facilities include a Hulls/HLGPT Compaction Facility and LLGPT Incineration Facility. The Hulls/HLGPT Compaction Facility is designed to handle approximately 500 hulls containers per year and 3400 drums of HLGPT per year. The LLGPT Incineration Facility will handle 3000 drums per year. These capacities are sufficient to service a 1500 MTU/yr reprocessing plant, including Separations Plant, UF Facility, Product Conversion Facility and Liquid Waste Solidification Facility.

4.2.1.3.2 Indication of Need

The possible generic use (reprocessing for Pu recycle), for which this specific use would be required, is discussed in Section 3.0, Generic Use Options, p. 85, and 4.2.1.1.2, Indications of Need/Interest/Support, p. 140.

Relative to the need for a HLW immobilization facility at BNFP if it is activated as either an R&D or production facility, it is felt that with the nation already embarrassed by the large accumulation of HLLW at Hanford and Savannah River it is doubtful that BNFP would be allowed to generate any HLLW unless there is an immobilization facility already in place and checked out.

4.2.1.3.3 Assumptions Made in Determining Schedules, Costs, and Evaluation

All dollar figures in the cost estimate are shown in mid-1979 dollars. Labor costs are based on Southeastern U.S. union rates with open shop rules. The facilities are sited on a new structural berm,

and the cost of the berm is prorated by area against each waste facility estimate. A common exhaust stack, costed in the Common Area estimate, is used by these facilities. The cost for additional utilities is not included, with the exception of emergency generators in the Common Area. Also, costs do not include consumable items such as fuel or paper products, roads or railroad tracks, cold checkout or modifications arising from cold checkout, land purchase, costs of regulatory delays, or research and development costs. In the schedule, it has been assumed that four years is required for further R&D, and that some engineering, procurement, and construction can proceed concurrently with R&D.

4.2.1.3.4 Schedule

See Table 4-16.

4.2.1.3.5 Costs

See Tables 4-17 and 4-18.

4.2.1.3.6 Evaluation

Technical Feasibility

The waste management facilities described above appear technically feasible, but some research and development must be carried out to answer remaining questions. Areas where R&D is needed are listed below:

- Liquid Waste Storage - identify parameters and mechanisms involved in radiolysis of nitric acid, and quantify the rate of acid destruction.

TABLE 4-16

SCHEDULE FOR LWR WASTE MANAGEMENT FACILITIES AT BNFP

LEGEND

	DESIGN & ENGINEERING
	CHECKOUT & MODIFICATIONS
	PROCUREMENT & DELIVERY
	CONSTRUCTION
	COLD CHECKOUT
	R&D, INCLUDING EQUIPMENT PROTOTYPE TESTING & DEVELOPMENT

SOURCES:

1. "Engineering Evaluations of Wastes Handling and Storage Facilities," AGNS-35900-4.2-26, November 1979.
2. "Storage and Handling of Wastes from Uranium Fuel Processing Alternatives," AGNS-1040-3.3-34, October 1978.

TABLE 4-17

WASTE STORAGE AND HANDLING FACILITIES
CAPITAL COST ESTIMATES*

(millions of Dollars)**

	Waste Processing Center			Common Area	Liquid	Solid	Solid	Total
	Liquid Waste	Hulls/HLGPT	LLGPT		Waste	Waste	Waste	Waste
	<u>Solidification</u>	<u>Compaction</u>	<u>Incineration</u>		<u>Storage</u>	<u>Assay</u>	<u>Storage</u>	<u>Facilities</u>
Direct Costs:								
Equipment	13.0	6.5	1.9	3.8	16.5	2.6	5.5	49.8
Bulk Materials	14.7	1.8	1.7	1.9	5.0	1.0	2.6	28.7
Subcontracts	2.8	.8	.8	1.0	1.6	.4	1.7	9.1
Labor	<u>27.8</u>	<u>4.2</u>	<u>3.2</u>	<u>2.7</u>	<u>7.6</u>	<u>1.9</u>	<u>2.5</u>	<u>49.9</u>
Subtotal	58.3	13.3	7.6	9.4	30.7	5.9	12.3	137.5
Indirect Costs:								
Distributables	26.4	4.6	3.1	3.0	8.3	2.0	2.9	50.3
Engineering	<u>19.5</u>	<u>3.7</u>	<u>2.3</u>	<u>2.6</u>	<u>6.4</u>	<u>2.9</u>	<u>2.2</u>	<u>39.6</u>
Subtotal	45.9	8.3	5.4	5.6	14.7	4.9	5.1	89.9
Subtotal - Engineering & Construction	<u>104.2</u>	<u>21.6</u>	<u>13.0</u>	<u>15.0</u>	<u>45.4</u>	<u>10.8</u>	<u>17.4</u>	<u>227.4</u>
Contingency:	<u>26.0</u>	<u>6.5</u>	<u>3.9</u>	<u>4.5</u>	<u>9.1</u>	<u>3.3</u>	<u>5.2</u>	<u>58.5</u>
TOTALS:	<u>130.2</u>	<u>28.1</u>	<u>16.9</u>	<u>19.5</u>	<u>54.5</u>	<u>14.1</u>	<u>22.6</u>	<u>285.9</u>

*Range of Accuracy: +25%

**Constant mid-1979 dollars.

TABLE 4-18

CAPITAL OUTLAYS FOR LWR WASTE MANAGEMENT FACILITIES AT BNFP

(millions of mid-1979 dollars)

Liquid Waste Solidification	26.04	26.04	26.04	26.04	26.04			
Hulls/HLGPT Compaction	5.62	5.62	5.62	5.62	5.62			
LLGPT Incineration	3.38	3.38	3.38	3.38	3.38			
Common Area	3.9	3.9	3.9	3.9	3.9			
Liquid Waste Storage		7.82	7.78	7.78	7.78	7.78	7.78	7.78
Solid Waste Assay	2.82	2.82	2.82	2.82	2.82			
Solid Waste Storage	7.54	7.53	7.53					
Total	49.3	57.11	57.07	49.54	49.54	7.78	7.78	7.78

Years from Start → 0 1 2 3 4 5 6 7 8

Note: This table was derived by distributing the costs in Table 4-16 to roughly coincide with the schedule in Table 4-15.

- Liquid Waste Solidification - select a solidification process; establish final waste canister criteria and repository constraints; establish optimum formic acid requirements; quantify fraction of P_4O_{10} volatilized during calcination/vitrification; obtain performance data for off-gas treatment; develop remote welding techniques; design and test a molten metal seal for connecting the calciner and melter; demonstrate glass encapsulation of sintered metal filter cartridges loaded with occluded solids; demonstrate accuracy and reliability of using radiation monitors for glass level monitoring.
- Solid Waste Storage - demonstrate reliability of blind retrieval system for drums; obtain a more realistic evaluation of expected dosages.
- Solid Waste Assay Facility - develop standards and calibration techniques for neutron and gamma assay; develop software; determine proper volume and shape of the passive gamma system.
- Hulls/HLGPT Compaction Facility - develop welding technique for attaching lid to repository container; establish repository criteria for HLGPT; complete development of compactor design.
- LLGPT Incinerator Facility - evaluate alternatives to cement solidification process for solidifying off-gas liquid waste stream; define transportation requirements, determine optimum cement/slurry mixture ratio; review expected LLGPT waste characteristics; review other incineration processes; determine whether incinerator feed preparation is required; determine best material for off-gas piping; determine incinerator maintenance requirements.

Cost Effectiveness

There being no production waste immobilization facility in the U.S. and little information available on the only one operating in the world (France), it is not possible to make a meaningful cost-effectiveness evaluation of the AGNS plan compared to other possibilities.

Internal to the work done to date, an economic analysis was conducted by AGNS using the Waste Management Economic Model (WMEM). The WMEM develops a mass-flow balance for all types of radioactive waste from the point of generation through volume reduction and transportation to final disposal at a Federal Repository. Economic evaluation of the detailed mass balance allows identification of parameters with significant dollar impacts and are used to direct evaluation efforts towards those variables with the greatest impact on the net present cost of the total waste management system. As uncertainties are removed by R&D efforts, the WMEM can be used to approach the most cost effective waste management system.

Supportiveness of National Energy Policies

See discussion under Section 3.0, Generic Use Options, p. 85, and 4.2.1.1.2, Indications of Need/Interest/Support, p. 140.

Supportiveness of National Nonproliferation Policies

See discussion under Section 4.0, Analysis of Use Options, p. 87.

Health, Safety, and Environment

The AGNS design concepts for liquid waste storage and solidification were independently reviewed by technical safety experts from AGNS and BNWL (Battelle Northwest Laboratories). Reference 7 discusses the environmental impact of a reprocessing complex, including waste management facilities, using BNFP as a model. The 50-mile population dose commitment from normal operations due to the liquid waste solidification stack is 0.0318 man-rem (whole body), a small fraction of the 325 man-rem (whole body) dose from the entire reprocessing plant. A serious accident involving the waste management facilities

is a waste storage area hulls container rupture, which would result in a whole-body dose of about 0.016 rem to an adult at the east site boundary. However the worst accident would be the rupture of HLW storage tanks as a result of a loss of coolant for the tanks. Therefore, a complex system of back-up cooling is contemplated.

Public Acceptance

See discussion under Section 4.0, Analysis of Use Options, p. 87.

4.2.2 Uses of BNFP in Support of a U.S. Breeder Program

There are five possible uses analyzed herein for the BNFP in support of a breeder program. The first three are essentially the same as those previously presented and analyzed for the LWR recycle option of (see 4.2.1).

These five are:

- The use of BNFP as a facility for development of a national capability to recover Pu from spent LWR fuel (4.2.2.1).
- As a facility for production of PuO₂ as required for research, developmental, or deployed breeders (4.2.2.2).
- As a developmental and/or production facility for immobilization of LWR HLW (4.2.2.3).
- As a facility for development of a national capability to reprocess spent breeder fuel (4.2.2.4).
- As a developmental and/or production facility for immobilization of breeder HLW (4.2.2.5).

4.2.2.1 Use of BNFP as a Facility for Development of a National Capability to Recover Plutonium from Spent LWR Fuel

4.2.2.1.1 Description of This Use Option

Technically, this use option is identical in this case to that described previously in Section 4.2.1.1.1, only in this case the recovered Pu is for use in support of a U.S. breeder program, rather than LWR recycle program.

4.2.2.1.2 Indications of Need/Interest/Support for This Use of BNFP

The currently expressed administration position is:

Breeder development would continue at a moderate level with emphasis on engineering and component development. A decision on a demonstration plant could be taken in 1981, but also could be deferred until 1986-1990. Plans for both a 20-year and a 30-year commercialization program could be developed. Reprocessing technology would be developed, while commercialization is deferred. This program attempts to minimize risk at a moderate cost.⁸

Whether this quote from NEP-II indicates plans to develop reprocessing technology on a large scale (such as the BNFP would represent), or on a laboratory scale, is still under study at this time. If it is decided that development at full scale is desirable, the BNFP, already partially built, could represent an attractive option to the U.S. government for development of this capability.

Additionally, the following Section 4.2.2.2, Use of the BNFP as a Facility for Production of PuO₂ as Required for Research, Developmental, or Deployed Breeders, indicates a possible role for the BNFP as a source of supply for the Pu that will be required in support of

breeder R&D work. If BNFP were to be called on to meet this Pu supply need, it would be necessary to complete and check out the plant in advance as envisioned in this option.

Whether the cost of electricity supplied by Pu-fueled breeder reactors will ever be competitive with electricity from other sources is not known at this time. What is known, however, is that present U.S. energy policy envisions development of the capability for deployment of breeders if and when desirable; that this will require a source of plutonium supply, even during the R&D phase; and that a completed BNFP could fulfill this need.

4.2.2.1.3 Sources Used in Determining Schedules, Costs, and Evaluation

Same as for Section 4.2.1.1.3, Sources Used in Determining Schedules, Costs, and Evaluation, p. 141.

4.2.2.1.4 Assumptions Made in Determining Schedules, Costs, and Evaluation

Same as for Section 4.2.1.1.4, Assumptions Made in Determining Schedules, Costs, and Evaluation, p. 142.

4.2.2.1.5 Schedule for This Option

Same as for Section 4.2.1.1.5, Schedule for this Option, p. 144. See Figure 4-3.

4.2.2.1.6 Costs for This Option

Same as for Section 4.2.1.1.6, Cost for this Option, p. 144. See Figure 4-14.

4.2.2.1.7 Evaluation

In regard to technical feasibility, cost effectiveness, and environmental health and safety the discussion in Section 4.2.1.1.7 is applicable. The use of BNFP to develop and demonstrate a capability to supply plutonium for future U.S. breeder programs would appear to be compatible with current national energy policies. As previously mentioned, if the U.S. is to have the "LMFBR as the primary (breeder) option" as called for in NEP-II, a reprocessing plant will be needed for supplying experimental breeders with plutonium fuel.

The relationship of this use to national nonproliferation policy and public acceptance is discussed in Section 4.0, Analysis of Use Options, p. 87.

4.2.2.2 The Use of BNFP as a Facility for Production of PuO₂ as Required for Developmental or Commercial Breeders

4.2.2.2.1 Description of the Use Option

This option would be for the use of the BNFP to extract plutonium from first cycle spent LWR fuel, and to convert it to PuO₂ to be used as fuel for the development and, if desired, the deployment of breeder reactors. This use would follow the completion and check out of the facility as described in Section 4.2.1.1. This use option differs, however, from the preceding one in that its objective is not using BNFP to develop a capability to produce PuO₂, but rather to produce PuO₂ as required for LWR recycle research, developmental, or operational breeders. The extracted uranium could be converted to uranium hexafluoride (UF₆), and sent for enrichment and ultimate utilization in LWR fuel, but this is incidental to the purpose of this use.

PuO₂ produced would be sent to a fuel fabrication facility or stored at the BNFP which has a specially designed PuO₂ storage facility with a capacity of 32MT. For further details, see Section 4.1.1.1, Description of AFR Storage Facilities.

4.2.2.2.2 Indications of Need/Interest/Support for This Option

Indications of interest for this generic category (in support of a national breeder program) of which this specific use would be a part, is discussed in Section 3.0, 4.2.2, and 4.2.2.1.2.

The NEP-II strategy calling for the U.S. to proceed on a course of research, and development of breeders, but withholding for the present a commitment to demonstration and deployment, could require the creation and supply of separated Pu (this use option) in quantities required for support of research and developmental reactors.

BNFP could be one source of supply for Pu in the 1990s, in support of U.S. breeder R&D programs during that period. However, operated at full capacity, the BNFP would be substantially over-producing for the needs of the R&D phase, with resultant unfavorable economic consequences.

The Hot Experimental Facility (HEF) being planned by ORNL for DOE, which is the focus of the breeder reprocessing R&D program, is a planned demonstration of breeder reprocessing technology and is designed to serve as a source of plutonium in support of breeder R&D. Its proposed timing (operational by the early 1990s) and throughput of 150MT HM/year was to serve as both a developmental reprocessing capability and a source of R&D quantities of Pu. Because of budget restraints, however, this facility has not been approved as yet. The HEF will not meet potential near-term plutonium requirements in the 1980s and early 1990s. However, options including recovery on a small-scale basis of experimental breeder fuel could satisfy the need but not the requirements of a breeder demonstration plant.

Another possible source of Pu for the R&D phase, further allocations from the defense programs, has, by direction, not been included in this study.

4.2.2.2.3 Sources Used in Determining Schedules, Costs, and Evaluation

- See References 1-4, which were used as sources for schedule and cost determinations.
- In addition, References 7 and 11 provided part of the basis for evaluation of this Option.

4.2.2.2.4 Assumptions Made in Determining Schedules, Costs, and Evaluation

- See Section 4.2.1.1.4, Assumptions Made in Determining Schedules, Costs, and Evaluation, p. 142.
- Additional pertinent assumptions:

The BNFP could be operated to produce at full (15 MT Pu/yr) or partial output as desired. See 4.2.2.2.2 above.

4.2.2.2.5 Schedule

- See Section 4.2.1.1.5 for schedule leading to this use.
- Essentially, that schedule shows that full-scale operation could begin approximately 10 years after an EIS is produced.

4.2.2.2.6 Costs

- See Section 4.2.1.1.6 for estimated costs expended to arrive at operational status.
- See Figure 4-15 for operational and maintenance (O&M) costs for full-scale Pu production at the BNFP at 1500 MT spent fuel in, 15MT Pu out per year.

4.2.2.2.7 Evaluation

- This option is technically the same as 4.2.1.1.7, and would thus have the same technical feasibility.
- The cost effectiveness of this use option is most important since the use envisioned here is as a production facility, and if it were determined that PuO₂ could be produced or reliably procured elsewhere at a lower cost the attractiveness of this option could be severely impacted. Unfortunately, however, there is no data available on other options for obtaining the PuO₂. Without this cost effectiveness cannot be evaluated. Reprocessing in France, (at a reported price \$750/kg HM) is of interest, but is not felt to represent a prudent option for the U.S.
- U.S. energy policy does not call for the civilian production of Pu. Such production would not have to be considered until there was a decision on a demonstration breeder reactor. The use of BNFP for the production of Pu for a demonstration reactor (and subsequent breeder deployment) would be supportive of U.S. energy policy.
- A discussion of the compatibility of this use with national nonproliferation policy is included in Section 4.0.

- There appears to be no insurmountable environmental, health, and safety problems which would preclude this use of BNFP. Although standards for radiation protection and waste management are in a state of flux, we have included the provisions necessary by the latest requirements in the Description. The Preliminary Safety and Environmental Evaluation for Alternate Fuel Processes, cited earlier, has analyzed the expected radiological effects of normal operation and concluded that the average annual whole body dose per person for everyone living within 50 miles of BNFP would be less than 0.05 mrem. Also, the maximum calculated annual whole body dose at the site boundary to any age group is less than 1 mrem. These figures are quite low in comparison with normal annual background and radiation of approximately 135 mrem per person. The maximum calculated dose for accidents, and the nonradiological impacts, also appear to be within reasonable limits, or this is attainable. In addition, the Final GESMO, Vol. 3,¹¹ concludes that the cancer and genetic defect risk from the entire LWR mixed oxide fuel cycle, including large scale reprocessing would be below the level detectable epidemiologically, and might even reduce occupational exposures by reducing the radiation worker force exposed.
- A discussion of the public acceptance of this use is included in Section 4.0, Analysis of Use Options, p. 87.

4.2.2.3: Demonstration and Production Facility for Immobilization of LWR HLW

The HLW to be immobilized is unaffected by the ultimate use of the separated Pu and uranium, whether it be for breeder reactors or LWR recycle. Therefore, the analysis of this use option would be the same as that presented in Section 4.2.1.3, Immobilization of HLW in Support of LWR Recycle, p. 151.

4.2.2.4 A Facility for Development of a National Capability to Reprocess Spent Breeder Fuel

4.2.2.4.1 Description of This Option

In the comparison between reprocessing of spent LWR fuel and spent breeder fuel,¹² the basic process is similar but major differences occur in certain steps of the reprocessing facility.

However, there is one major area that needs to be developed before the reprocessing of spent breeder fuel could be undertaken at BNFP.

R&D would be needed to develop a head end for reprocessing spent breeder fuel before it enters the BNFP chemical processing facilities. Equipment and operational procedures are needed to handle the fuel assemblies, remove them from sodium coolant, clean the residual sodium from the assemblies, and mechanically remove the shroud before cleaning. Also, R&D is needed to ensure adequate confinement of gaseous fission products.

An R&D program¹² to resolve these problems has been conceived and it is estimated that it would take 12-15 years and \$350-500 million to complete.

Though BNFP was originally slated to be used as a reprocessing facility for LWR spent fuel only, the option of using BNFP as the LWR spent fuel reprocessing plant and additionally, as a demonstration plant for reprocessing spent breeder fuel, with the necessary modifications, is considered technically feasible.

4.2.2.4.2 Indications of Need/Interest/Support of This Use Option

The DOE is interested in further evaluation of this option. A study¹³ to utilize the BNFP in support of the U.S. Breeder program is being defined. The study would be done by the ORNL and AGNS staffs and would examine the following:

1. Can breeder reprocessing demonstration be accomplished in BNFP?
2. Could the plant be modified to achieve these objectives?
3. Are there scenarios where siting the Hot Experimental Facility (HEF) adjacent to BNFP is logical and would save substantial money?
4. Does reprocessing demonstration with LWR fuels in BNFP simplify breeder reprocessing demonstration?

4.2.2.4.3 Assumptions Made in Determining Schedules, Costs, and Evaluation

If approved and funded by DOE, the results of the AGNS/ORNL study addressing this option should be available in a year.

4.2.2.4.4 Schedule

The study¹³ to use BNFP for the Consolidated Fuel Reprocessing Program (CFRP) would take year after which the R&D effort would span 12-15 years. The R&D effort would be directed at achieving a pilot plant operation for reprocessing spent breeder fuel.

4.2.2.4.5 Costs

The study¹² on the CFRP indicated that the R&D effort, including the pilot plant operations, for reprocessing spent breeder fuel is estimated at \$350-500 million for the 12-15 year span.

4.2.2.4.6 Evaluation

An evaluation of this use option would be premature prior to the completion of the ORNL/AGNS study.

4.2.2.5 Demonstration and Production Facility for Immobilization of Breeder HLW

4.2.2.5.1 Description of This Option

If BNFP were used for the reprocessing of spent breeder fuel, facilities for immobilization of the resulting HLW would be required. Design concepts for facilities to handle breeder fuel reprocessing wastes are not currently available. However, it is believed that such facilities would not have to be significantly different than the facilities described for handling wastes from spent LWR fuel reprocessing.

4.2.2.5.2 Indication of Need

There would be a need for breeder HLW management facilities only if BNFP were used to reprocess breeder fuel.

4.2.2.5.3 Cost and Schedule

The cost and schedule for constructing and operating breeder HLW management facilities at BNFP are not currently available.

4.2.2.5.4 Evaluation

Since it is believed that breeder HLW management facilities would not have to be significantly different than LWR HLW management facilities, the evaluation in Section 4.2.1.3.7 is believed to be generally applicable.

4.2.3 RD&D Facility for Development of More Proliferation-Resistant LWR Fuel Cycles

4.2.3.1 Description

Since President Carter's 1977 decision to defer the reprocessing of LWR fuel, the staff at BNFP has been under contract to DOE to undertake research and development programs which can provide information for INFCE and NASAP. Among these studies has been the evaluation of more proliferation resistance alternatives for processing uranium-based LWR fuel.

The classical approach to reprocessing is treated in Section 4.1.2.1. There are two types of general alternatives; (1) uranium/plutonium partitioning options (referred to as coprocessing), and (2) spiking variations.

The coprocessing options include:

- complete partitioning (100% plutonium)
- partial partitioning (75% uranium - 25% plutonium)
- no partitioning (99% uranium - 1% plutonium)

The spiking variations are of two types:

- a) as a deterrent to diversion using highly radioactive additives or residues. This can be accomplished using Cobalt-60 as an external spike, or adjusting process flow sheet conditions to increase residual fission products.
- b) spiking to reduce the attractiveness of the plutonium for weapons production by increasing the heat content or adding a neutron source to the plutonium.

BNFP analyzed numerous combinations of these alternatives. Comparison of the alternatives addressed the technical parameters related to enhancing proliferation resistance, including accountability, diversion detection, diversion deterrence, the attractiveness of using plutonium as weapons material, and the ability of each process to be modified for plutonium purification (revertibility).

Additionally, alternatives were evaluated in terms of their impacts on the fuel cycle, such as cost, operation, maintenance, licensability, fuel compatability, and resource utilization.

The following three options were selected for conceptual design by AGNS.

4.2.3.1.1 High Decontamination Factor (high-DF) Coprocessing

This employs the decontamination of both the uranium and plutonium from the fission products. As shown in Figure 4-19 the high-DF coprocessing alternative reflects the minimum deviation from the classical Purex process. However, the plutonium is not fully separated from the uranium as in the base case. Instead a portion of the uranium accompanies the plutonium so that the plutonium product stream is diluted to 3 parts uranium to 1 part plutonium. This reduces the attractiveness of the plutonium for diversion for weapons production, while maintaining its suitability for either LWR or breeder reactor fuel.

The uranium/plutonium ratio can be controlled by adjusting operating conditions of the partitioning column (1BP on Figure 4-19). This mixture is maintained by eliminating the uranium scrubbing section on the final strip column (3B).

FIGURE 4-19

SOURCE: Reference 14.

Though not a part of the AGNS conceptual design for high-DF coprocessing, an optional gamma spike, Co-60, could be added to provide additional diversion deterrence during conversion from mixed nitrate-to-oxide form and storage.

4.2.3.1.2 Low Decontamination (low-DF) Coprocessing

The low-DF coprocessing variation is shown in Figure 4-20. In this option, the uranium product stream is fully decontaminated from the fission products. The plutonium product stream, however, is not further purified following separation from the bulk of the uranium. This substantially reduces the level of decontamination of fission products from the plutonium product (which again contains 75% uranium - 25% plutonium). This alternative not only dilutes the plutonium with uranium, but also maintains a high level of radiation sufficient for deterrence (1000 R/hr one foot from the surface of the mixed oxide product container). Calculations indicate that the use of residual fission products may not meet the deterrent level if the fission products decay for two years or more. A supplemental spike of Co-60 will be used to continue to protect the Pu during storage of the nitrate, conversion, and later storage of the oxide even if the fission products decay.

Some of the major differences from the high-DF case include:

- spent fuel element disassembly prior to shearing
- combination of the first cycle scrub stream (HSW) and the plutonium stream (1BP) with the second uranium cycle raffinate (2DW) to make up the mixed nitrate product stream (see Figure 4-20).
- elimination of the second and third plutonium purification cycles.

————— AQUEOUS STREAMS
- - - - - ORGANIC STREAMS

SOURCE: Variations of Uranium and Plutonium Coprocessing As Proliferation-Resistant Alternatives to the Classical Purex Process, AGNS-35900-CONF-14, August 1979.¹⁴

4.2.3.2 Need/Interest/Support for Proliferation-Resistant Technologies

When President Carter indefinitely deferred fuel reprocessing, it immediately underscored the need to develop and commercialize effective proliferation-resistance technologies.

The Nonproliferation Alternative Systems Assessment Program (NASAP) has evaluated several alternative recycle systems for their proliferation resistance. Coprocessing and partial decontamination options are found to increase proliferation resistance, especially versus subnational threats. Coprocessing was found to be the least intrusive and least costly measure to implement.

The International Nuclear Fuel Cycle Evaluation (INFCE) has also examined several alternatives to basic recycle technology. Coprocessing is seen as a method, reducing the presence of plutonium in the fuel cycle in separated form. INFCE evaluates coprocessing regarding its environmental impact, economic factors, resource utilization, and proliferation risk. INFCE has seen coprocessing as technically feasible although some process control problems have been encountered. INFCE notes that it could be viewed as an option for a future generation of reprocessing plants.

4.2.3.3 Sources Used in Determining Schedules, Cost, and Evaluation

Full use was made of several AGNS studies on fuel cycle alternatives. Much of the process information is derived from Reference 14. Design, and schedule information is taken from Reference 15. Cost information is taken from Reference 16.

The sources used in the evaluation of the fuel cycle alternatives were culled from the range of relevant AGNS studies as well as the Working Group 4 reports of INFCE^{17,18} and Volumes II,¹⁹ III,²⁰ IX,²¹ and Executive Summary²² of NASAP.

4.2.3.4 Cost and Schedule Assumptions

- The ban on reprocessing is lifted, and one of the alternative technologies is selected.
- There is sufficient economic stimulus to warrant attempted commercialization.
- It is assumed that the decision to switch to an alternative fuel cycle is made soon enough such that modifications to BNFP plant designs could meet the schedule envisioned.
- Costs are in millions of mid-1979 dollars.
- The results of the capital cost comparison are estimated to within $\pm 25\%$ accuracy.
- Costs include detailed engineering, procurement, construction of the building, and installation of the equipment. Security fencing, cold chemical storage, and access roads are also included.
- Licensing costs, R&D costs required in support of MOX conversion and initial provisioning costs are not included.
- O&M costs were unavailable for any of the three alternatives. They are assumed to be comparable to the reference case.
- The schedule for detailed engineering, procurement, and construction of a mixed oxide conversion facility is assumed to be equally applicable to the high-DF and low-DF variations.
- An environmental impact statement would be completed prior to government acquisition. Government procurement is assumed to occur after public comment on the EIS, which is assumed to take one year.

- Two years of planning and design would be required prior to the submission of an application for a construction permit (CP).
- The operating license (OL) would be processed in parallel with construction.
- Capital outlay, engineering design, procurement and construction are assumed to begin prior to issuance of the operating license by the NRC.
- The schedule assumes 18 months after construction for checkout prior to beginning hot operations.
- Any delays due to protracted public hearing or court proceedings are not included in this schedule.
- Using BNFP in support of the development of improved LWR recycle technologies is assumed to be an add-on to its use for support of the U.S. Breeder program or for its use for production of Pu and U for LWR recycle.

4.2.3.5 Schedule

The schedule shown as Figure 4-21 is for construction of the mixed oxide conversion facility only. If a timely decision is made, BNFP could begin operations in 10 years. If other reprocessing modes are chosen (i.e., conventional recycle, pre-breeder cycle), the switch to a more proliferation resistant technology will be more lengthy and costly.

4.2.3.6. Costs

A comparison of the capital cost estimates of principal facilities is shown below for the three alternatives.

FIGURE 4-21: SCHEDULE FOR PROLIFERATION RESISTANT TECHNOLOGIES

Cost Comparison of Alternatives
(millions of mid 1979 dollars)

<u>Facility</u>	<u>High-DF</u>	<u>Low-DF</u>
Separations ^a	346	296
MOX Conversion	211	243
UF ₆ Conversion ^b	38	38
Liquid Waste Storage Expansion	54	54
Liquid Waste Solidification	130	130
LLGPT Incineration	17	17
Solid Waste Assay	14	14
Solid Waste Storage	23	23
Hulls Compaction	28	28
Common Waste Area	20	20
Site Utility Expansion	41	41
TOTAL	922	904

NOTE: a,b costs are from conceptual design through construction. Since these facilities already exist, the capital outlay involved would be substantially less.

Table 4-22 spreads the entire capital cost of developing proliferation-resistant alternatives over a seven year period. These costs cover the design and construction of facilities through cold check-out; costs beyond this point were unavailable. The major effort will be the construction of the mixed-oxide conversion facility.

TABLE 4-22

CAPITAL COST FLOWS FOR THE PROLIFERATION-RESISTANT FUEL CYCLE ALTERNATIVES

(Millions of Mid-1979 Dollars)

Alternative Fuel Cycles	YEAR							
	1	2	3	4	5	6	7	
High DF	9.22	64.54	110.64	129.08	248.94	267.38	92.20	922
Low DF	9.04	63.28	108.48	126.56	244.08	262.16	90.4	904
								TOTAL

Due to the high levels of radioactivity present in some of these fuels, their use could result in substantial increases in handling, shielding, storage, and transportation costs. These costs will only apply, however, outside the BNFP.

Operating and Maintenance costs were unavailable in published form.

4.2.3.7 Evaluation of This Use Option

4.2.3.7.1 Technical Feasibility

The AGNS technical staff feels it would be technically feasible to develop and incorporate modifications to the BNFP plant design to accommodate any of the three alternate flow sheets described in this option. However, none of the alternative fuel cycle processes described are ready for engineering design and implementation. All would require significant amounts of R&D over a period of several years before the engineering design for the plant modifications could be fully developed. Additional research and study would be required to arrive at realistic cost and schedule estimates of the R&D required.¹⁴

4.2.3.7.2 Cost Effectiveness

There is insufficient comparative data available to make a quantitative evaluation on the cost effectiveness of using the BNFP, as opposed to some other reprocessing plant, or to build a new one for these alternative fuel cycles. However, most of the plant as it exists today would be usable in one of the alternative fuel cycles, thus giving the BNFP a time advantage over a new facility that, for large construction projects, is readily transferable to a cost advantage.

4.2.3.7.3 Support for U.S. Nonproliferation Policy

The use of the BNFP as a plant for producing radioactive materials used in some of the proliferation-resistant fuel cycles would represent a national policy trade-off in which a means to further nonproliferation objectives would be considered as worth the extra cost to the utilities for handling other radioactive fuel throughout the front end of the fuel cycle. It should be kept in mind, however, that the decision to whether or not to reprocess in the first place is of fundamental importance from the nonproliferation point of view.

The nonproliferation benefits to be gained from technical modifications of the sort envisaged in this option would vary in terms of the perceived threat (national vs. subnational proliferation) and the context in which the proliferation occurred (e.g., access to reprocessing facilities, whether the proliferation act involved seizure of the facility or diversion).

Coprocessing would increase the amount of material that must be taken, thus increasing the chances of detection, and would require separation of plutonium from uranium, a relatively simple process. Radioactive contamination, though at levels less than those found in new spent fuel, would require special handling and remote radioactive chemical reprocessing to recover plutonium. As a result of the relatively shorter isotopic half-lives involved, partial decontamination and pre-irradiation would provide lower long-term protection than spiking.

These chemical and radiation barriers might pose substantial, and perhaps insurmountable, obstacles to subnational proliferators. On the other hand, in cases where the material was exported, their impact national proliferation would be less clearly definable. The benefits of coprocessing in this export case may be limited. A mixed

oxide, rather than pure plutonium, would be shipped in any case, whether coprocessing were used or not. MOX would provide only marginally greater proliferation resistance where the receiving country had modest chemical separation facilities. Use of coprocessing at BNFP, however, might reduce the magnitude of diversion risks at the plant itself by increasing the probability of detection.

Addition or retention of a radiation barrier would offer somewhat greater proliferation resistance than would coprocessing, since more elaborate facilities would be required to recover plutonium from diverted materials. Improved proliferation resistant LWR cycles have the advantage that they would require greater technical skill of the divertor. Such facilities would have to provide for shielding and remote operation and would take up to twice as long to design, construct, and test as would facilities processing nonradioactive material. This extra time required might increase detectability and provide greater warning time of a weapons project before removal of material. Once removed, however, the material could be processed, and plutonium recovered, in only slightly longer time than where nonradioactive material was involved. A radiation barrier, although a substantial impediment to subnational threats, would be highly detrimental to material accounting for safeguard methods and procedures.

4.2.3.7.4 Health, Safety, and Environment

The health, safety, and environmental, aspect of using BNFP for this purpose could be somewhat more serious within the plant than for the as-designed Purex flowsheet. This additional, in-plant, occupational exposure requires further analysis. HS&E factors outside the plant would be serious with hot fuel being used in the front end of the fuel cycle, but this does not involve the BNFP.

4.2.4 Use of BNFP as an International Fuel Service Center

4.2.4.1 Description of the Option

This section envisions the expansion of the BNFP to become, first a national and, ultimately, an international fuel service center containing the following elements:

- indefinite term storage facilities (ITS) for spent fuel
- spent fuel reprocessing plant
- facilities for converting uranium and plutonium nitrate solutions into UF_6 and PuO_2 , respectively
- fuel fabrication facilities for producing mixed oxides fuels for use in breeders, or recycle in LWRs, or both
- waste immobilization facilities
- indefinite-term storage facilities for HLW

For the purpose of this study, the concept envisages the cooperation of one or more countries to operate the facility, offering -- at the outset -- storage facilities for spent fuel. The concept covers fuel from the time it leaves the nuclear power reactor through all subsequent steps (except uranium re-enrichment), including fuel fabrication and immobilization (but not ultimate disposal) of radio active wastes.

Participation by cooperating nations could be on the basis of mutual needs, interests, and capabilities, and would not necessarily be limited by geographical considerations. The IAEA studies^{22,23} indicated that the variation in spent-fuel transport cost as a function of shipping distances to the fuel service center should not add significantly to the total fuel cycle cost.

One way of approaching the concept of the IFSC would be to start such multinational cooperation by first offering the BNFP storage facilities to meet the needs of the participants at a site that subsequently would include facilities for reprocessing and fuel fabrication. By offering spent fuel storage as a near-term alternative, the IFSC concept could thus eliminate one of the reasons compelling some states to consider national reprocessing. The U.S., if the initial decision is taken to use Barnwell as a domestic AFRS, could initiate the required proceedings for national use and authorize completion, or expansion, or both, of the existing facilities while the international institutional arrangements are being negotiated.

4.2.4.2 Indications of Need/Interest/Support for This Use

This concept of an IFSC has been studied by the International Atomic Energy Agency. In 1975, the IAEA initiated "The Study Project on Regional Nuclear Fuel Cycle Centres" to examine the fuel disposition problem and also the broader need for detailed planning for the entire nuclear fuel cycle. Specifically, the IAEA study examined the backend of the fuel cycle and covered spent fuel transport, storage, reprocessing, and recycle activities, starting from the time the spent fuel leaves the nuclear power reactor through all subsequent steps until recycled fuel, in the form of fuel elements, is ready for shipment to the reactor. Production of new uranium fuel and enrichment activities were not included, but the study did include those activities involving management of radioactive wastes generated in the backend of the fuel cycle, and extended storage of spent fuel. The IAEA study also developed basic ideas concerning the important areas related to the regional fuel cycle center concept, such as: nonproliferation and safeguards; nuclear material control; physical protection; institutional-legal arrangements; organization and administration; health, safety, and environment; and general financing considerations. The 1977 IAEA report on this study²² concluded that an international regional fuel cycle center could be feasible, flexible, and economical approach to managing fuel cycle problems with potential for adequate controls for safeguards and nonproliferation concerns.

While most studies concerning the need for international fuel service centers have focused on the obvious need for servicing the back end of the LWR fuel cycle, there is now a growing realization of a possible role for IFSC's in supplying the front end of the breeder reactor programs, which are being pursued in several countries.

Discussions of the concept within INFCE, however, indicate that there is little interest in the IFSC approach, and that at best it should be viewed as long-term option.

4.2.4.3 Sources Used in Determining Schedules, Costs, and Evaluation

In November of 1979, Hanford Engineering Development Laboratory, under contract to DOE, published a report summarizing the Alternative Fuel Cycle Evaluation Program (AFCEP) studies which supported the U.S. Nonproliferation Alternative System Assessment Program (NASAP). This comprehensive study focused on the International Fuel Service Center (IFSC) concept as an attractive institutional approach which could provide greater proliferation resistance than dispersed deployment of fuel cycle activities.^{24,25}

Programmatic sources relative to costs and schedules were the same as those used in Section 4.2.1 and Section 4.1.3 addressing development of BNFP for storage and reprocessing nuclear fuels for national programs. The cost baseline, except where noted otherwise, is from the AGNS May 1979 study reassessing "Nuclear Fuel Cycle Closure Alternatives."³ The data for addition of fuel fabrication facilities was obtained from the 1978 DOE study on BNFP utilization options as indicated in Figure 4-23.¹ The basic documents used for studying and evaluating the IFSC as an international concept supporting non-proliferation goals are those described in Sections 4.2.4.1 and 4.2.4.2 above.

FIGURE 4-23

ESTIMATED CAPITAL COSTS FOR BNFP
AS A FUEL CYCLE SERVICE CENTER (Millions of 1978 Dollars)¹

ACTIVITY	YEAR												
	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
Fuel Storage	1.6	11.0	7.4										20
Reprocessing ²	12	6			35	45	21						119
Pu Conversion and Storage ²	5	6	3		10	15	25	35	28	15			142
MOX Fuel Fabrication ³	1	3	3	3	65	79	40	31	15	10	5	5	260
Waste Management ²	25	18	4	2	77	88	38	5					257
Balance of Plant Safeguards ²	5	5			15	22	15						62
TOTALS	49.6	49	17.4	5	202	249	139	71	43	25	5	5	860

+ "Sunk Cost"³ 342

1202

1. These cost estimates are "Rough Order of Magnitude" only.
2. These cost estimates are aggregate figures obtained from the more detailed cost information in Figure 4-14.
3. These costs were obtained from the 1978 DOE BNFP utilization study.¹

4.2.4.4 Assumptions Used in Costs and Schedules for the International Fuel Services Center Option

In order to pursue, study and evaluate the IFSC concept - especially in regard to the specifics of cost and schedule matters - the following assumptions were made:

- The baseline concept is an international service center for reprocessing spent LWR fuel (as per the 1977 IAEA study,²² and the 1978 DOE Barnwell Application Study,¹ and as described in Section 4.2.4.1 "Description of the International Fuel Service Center", above).
- While many time-phased scenarios are possible, this use concept appears unlikely to gain timely support, funding, and program definition by any means other than the scenario assumed herein, i.e., the U.S. would decide first that Barnwell is required to support U.S. national interests (especially AFR and LMFBR programs); to meet the urgency of national needs the U.S. would proceed on a national basis with the immediate acquisition of BNFP from AGNS. The U.S. would also state the intention of operating initially in a U.S. government owned, contractor operated (GO-CO) mode of operation, hoping to shift to an international mode when arrangements can be successfully negotiated in the future.
- All the plutonium oxide output from this reprocessing will be reserved for the U.S. LMFBR program; the uranium hexafluoride (UF₆) could be used to support both the LWR and LMFBR programs.
- Cost estimates assume that part of any option would include purchase of the plant, as is, from AGNS at a price equivalent to the sunk costs stated in the 1978 DOE study (\$342 million in 1978 dollars, for Figure 4-23). This assumption was necessary for study purposes, but may have no relation to the real price which may be negotiated between AGNS and the DOE in the future.

- Sizing of the facilities to be adequate for accommodating 1500 MTU of spent LWR fuel per year (a daily average output of 6 MTU for 250 operating days) and 16 MTU plutonium per year. (Basic BNFP design adjusted for recent estimates of annual output).²⁶
- Solidification of HLW prior to indefinite term storage or transportation offsite is assumed to be accomplished by the Battelle borosilicate glass spray-calciner in-can-melter system.
- Spent fuel input to the BNFP service center is assumed to be LEU LWR fuel irradiated to a burnup of approximately 33,000 MWd/ton and containing approximately 1% plutonium.
- Purex process as per original BNFP design.
- Safeguards will be upgraded to meet or exceed the latest requirements of the NRC and the IAEA.
- Fuel fabrication is assumed to be for LWR fuel containing 5% plutonium, or for breeder reactor fuel containing 17% plutonium, or for both.
- Operating costs for eventual international operation of the IFSC are assumed to be approximately 150% of those developed in the 1978 DOE utilization study¹ owing to the additional personnel and administration required for international versus national operation. See Figure 4-24.

4.2.4.5 Schedule for the International Fuel Service Center (IFSC)

Figure 4-25 shows the current estimate of a reasonable schedule for development of the BNFP as Fuel Service Center for reprocessing commercial fuel. The estimates in Figure 4-25 were based upon adjustments to schedules contained in AGNS study report to DOE in May 1979,³ and are similar to the schedules found in Section 4.1.2.1.

FIGURE 4-24

OPERATION AND MAINTENANCE COST ESTIMATES
FOR THE IFSC OPTION

NOTE: Above estimate is of a rough order of magnitude based upon the \$297 M estimate for normal, steady-state, "full service" operations in the U.S. "national" mode. When/if the shift is made to international operation, the operational costs would increase (by 50 percent in the IEAL assumptions for this study).

FIGURE 4-25: SCHEDULE FOR FUEL SERVICE CENTER

- (1) This schedule is for the development and operation of BNFP as a national fuel cycle center. It is not realistic to predict the number of years it may take to convert from national to international operation until the institutional arrangements can be clarified.
- (2) The two-step licensing process for a reprocessing facility is estimated to be of similar duration for all of the fuel cycle facilities.

4.2.4.6 Cost Estimates for the International Fuel Service Center (IFSC)

4.2.4.6.1 Capital Cost Estimates

Capital Cost Estimates are shown in Figure 4-23. The costs are similar to those shown earlier for national fuel storage and reprocessing options with the addition of costs for fuel fabrication facilities.

4.2.4.6.2 O&M Cost

Operating and Maintenance cost estimates are shown in Figure 4-24. They are derived from the 1978 DOE applicability study estimate that \$280M per year (1978 dollars) would be required for normal operation of BNFP in the fuel service center mode, \$230M of which would be for fuel fabrication alone. The \$230M figure was added to the May 1979 AGNS estimates for fuel reprocessing and storage (\$73M [1979] adjusted to \$67M 1978 dollars) to reach a total of \$297M per year in 1978 dollars for "steady state", full service operations as a U.S. national facility. Lacking specific data for estimating the exact nature and cost of international versus national operations, the O&M costs were arbitrarily increased by 50% (to \$445M) for such a shift at an undefined date in the future.

4.2.4.6.3 R&D Costs

No R&D funding requirements have been clearly identified for this option. However, it is considered significant to note that most of the studies and references examined thus far in relation to the fuel service center concept show some R&D activity (see Figure 4-24 for example). The apparent dichotomy is that those who plan options for future BNFP utilization seem to have considered early engineering design and planning work to be in the R&D area without any clear definition of R&D versus other activity. Those who established cost

estimates were inclined to lump most of the costs for such R&D activities under the general (and larger) scope of Capital Costs. Such treatment may be more appropriate for the case of Barnwell as an IFSC, because most of the plant is already constructed and the remainder (plutonium conversion and fuel fabrication) is existing, demonstrated technology and therefore "engineering and construction" more than R&D.

4.2.4.7 Evaluation of the International Fuel Service Center

Expanding the existing Barnwell facility to develop an IFSC appears to be technically feasible relative to the technical feasibility of the various component facilities, most of which have been described in previous sections (i.e., AFR storage, reprocessing, plutonium conversion, and waste treatment). The technology for LWR and breeder fuel fabrication has been established; however, a specific site design for the Barnwell facility remains to be developed. According to the study done by Hanford Engineering Development Laboratory²⁴ Exxon currently has a licensed one-MTM/day-capacity mixed-oxide fuel-pellet-fabrication plant on standby. Westinghouse, Kerr-McGee, and Babcock & Wilcox (Lynchburg facility) have licensed development facilities that have been working on fuel-rod production for the Fast Flux Test Facility. The Kerr-McGee plant is now on standby, and Kerr-McGee is considering decommissioning it. Westinghouse has filed an application to construct and operate a commercial plant in South Carolina. The suspension of the GESMO hearings resulted in NRC's stopping all case reviews of the Westinghouse application.

The IFSC option for Barnwell would have definite and obvious cost-effectiveness advantages over having the final fabrication facility remotely located from the reprocessing facility, e.g., transportation and handling savings. The cost of safeguards and physical protection would also be minimized through reduction and overlap of repetitive

functions. The number of and support from the international participants could also enhance the cost effectiveness of this option. Compared to separate facilities at dispersed sites, the HEDL study estimated that an IFSC may realize a potential cost savings of between \$190-\$880 million through the use of common facilities.²⁵ These estimates are not specific to the Barnwell facility, and they represent four types of IFSCs, respectively:

- (1) Type A - Long-term spent fuel storage only (30-year storage).
- (2) Type B - Spent fuel storage, reprocessing, and fabrication.
- (3) Type C - Spent fuel storage, reprocessing, fabrication, and onsite plutonium burner reactors.
- (4) Type D - Spent fuel storage, reprocessing, fabrication, and onsite plutonium breeder reactors.

The potential savings for Type B facility, the most applicable for the purpose of this study, although at the lower end of the range of cost savings, would still be significantly more cost effective when compared to construction and operation of separate facilities.

In addition to the potential savings achieved through the collocation of facilities, using Barnwell as compared to building a "greenfield" fuel service center must also be considered in evaluating potential cost effectiveness.

From the standpoint of the nonproliferation implications of this option, assuming the policy decision to reprocess, the principal technical feature distinguishing the international fuel cycle

center from the reprocessing options discussed in Sections 4.1.2.1 and 4.1.2.2.1 is the inclusion of a fuel fabrication facility. Inclusion of such facilities makes it possible to ship fully-clad fuel elements (as opposed to PuO_2) from the BNFP site. Consequently, the impact of this option on proliferation resistance is due to the nature of the center's product. Other proliferation risks, such as diversion at the reprocessing or fabrication facility, would not necessarily be affected by the technical characteristics of this option. The overall nonproliferation implications of the IFSC are fundamentally related to decisions as to if and when the U.S. decides to proceed with reprocessing.

The rationale for shipping fabricated fuel elements only is to reduce the proliferation risks accompanying the material at and during transport to locations away from BNFP. Several benefits might be obtained in this case. Shipping only fabricated fuel elements might facilitate the task of safeguarding by facilitating material accounting procedures (certainly as compared to where MOX powders were involved) and by increasing the likelihood of detection of diversion. Shipping fabricated fuel elements, however, might not necessarily improve the timeliness of detection, which would depend upon the nature and strength of the safeguards measures themselves.

Another benefit is confinement to BNFP of the MOX inventories that would otherwise accompany dispersed fabrication facilities. In doing so, the level of proliferation resistance achieved would be only as high as that prevailing at BNFP. This option, however, would not necessarily affect the risk of seizure of the fuel.

As was the case with technical modifications of the fuel cycle (Section 4.2.3) the level of proliferation resistance achieved could vary considerably with the context, and specifically with the technical sophistication of the adversary and the resources available to it.

While fabricated fuel elements might complicate the task of a sub-national proliferator, they would pose less of an obstacle to national adversaries.

As far as the health, safety, and environment are concerned, the IFSC appears to offer no greater potential hazard than that of each component facility. In fact, it has been pointed out that colocation of the fuel cycle facilities would actually lower integrated population dose compared to multiple, dispersed sites.²⁵ Nevertheless, the growing reluctance of any state to accept the "burden of nuclear hazards" suggests that this international concept could encounter considerable local acceptance problems in spite of the many advantages it offers.

4.2.5 Technical Assessment of Barnwell Plant Design

4.2.5.1 Introduction

During the course of the design of the BNFP and, subsequently, in the many studies of the facility and its reprocessing flow sheet, several technical issues have been raised regarding potential problems that might limit the economic viability or the licensability of the operation of the facility. Many of these issues have been partially resolved either by engineering fixes at BNFP or by successful implementation of similar techniques in other facilities, and in the opinion of some qualified experts the BNFP Purex process is not pushing the state-of-the-art - that used with 3- to 5-year old LWR fuel (as opposed to the less than 1-year old fuel for which the BNFP was designed - the plant would operate up to expectations. However, there are still questions that need to be answered. The purpose of this section of the report is to describe these issues and the events that are likely to settle them.

This discussion was limited to the examination of a few documents and consultation with some key experts versed in the BNFP design and other reprocessing facilities. Thus, the discussion does not represent an independent technical analysis of the BNFP, but a compilation of the views of others.

The issues considered relate only to reprocessing LWR fuel and not to coprocessing or other modifications that have been suggested as alternative fuel cycles for BNFP.

4.2.5.2 Findings

A 1978 EPRI study concludes:

Considering only technical factors, the unanimous conclusion is that plant is operable on aged (3- to 5-year) LWR fuel without major modifications

This conclusion is qualified somewhat:

While review has called attention to several technical areas where further analysis, demonstration, testing, and/or minor modifications may improve the expected operability and reliability of the plant, these appear fully within the capability of present engineering practice and resolvable in conjunction with a program to operate the facility.²⁶

Answers to the unresolved technical questions raised in the EPRI study, and in other reviews of the BNFP technical viability, must await a more in-depth analysis, or in some cases, actual operation of the facility. These questions fall into three related areas:

1. The efficiency of the design mixture of contact/remote maintenance.

2. The licensing criteria that will be used by NRC.

3. The capacity of the plant.

These areas are related because resolution of the questions in one area will influence the answers to questions in another. For example, NRC safety and safeguards requirements will affect the amount of downtime for maintenance and inventories. The downtime will have a bearing on the efficiency of the plant, as it affects overall throughput. Such interactions are apparent in the following discussions.

4.2.5.2.1 Contact Maintenance

In the conceptual design stage, AGNS planners considered the relative cost benefits of contact and remote maintenance and concluded that commercial considerations dictated the use of contact maintenance where feasible and remote maintenance where necessary. In doing so, the planners traded off the significant additional capital cost outlays of remote maintenance, which require a much larger plant and a considerable increase in equipment, against the possibility of increased operating costs of contact maintenance, which can require long down times to permit access to contaminated equipment.

The combination of remote and contact maintenance is not unique to BNFP. The NFS plant, the Idaho Chemical Processing Plant, Windscale (U.K.), La Hague (France), and the Eurochemic (Belgium), all have used a mixture of contact and remote maintenance. However, none of the plants have operated for extended periods on high burn-up LWR fuel. DOE production facilities at Savannah River and Hanford have remote maintenance plants.

A general criticism of contact maintenance is that it results in process cells crowded with equipment and pipes, which means that effective decontamination is time consuming, that the access is limited, and that devices such as shields, which could be used in less crowded cells, are precluded.

The BNFP contact cells are constructed to reduce maintenance requirements to the minimum. In operation, flow blockage, which is a common problem, must be avoided.²⁶ This can be accomplished with careful attention to line and tank flushing. AGNS is planning for a program of meticulous maintenance in an attempt to keep the requirement for contact to an absolute minimum. The goal is to avoid any entries into the contact cells.

Background material for the EPRI study expresses some reservations about certain pieces of equipment that are inside contact-maintained cells and how often that access to them will be needed. Specifically, the placement of the solvent burner, six evaporators, and many condensers and exchangers in contact cells is questioned. The study concludes that inclusion of these items in contact-maintained cells means that "...probably all of the contact-maintained cells will have to be entered one or more times over the twenty-year life of the plant." A range of downtimes, based on AGNS estimates, for major maintenance shutdowns is given in the study as an average of 65 to 125 days/year.

In summary, the potential impact of the liquid contact maintenance concept on the plant's availability factor remains an unanswered question that will depend principally on how maintenance-free the equipment within contact cells operates over the life of the plant.

4.2.5.2.2 NRC Licensing Criteria

NRC licensing activities for the BNFP were suspended in late 1977, but activities had slowed considerably before that time because of the President's decision. As a result, there are areas where no licensing criteria specific to BNFP exist. This applies both to safety and safeguards. Furthermore, the licensing environment has and will continue to change, so that the direction that criteria would take should NRC renew licensing activities is difficult to predict.

The licensing activity that took place prior to December 1977, indicates that there are no severe safety problems and that the safety concerns that exist would relate generally to maintenance of the contact cells.* However, further safety analysis as related to licensing will be required. The licensing area of greatest uncertainty appears to be safeguards, particularly in the area of nuclear material measurements. NRC physical security requirements are delineated in a recently revised rule for all fuel cycle facilities, but material control and accounting regulations are now under intensive review.

Recent developments at NRC²⁷ indicate a trend toward regulations requiring material accounting that can measure an SNM inventory to within a specified fixed amount. This requirement would be in addition to current regulations, which specify measurement accuracy as a percentage of plant throughput (1% for plutonium and 0.7% for uranium) for inventories conducted every two months.

NRC's study of the safeguards need of a reprocessing plant [3 Appendix C] uses 2 kg of plutonium as the threshold for diversion detection.

*Also see Section 4.2.5.2.4, The Waste System p. 206, for a discussion of a safety issue related to high level liquid waste storage tanks.

Then having projected a plant-wide measurement uncertainty for a two-month inventory of about 36 kg, the study concludes that a two kilogram diversion would not be detected by material accounting means.

Given NRC's movement toward fixed inventory difference threshold criteria and the figures quoted above, it is likely that compensatory measures will be required. NRC's policy is to view physical security, material control, and material accounting as a total safeguards system, allowing physical security to compensate for inherent measurement limitations. Special inventories and more frequent routine inventories are also possibilities. All of these measures have costs, especially increasing the frequency of inventories, since inventories generally require shutting down the process line.

AGNS has developed plans for and is conducting research on a dynamic accounting system (see Section 4.3) that eventually would provide real-time accounting and continuous measurement of material in process. If this system is successful, its implementation could also help reduce the uncertainties of the periodic inventories and satisfy NRC's requirements.

In summary, NRC's requirements, as they might apply to LWR recycle at the BNFP, represent a significant uncertainty in the economic viability of the plant. Until the Commission's criteria are developed, particularly for materials measurement, the uncertainty will persist. Thus, the answer to the licensability question also must await: (1) a decision to proceed with reprocessing; and (2) a period for assessing the safety and safeguards programs in operation.

4.2.5.2.3 Plant Capacity

The nominal throughput for BNFP is usually quoted as 1500 tonnes of LWR spent fuel per year. This figure is based on assumptions of 300 operating days per year and 5 tonnes of processing capacity per day.

Both of these assumptions have been questioned²⁶ however, AGNS believes that 1500 tonnes per year is well within the capacity of the BNFP.

Most questions concerning BNFP capacity center on the available operating days, which is a particularly critical issue because its resolution depends on important uncertainties concerning the questions in the two previous sections, i.e., the frequency and period of maintenance required in the contact cells and the frequency of material inventories required by NRC.

The EPRI study obtained rough estimates from AGNS personnel concerning the times to decontaminate each cell for entry and the frequency of entry in the 20-year life of the plant. These estimates were used to derive an estimate of the average yearly downtime, using the assumption that all entries would take place at mutually exclusive times. This, as the study points out, is a conservative assumption, since in some cases more than one entry could be scheduled at the same time. Using this approach, the study estimates available operation time to be between 240 and 300 days per year.

Although the assumption of mutually exclusive entry times, which tends to decrease the expected operating times, may be overly conservative, there are other factors not accounted for in the EPRI approach that also tend to decrease available operating time. The 240-300 day estimate is for major shutdowns only and does not allow for special or routine safeguards inventories, which could add significantly to downtime (estimated at 15 to 60 days in the EPRI study).

AGNS officials, in a private communications, accept that their original estimates of 300 days of operation per year is probably optimistic and that 250 days is more realistic, but at the same time point out

that the plant should actually be able to process at least 6 tonnes of spent fuel per day. The combination of 250 operating days and 6 tonnes per day again yields 1500 tonnes per year. Further study is required for a more exact estimate of operating time.

A second area in which BNFP's throughput capacity has been questioned is in the receiving capacity. The estimate of 5 tonnes per day capacity is based on the assumption that 80% of the fuel arrives by train and 20% by truck. At BNFP the receiving capacity (in volume of LWR fuel) ratio of rail casks to truck casks is about 4:1. This means that, should the fraction of casks arriving by rail be less than 80%, the receiving capacity will be less than 1500 tonnes. EPRI estimates 1000 tonnes capacity for 40% train receipts and 800 tonnes capacity for 20% train receipts.

In making these estimates, the EPRI study addresses only receiving capacity, so that their projected limitations on receiving do not necessarily translate into limitations on processing capacity. This is true for two reasons. First, the storage pools provide a buffer that would allow inventory to build up before a processing campaign begins. Second, since shutdown of the processing operation does not necessarily mean shutdown of the receiving area, receiving operations could continue during process shutdown as long as pool storage space is available.

Nevertheless, AGNS is aware of the potential for a problem and has developed plans for adding equipment as a partial remedy (another crane and additional receiving stations) at a cost of \$4.5 million, which is included in AGNS estimates of the costs of completing the BNFP facility.

4.2.5.2.4 Other Issues

In addition to the questions that fall into the three general areas addressed in Sections 4.2.5.2.1 through 4.2.5.2.3, some questions that are more specific to particular procedures or equipment have been raised. These are the following:

Fuel Dissolution

Critics of contact maintenance point out that the desire for essentially zero scheduled maintenance in contact cells means that the BNFP must restrict the use of certain corrosive chemicals (specifically, fluorides). These critics claim that this may prevent complete dissolution of typical highly-irradiated (30,000 MWD/MT) LWR fuel. AGNS disagrees, pointing out that Oak Ridge National Laboratory experiments have shown the BNFP flowsheet will completely dissolve LWR spent fuel.

Also, according to the critics, the restriction of corrosive chemicals will preclude reprocessing mixed-oxide (MOX) fuel. However, AGNS included reprocessing of MOX fuel in the BNFP license application and is confident that MOX fuel can be accomplished with the currently planned nitric acid dissolution. However, the process has only been demonstrated in the laboratory, and a full-scale demonstration will be required.

Breeder fuel, which in contrast to MOX fuel's 5% plutonium content has 16-25% plutonium, presents a different problem. Complete dissolution of breeder fuel in the nitric acid is questionable. Thus, conversions of the BNFP to reprocess breeder fuel would require resolution of this question. (See Section 4.2.2.4 for additional discussion of this use of BNFP.)

Centrifugal Contactor

The centrifugal contactor is used for separation of uranium and plutonium from fission products. Critics claim it is extremely complex and that any solids reaching the unit will cause serious problems. The EPRI Study²⁶ points out that the concept has been demonstrated in hot operation in France, and that an upstream centrifuge prevents solids from reaching the centrifugal contactor. In addition, there are backup systems available should it be necessary to bypass the centrifugal contactor.

The Waste System

Critics suggest that there is little excess capacity for concentration of liquid waste to handle spills, flushes, etc. Also, concern has been expressed that the titanium, which is the material used for the High Level Liquid Waste (HLLW) concentrator unit, is particularly sensitive to corrosive materials, that, given the concentration levels of fission products in this unit, the chemistry of this waste will be complex, and that any problem with this unit would be a major one. Similarly, the single HLLW storage tank will generate a significant heat load. A loss of coolant to the tanks could lead to a major accident with potentially catastrophic effects. As a result, the tank features a complex system of backup cooling systems. NRC's licensing criteria for this tank are not definitive, but this is a system that will probably receive close review.

In answer to these comments, AGNS states that their waste system is designed to minimize liquid waste and that their liquid waste concentrator capacity is ample. Regarding the titanium structure of the HLLW concentrator, AGNS points out the BNFP uses no corrosive materials

that would attack the titanium. Also, the evaporator is in the remote process cell (RPC) so that maintenance or removal could be accomplished in the RPC with relative ease, i.e., relative to the contact-maintenance cells.

Finally, AGNS points out that the BNFP HLLW storage tanks are of the same design as the tanks used without problem at Windscale. Also, NRC has raised no objections to its use, although the Commission, of course, has not approved its use either. In addition, AGNS notes that the high heat levels that caused the concern about a loss-of-coolant-accident (LOCA) at the HLLW tanks resulted from analysis of the waste from the relatively young spent fuel for which BNFP was designed, i.e., less than one-year old. As noted previously, the EPRI study suggests that operation of BNFP should be for 3- to 5-year old fuel. Since the temperature drops exponentially with time, the heat generated in the HLLW tank would be considerably lower if only the older fuel is processed.

REFERENCES

1. Barnwell nuclear fuels plant applicability study. 1978. DOE/ET-0040. Vol. 2&3, App. C&F. U.S. Department of Energy.
2. Use of the Barnwell nuclear fuel plant for discharging responsibilities of the United States government. Draft. 1979. Allied-General Nuclear Services.
3. Nuclear fuel cycle closure alternatives: a reassessment. 1979. Allied-General Nuclear Services.
4. Engineering evaluation of wastes handling and storage facilities. 1979. Allied-General Nuclear Services.
5. Storage of foreign spent power reactor fuel. Draft Environmental Impact Statement. 1978. DOE/EIS-0040. U.S. Department of Energy.
6. Storage and handling of wastes from uranium fuel processing alternatives. 1978. AGNS-1040-3.3-34. Allied-General Nuclear Services.
7. Darr, David G. Preliminary safety and environmental evaluation for alternate fuel processes. 1979. AGNS-35900-4.4-34. Allied-General Nuclear Services.
8. Office of the White House Press Secretary. May 17, 1979. National Energy Plan II.
9. Hoof, D. 1980. Telephone conversation with DOE staff member 10 February 1980.
10. Elgen, O.J. Forecasts of nuclear material requirements. 1980. Letter from the Director, Nuclear Fuel Cycle and Production Division, DOE, Richland, to Mr. R. Staker, DOE, Germantown, 14 February 1980.
11. Final generic environmental statement on the use of recycle plutonium in mixed oxide fuel in light water cooled reactors; health, safety, and environment. NUREG-0002. Vol.3. U.S. Nuclear Regulatory Commission.
12. Reprocessing of reference LWR fuel and reprocessing of LMFBR fuel. 1979. Alternative fuel cycle evaluation program. Hanford Engineering Development Laboratory.
13. Potential involvement of AGNS in the CFRP. 1979. Letter from W.D. Burch, Director, Consolidated Fuel Reprocessing Program (CFRP) to Dr. J.A. Buckham, AGNS, 17 September 1979.

14. Variations of uranium and plutonium coprocessing as proliferation-resistant alternatives to the classical Purex process. 1979. AGNS-35900-CONF-14, August 1979. Allied-General Nuclear Services.
15. Preliminary conceptual designs: high-DF mixed oxide conversion facility, heat spike mixed oxide conversion facility. AGNS-35900-4.3-27. Allied-General Nuclear Services.
16. Cost comparison of alternatives. AGNS-35900-4.1-25. Allied-General Nuclear Services.
17. Reprocessing, plutonium handling, recycle. Draft final report. 1979. Working group 4. International Nuclear Fuel Cycle Evaluation.
18. Summary. 1979. Working Group 4. International Nuclear Fuel Cycle Evaluation.
19. Proliferation resistance. Vol. II. Nonproliferation Alternative System Assessment Program.
20. Resources and fuel cycle facilities. Vol. III. Nonproliferation Alternative Systems Assessment Program.
21. Reactor and fuel cycle descriptions. Vol. IX. Nonproliferation Alternative Systems Assessment Program.
22. Regional nuclear fuel cycle centers. Vol. I&II. 1977. International Atomic Energy Agency.
23. IAEA data as referenced in Reference 1, Vol. II:4-53.
24. Alternative fuel cycle evaluation program, data base. Vol. IA. 1979. Hanford Engineering Development Laboratory. November 1979.
25. AFCEP, Volume IV. International fuel service center evaluation. 1979. Hanford Engineering Development Laboratory. November 1979.
26. Electric Power Research Institute. 1979. Technical assessment of BNFP, phase I. Vol. I. May 22, 1979.
27. Report of material control and material accounting task force. 1978. NUREG-0450. U.S. Nuclear Regulatory Commission. April 1978.

ADDITIONAL SOURCES

1. Breeder utilization of plutonium recovered from LWR and breeder discharged fuel. AGNS memorandum from J.H. Gray to A.K. Williams.
2. Burns and Roe. 1979. International fuel service center study. Prepared for DOE under contract No. EN-77-C-01-5066. May 1979.
3. Safeguarding a domestic mixed oxide industry against a hypothetical subnational threat. 1978. NUREG-0410. U.S. Nuclear Regulatory Commission. May 1978.

4.3 SAFEGUARDS DEVELOPMENT, DEMONSTRATION, AND TRAINING

4.3.1 Description of Option

Safeguards, as the term applies to the nuclear energy industry, refers to measures taken in response to a perceived threat of facility sabotage, radiological sabotage, material theft, or material diversion. On the international level, safeguards utilize methods to inspect and verify that nuclear material intended for peaceful use is not being diverted to non-peaceful use. At the domestic level, safeguards utilize methods to prevent radiological sabotage, and unauthorized possession or use of nuclear materials through theft or diversion.

The safeguards of power reactors in the United States are designed for the prevention of radiological release by sabotage, while the safeguards of fuel cycle, research, and other non-reactor nuclear facilities, both foreign and domestic, are designed to prevent theft or diversion of nuclear materials. The former depend on physical protection systems; the latter on both physical protection and materials control and accounting systems. Within the U.S. government, the Nuclear Regulatory Commission (NRC) and the Department of Energy (DOE) have the primary safeguards function. Individual licensees are responsible for establishing safeguard programs for their facilities. The lead agency in international safeguards is the International Atomic Energy Agency (IAEA), formed in 1957 under United Nations sponsorship.

The Barnwell plant is equipped with analytical and physical measurement facilities, and is developing a highly automated and computerized materials accounting system that is superior to the accounting systems of other reprocessing plants, such as those in the U.K. (Windscale)

or Japan (Tokai Mura). Because of its commercial size, its state of construction, and its experienced staff, Barnwell appears to be a logical facility to install and to test fully integrated containment, surveillance, and accounting safeguards systems for potential use by the IAEA or by multinationally operated reprocessing facilities.

A possible adjunct to an advanced safeguards development and demonstration program would be the development of a training program for international safeguards inspectors (i.e., IAEA inspectors). Since the present training programs at Barnwell are well established and formally structured, the training expertise and experience of the AGNS staff could be utilized in an extension of that program.

Currently all personnel receive orientation and training in radiological and conventional safety, emergency procedures, quality assurance, physical security, and nuclear materials control. Formal classroom training is administered by the AGNS Training Department prior to assignment of the employee to a specific job. Retraining or refresher training is conducted for both the Separations Facility operators and security personnel on a regularly scheduled basis throughout the calendar year. Retraining activities for all other employees are conducted on an as needed basis. Thus, it appears that the present AGNS curriculum has many of the basic elements already in place from which to extend the present training program.

An ongoing DOE-sponsored activity, called the Advanced Integrated Safeguards System which is already partially in place and undergoing component testing at Barnwell. This system is comprised of physical protection components and technology developed by Sandia Laboratories and by AGNS, and computerized material control and accounting components and technology developed by AGNS personnel. DOE has provided

funding support for 1978, 1979, and 1980 for this research, test, evaluation, and demonstration project. The program time frame is open-ended as new components will be added and tested as they are developed. An operational forecast for completion of the integrated system as a whole, however, is 1984, pending continued financial support. This is a generic system for a fuel processing facility and is designed around the existing Barnwell plant. Some international involvement has already transpired. An indoctrination session and demonstration of certain components to a class of foreign participants in December 1979.

The BNFP Advanced Integrated Safeguards System, as presently conceived, consists of the following three major subsystems:

- A Computerized Nuclear Materials Control and Accounting System (CNMCAS).
- Verification and control of entry authorization.
- A Safeguards Coordination Center (SCC).

The CNMCAS contains a modular network of hardwired and dedicated computers, communications equipment, data collection, storage, and retrieval devices. These devices collect data directly from precision process instrumentation and from analytical instruments or analysts. The collected data can be used to estimate quantities of Special Nuclear Material (SNM), calculate uncertainties, provide near real-time accounting, calculate physical inventories, and monitor the process to detect unauthorized movement of SNM.

The APPS component development is focused on boundary and barrier configurations, entry control mechanisms, and electronic detection and assessment equipment. The effectiveness of the boundaries against unauthorized penetration is maintained by multiple detection

devices and by rigid entry control mechanisms. Entry control is established by the use of access portals through which all entry and egress traffic, both personnel and vehicle, must pass. Personnel access will be controlled by a series of successive real-time identification, verification, and authorization procedures within the plant. Further, sensitive zones will be continuously monitored by closed-circuit television to observe employee activity. These zones will also incorporate remote control of selected valves from the safeguards coordination unit to safeguard against the possibility of an employee endangering the plant by following incorrect or unauthorized procedures. Each employee will receive a thorough personal background investigation and screening prior to employment.

The access portals provide a mechanism for:

- Positive identification and search of individuals and vehicles
- Verification and control of entry authorization
- Real-time personnel inventory
- Documentation of approved access, as well as any attempted unauthorized access.

The SCC coordinates the activities of operations, physical security, nuclear materials control and accounting, safety, and others to assure that the activities are authorized and are performed by authorized individuals. Specifically, the center will provide:

- Continuous assessment of the status of the entire safeguards system and alerts to any actions that do not conform to established practice, or have not received proper authorization for revisions, or both;

- An auditable record of activities, procedures, material movement, and personnel access;
- Access by national and international inspectors to files which monitor pertinent aspects of the operations; and
- Zone operational control for all areas that have activities or materials that are sensitive from a safeguards point of view.

This Zone Operational Control System monitors all activities by personnel and all material movements within specified sensitive areas. It can interrupt authorized operations, alert operational control of procedural discrepancies, or initiate a physical security response.

Major construction items are:

- A site reception center for security screening of all personnel entering the site;
- Perimeter fences, barriers, alarms, and alarm assessment equipment;
- Improved vehicle and personnel access portals;
- Secured evacuation corridors and an evacuation search area for segregation of, and search of, personnel from material access areas after an evacuation;
- Improved Secure Access Passageways at portals to material access areas and vital areas;
- Hardened building(s) for Safeguards Coordination Center, Zone Operation Control, Central and Secondary Alarm Stations, together with related supporting equipment; and

- Installation of secure transmission links between all segments of the Advanced Integrated Safeguards System.

While design and construction of the Advanced Safeguards System are being carried out, software development and plant testing will be continued in order that all major data processing segments of this system will be fully operational when construction is completed.

Another variation has been proposed involving the development and application of international safeguards for interim spent fuel storage. On this theme, AGNS is developing a physical protection system for AFR domestic spent fuel storage at Barnwell. This AFR protection system will be designed to comply with existing NRC licensing requirements and will be fully in place when the first spent fuel arrives. One constraint, however, is that the two systems, the AGNS AFR and Advanced Integrated Safeguards System, will be completely independent of each other. Major engineering work for the AGNS AFR system will involve component installation, cabling, and the construction of a Central Alarm Station and Secondary Alarm station.

Still another addition to the above scheme is the development of an advanced material control and accountability system to be demonstrated in the AGNS fuel handling and storage area, which will exceed the current NRC licensing requirements and meet the IAEA goals. This system would use computerized input and accountability to monitor, track, and control all the fuel elements in storage in the AFR, and will eventually become part of the overall AGNS CNMCAS system.

4.3.2 Indications of Need/Interest/Support for This Use

The following quotation from the Nuclear Non-Proliferation Act of 1978 indicates the national need, interest, and support for safeguards development, demonstration, and training project requirements:

The Department of Energy, in consultation with the Commission, shall establish and operate a safeguards and physical security training program to be made available to persons from nations and groups of nations which have developed or acquired, or may be expected to develop or acquire, nuclear materials and equipment for peaceful use purposes. Any such program shall include training in the most advanced safeguards and physical security techniques and technology, consistent with the national security interests of the United States.

4.3.3 Sources Used in Determining Schedules, Costs, and Evaluation

The specific information used in determining the schedules and costs was obtained through informal verbal communication with AGNS personnel. The evaluation is based on material from the following studies:

- Barnwell nuclear fuels plant applicability study. 1978.
DOE/ET-0040. U.S. Department of Energy. April 1978.
- The development of an advanced safeguards system as a proliferation deterrent. 1978. AGNS-1040-CONF-67. Allied-General Nuclear Services. November 1978.
- Development of a computerized nuclear materials control and accounting system for a fuel reprocessing plant. 1979. AGNS-35900 CONF-4. Allied-General Nuclear Services. July 1979.
- Studies and research concerning BNFP, nuclear materials control and accounting system development FY-79 evaluation report. 1979. AGNS-35900-2.2-22. Allied-General Nuclear Services. November 1979.
- Studies and research concerning BNFP, in-process inventory evaluation. 1979. AGNS-35900-2.2-23. Allied-General Nuclear Services. November 1979.

- Studies and research concerning BNFP technician training. 1979. AGNS-35900-5.3-40, Allied General Nuclear Service, September 1979.

4.3.4 Assumptions

Assumptions for the basis of costs and schedules for the Safeguards Development Demonstration and Training Option are as follows:

- Any collateral use of BNFP would not affect the schedule for the design, procurement, and operation of a safeguards program.

4.3.5 Estimated Costs

See Figure 4-26.

4.3.6 Estimated Schedules

See Figure 4-27.

4.3.7 Evaluation of Safeguards Development, Demonstration and Training

Continued development and expansion of AGNS safeguards and training programs appear to be technically feasible given the current operable status of the AGNS programs. The fact that Barnwell has not yet been contaminated provides some initial flexibility in that selected safeguards methods could be demonstrated on an international basis without interfering with the normal "hot" operation of a reprocessing facility. However, the usefulness in the "cold" mode is limited and would decrease with time if the facilities are never run "hot" so that safeguards concepts can be developed and tested, and personnel trained, in a real world environment.

FIGURE 4-26

CAPITAL COSTS FOR SAFEGUARDS DEVELOPMENT,
DEMONSTRATION, AND TRAINING 1980
(Millions of 1980 Dollars)

	YEAR										
	1	2	3	4	5	6	7	8	9	10	TOTAL
AFR Safeguards	.22	1.3									1.52
Advanced Integrated Safeguards	2	3	4	8	16	16	6	5	2		62
AFR Advanced Safeguards	.8										.8
Training	.25										.25

NOTE: Operational and Maintenance costs are complex to derive as these may or may not interact with other Barnwell functions (e.g., electricity, building maintenance, maintenance personnel) and are not included herein.

FIGURE 4-27

This option is not cost effective as stand alone program. The price to the U.S. government for the Barnwell facility could be expected to bear some relation to the quoted sunk costs in the neighborhood of \$342M, 1978 dollars, and could not be justified to support stand-alone safeguards development, demonstration, and training program. However, if Barnwell were a staffed facility, used for other purposes, a safeguards program would be a cost effective adjunct. Furthermore, the cost effectiveness of this option would increase with the number of international participants and the economies achieved through co-location of various fuel cycle facilities.

As previously noted, the safeguards development, demonstration, and training option is supportive of national nonproliferation policies. Both Administration policy and the NNPA emphasize development of more effective safeguards. Safeguards development similarly is endorsed by INFCE. This option would directly promote this objective. This assessment, of course, is applicable to the safeguards use option and not necessarily to the collateral use that may have been selected for BNFP.

IAEA involvement in a development and training program would enhance the safeguards value of such an effort by providing IAEA input into the development effort and improving IAEA safeguard capabilities. As in any program which affords international access to BNFP, there would exist a potential conflict between the benefits of such access and the risks of transfer of sensitive technology. The magnitude of this risk, however, is mitigated by the fact that safeguards trainees would not obtain hands-on experience in operating the plant. This risk appears to differ little in seriousness from that arising from inspection in the first place.

4.4 NON-USE

4.4.1 Description of the Non-Use Option

Should no acceptable use option be found, one possible alternative would be to decommission BNFP.

Two decommissioning base cases, mothball and ready standby, were established. One alternative to the base case is the partial decommissioning (except for the Fuel Receiving and Storage Station) of BNFP should a spent fuel storage option be chosen. Following are definitions of the base cases.

Mothball

The plant, equipment, and systems are placed in a condition of shut-down, optimized for long-term storage. Staff and attendant costs are reduced to the minimum necessary for long-term surveillance and plant security.

Ready-Standby

A plant status that maintains selected systems and equipment in operational condition, but includes only such operation as required to preclude deterioration. Sufficient key personnel are retained to allow for orderly and rapid staff build-up and training effort in the event of recovery to operational readiness.

4.4.1.1 Primary Activities

Each of the base cases involve the three primary activities of phase-down, equilibrium and recovery. Below are definitions of the primary activities associated with this option.

Phase Down

A series of planned, orderly activities designed to place the plant in either mothball or ready-standby condition.

Equilibrium Shutdown

This is the condition in which phase-down activities have been completed, the plant has been placed in a stable shutdown mode, and costs and manpower are placed at minimum levels.

Recovery

Activities designed to place the plant in an operational readiness condition in which all functions required for licensing and operating the facility are complete. This would include the reversal of phase-down activities and any modifications or additions required to place the plant in operational readiness.

4.4.1.2 Summary of Decommissioning Modes and Alternatives

The requirements for the primary activities, costs, and time-frames may be defined as follows:

	Mothball	Ready-Standby
Total Decommissioning Base Cases	X	X
Partial Decommissioning AFR Option	X	X

Areas to be examined for implementation of the non-use option may be approached compositely for both the base cases and the alternatives. In the spent fuel storage option, only the Fuel Receiving and Storage Station (FRSS) and necessary supporting services and utilities would be required to be maintained operational. The remainder of the plant may be mothballed.

Implementation plans including their cost and scheduling, would have to be developed for each of the primary activities in the following areas: process equipment; piping; spent fuel storage; rotating equipment; HVAC equipment; process and portable instrumentation; surveillance procedures; support services during equilibrium; projected development monitoring; retraining; definition of recovery activities; and testing and upgrading to operational readiness including consideration of design planning for other balance-of-plant facilities.

4.4.1.3 Salvaging and Abandonment

The question of salvaging and abandonment arises if the U.S. government has no use for BNFP. The decision to salvage or abandon the Barnwell facilities is one determined solely by AGNS. It would be a reflection of nonproliferation policy or of financial considerations. Costs and criteria for this possibility are not examined. They would be largely determined by negotiations of a political or legal nature.

4.4.2 Interest in the Non-Use Option

The Barnwell Applicability Study of 1978 included the possibility of decommissioning the BNFP. Mothball or decommissioning is not considered a likely option, but it is treated here for reasons of completeness.

Subsequent to the 1978 study, Allied-General Nuclear Services developed cost and schedule estimates for mothball and decommissioning programs in fulfillment of this task, mandated for FY-1978.

Should no feasible alternative for BNFP be possible due to public opposition, or should no appropriate legislation be enacted in the South Carolina State Assembly to allow BNFP to remain operational, the plant may have to be decommissioned.

4.4.3 Sources Used in Determining Costs and Schedules

AGNS study 1040-5.2-27 The Requirements for Development of Evaluation Programs for BNFP Mothballing and Decommissioning August 1978, served as the basic source for projected cost and schedule estimates for placing BNFP in the mothball mode.

Other studies on decommissioning which might be of use regarding BNFP would be those related to General Electric's Midwest Fuel Reprocessing Plant (MFRP) in Morris, Illinois, the Hanford Purex plant in Richland, Washington, and the National Fuel Service plant in West Valley, New York.

4.4.4 Assumptions

The AGNS study assumed that, should the AFR option be chosen, only the Fuel Receiving and Storage Station, supporting services, and utilities would be required to be maintained operational. Costs and time schedules are assumed to be developed for these areas defined in 4.4.1.2.

4.4.4.1 Phase-down Assumptions Related to Costs and Time Frames

Eighteen months was projected by AGNS as the duration of phasedown activities for either the mothball or ready standby modes. The costs are estimated to be \$15 million (in 1978 dollars) for either variation. However, phase-down and recovery activities for the mothball mode would be of longer duration and cost somewhat more than for the ready standby condition. Costs during the equilibrium period (see Table 4-28) are minimized. Conversely, phase-down and recovery costs associated with the ready standby mode would take less time than in the mothball mode, while the costs in the equilibrium period would be higher. While these disparities in cost will exist, AGNS's preliminary planning has simplistically assumed identical costs and schedules for both modes during phase-down.

TABLE 4-28

COSTS: PLANNING, CAPITAL, AND O&M

	1	2	3	4	5	6	7	8	9	10	11	TOTAL
<u>Phasedown*</u>												
Planning Costs	2.5	1.25										3.75
Capital Costs (*Similar cost, either mode)	7.5	3.25										11.25
<u>Equilibrium</u>												
O & M (Mothball)		1.5	3.0	3.0	3.0	3.0	1.5					15.0
O & M (Ready/Standby)		2.25	4.5	4.5	4.5	4.5	2.25					22.5
<u>Recovery</u>												
From Mothball:												
O & M							5	5				10.0
Planning							12.5	12.5				25.0
Capital									32	32	16	80.0
From Ready Standby:												
O & M							5	5				10.0
Planning							15					15.0
Capital								40	40			80.0
<u>Total Costs</u>												
Mothball	10.0	6.5	3.0	3.0	3.0	3.0	19.0	17.5	32.0	32.0	16.0	145.0
Ready Standby	10.0	7.25	4.5	4.5	4.5	4.5	22.25	4.5	40	0		142.5

4.4.4.2 Assumptions for Cost and Scheduling in Equilibrium Shutdown

Costs in 1978 dollars are estimated at \$3 million per year for the mothball mode and \$4.5 million in the ready standby mode at sustained equilibrium.

4.4.4.3 Assumptions for Cost and Scheduling in the Recovery Phase

Recovery from equilibrium mothball to operational readiness was estimated to cost \$115 million in 1978 dollars, and to require 48 months. Recovery from equilibrium ready standby to operational readiness was estimated to require 42 months and cost \$105 million.

According to AGNS officials, a substantial portion of the recovery costs involve training, cost for operations and cold checkout. Additional runs with natural uranium during cold checkout are a costly process.

4.4.4.4 Summary of Assumptions

If the equilibrium condition is assumed to be five years, then the cumulative cost and duration (see Table 4-28 and Figure 4-29) from the decision to proceed to mothball or ready standby until recovery to operational readiness would be:

<u>MOTHBALL</u>		
<u>ACTIVITY</u>	<u>TIME</u>	<u>COST</u>
Phasedown	1.5	\$ 15.0
Equilibrium	5.0	15.0
Recovery	4.0	115.0
	10.5 years	\$145.0 million

FIGURE 4-29

TIME SCHEDULE FOR MOTHBALL AND READY-STANDBY DECOMMISSIONING ALTERNATIVES

READY-STANDBY

<u>ACTIVITY</u>	<u>TIME</u>	<u>COST</u>
Phasedown	1.5	\$ 15.0
Equilibrium	5.0	22.5
Recovery	3.5	105.0
	10.0 years	<u>\$142.5 million</u>

It is assumed that these costs are exclusive of capital requirements for balance-of-plant facilities. Cost and time schedules for the alternative case assuming the AFR storage option are unavailable.

4.4.5 Evaluation of the Non-Use Option

4.4.5.1 Cost Effectiveness

Whether the decommissioning of BNFP is cost effective or not depends initially on the comparison of possible alternative uses for the plant.

Should future uses of BNFP be considered, the recovery cost of bringing into a state of operational readiness would have to be added to the cost of any projected use. This would lessen the cost effectiveness of any future option.

Additionally, the longer the equilibrium shutdown period, the less cost effective decommissioning becomes relative to any other alternative which could have been pursued during that time frame.

4.4.5.2 Non-Use Option in Support of National Energy Policy

The non-use option could have a negative effect on U.S. energy policy. Non-use would reduce the possible storage space available for U.S. spent fuel if BNFP were not utilized in the AFR mode. Second,

non-use would eliminate the possibilities for international energy cooperation using BNFP. Furthermore, non-use and especially de-commissioning might constrain, delay, or even foreclose certain future U.S. breeder options, given the lead time required to complete the plant and bring it into operation. The seriousness of this potential cost, however, can be judged only in relation to the magnitude and timing of potential U.S. need for plutonium, and to the costs and benefits of potential alternatives to Barnwell in meeting U.S. nuclear-related energy needs.

4.4.5.3 Non-Use and U.S. Nonproliferation Policy

Since it is Administration policy to defer commercial reprocessing of nuclear fuel, continued non-use would be supportive of U.S. nonproliferation policy.

5.0 INSTITUTIONAL OPTIONS

The consideration and evaluation of institutional and related management options for the utilization of the Barnwell Nuclear Fuels Plant in various modes is a central component of this study. A particular use of Barnwell would provide an opportunity for the U.S. to exercise leadership in advancing beyond the conceptual stage the development of more effective international and multinational institutional arrangements appropriate to that use, and to influence the construction of a new international nonproliferation regime, in which these institutional arrangements would be a central element. At the same time, specific institutional arrangements may enhance, or detract from, the achievements of U.S. energy and nonproliferation objectives through various uses of BNFP.

Possible institutional arrangements for Barnwell are a foremost consideration in the evaluation of utilization options for several reasons. Among the most prominent of these are the direct relevance of institutional arrangements for the reduction of proliferation risks and the enhancement of energy security and other aspects of the political and economic acceptability of nonproliferation undertakings, the necessity of institutional arrangements to deal with proliferation risks, regardless of technical modification of sensitive materials and facilities, and the provisions of the Nuclear Non-Proliferation Act of 1978, with respect to the conduct of sensitive fuel cycle operations under "effective international auspices."

The term "institutional arrangements" has a broad meaning, and includes a range of undertakings to ensure the efficient and secure functioning of the nuclear fuel cycle through such means as commercial contracts, intergovernmental agreements, technical assistance programs, nonproliferation accords, supply assurances, and organizational measures designed for the ownership, management, or control or oversight of sensitive facilities and materials. With regard to the applicability of such arrangements specifically to BNFP, the latter

set of measures -- for ownership and for control or oversight of sensitive facilities and materials -- are especially pertinent, if for no other reason than if Barnwell eventually operates in a sensitive mode, how it does operate in both an institutional and technical sense will be closely watched by other countries and may have precedent-setting effects.

The centrality of institutional arrangements to the international nuclear regime, and specifically to nonproliferation and assurance of supply, is evident in the deliberations within INFCE and the conclusions of DOE's NASAP report. Both INFCE and NASAP recognize that institutional arrangements for nonproliferation and energy security purposes can be mutually reinforcing. As the discussion of INFCE and NASAP in Section 1.0 indicates, institutional responses to proliferation and supply assurance issues have been accorded a prominent place in deliberations on the international nuclear regime, although it must be pointed out that, while interest in INFCE is considerable, there is no international consensus as to which specific institution is most desirable.

The effectiveness of these institutional measures, from a nonproliferation point of view, is much less dependent on location or time than are technical measures adopted for comparable purposes. In advanced countries, technical nonproliferation measures may not pose much of a barrier to misuse. Similarly, their effectiveness over time may decline as the requisite technical capabilities to overcome them diffuse throughout the world. At the same time, institutional and technical approaches to the reduction of proliferation risk are not mutually exclusive and, indeed, may be complementary. A technical modification that reduces the sensitivity of a facility or material is not an effective nonproliferation measure unless accompanied by an institutional arrangement through which countries undertake to use this fuel cycle. Institutional arrangements for the enforcement and monitoring of compliance, and punishment of violation, are a necessary complement to technical measures.

Finally, the NNPA makes specific reference to the concept of "effective international auspices." This term appears in several provisions of the NNPA as a necessary condition for the acceptable condition of reprocessing or other sensitive fuel cycle activities. While granting that the intent of the NNPA was to apply this condition to foreign plants, and perhaps not necessarily to domestic ones as well, the institutional arrangements for BNFP could have a profound effect on the prospects for implementation of "effective international auspices" at foreign facilities.

The legislative history of the Act stresses that flexibility in its meaning was deliberately intended, since "considerable study and negotiation will be required to determine precisely what arrangements would be most desirable from the standpoint of reducing the risk of proliferation ... and achieving widespread participation." Thus, the emphasis in defining compliance with this requirement has been placed on the results achieved, rather than on the means of achieving them per se. It is clear, however, from the language of the Act that something more than international safeguards was intended. The Report indicates that "there should be international participation in the operation and/or ownership of the facility."¹

The ensuing analysis of institutional options is structured in the following manner:

- nature of institutional arrangements
- ownership arrangements
 - multinational ownership and management
 - international ownership and management
 - national ownership and management
- material control and oversight arrangements
 - international plutonium storage
 - international or multinational custody of sensitive materials and facilities

The distinction between the two categories of institutional arrangements is an important one, as it relates to the degree of flexibility available to the U.S. in establishing the institutional arrangements. The ownership arrangements could be tailored to specific features of a particular use for Barnwell. For example, multinational ownership clearly would not be feasible for an AFR servicing only domestic utilities. Arrangements for international or multinational control and oversight of sensitive material produced at BNFP, on the other hand, would be part of an international system for this purpose in effect at a number of reprocessing plants here and abroad and thus, might not be so tailored to the specific characteristics of BNFP.

Each specific institutional option is discussed in terms of:

- description of the institution; and
- generic evaluation, both in terms of individual merits and vis-a-vis other arrangements.

An analysis of the applicability of these institutional options to, and appropriateness for, identified use-options at Barnwell is found in Section 6.0.

5.1 NATURE OF INSTITUTIONAL ARRANGEMENTS

Institutional arrangements derive their proliferation resistance from the way in which the various features of the institution enhance the difficulty, detectability, or penalties of each of a number of proliferation threats, including national diversion, national seizure, abrogation of or withdrawal from nonproliferation undertakings, and abuse of technology transfer, and from their overall effectiveness in limiting the number and location of sensitive facilities. How the institution achieves its proliferation resistance, specifically in terms of how it combines institutional features, can have a direct and significant effect upon the economic and political acceptability of the institution. The relationship between the two -- proliferation resistance and acceptability -- is crucial not only to whether

the institution is worthwhile but also to whether it has reasonable prospects for adoption.

Among the features of an institution are:

- the composition of the membership;
- the provisions for ownership and management of a fuel cycle facility;
- whatever siting restrictions prevail; and
- the functions that the institution performs, e.g.,
 - safeguards,
 - setting and enforcing a code of exporter conduct,
 - storage and oversight of sensitive material, and
 - ownership and operation.

These are general features, however, and not all are relevant to the specific case of Barnwell. Although siting restrictions as a non-proliferation measure have no direct relation to Barnwell, the effect of whatever institutional arrangements are devised and implemented for Barnwell on the establishment of, and institutional arrangements for, sensitive facilities elsewhere in the world is a particularly important consideration. Similarly, a code of export policy conduct is not especially dependent upon what is done with Barnwell. Such a code already exists in the form of the London Suppliers' Group guidelines and would likely be elaborated on in the future without direct reference to a specific activity or facility. Nevertheless, the regulations that might be established in such a code to govern the availability of certain kinds of fuel services and the distribution of sensitive material could be incorporated as a feature of other institutional options implemented explicitly for Barnwell.

There are important institutional factors that are not affected by the nature of specific institutional options. The first is the application of safeguards to Barnwell. International safeguards are

presently applied by the IAEA through the INFCIRC/66 system and the INFCIRC/153 system established pursuant to the NPT. Application of safeguards by the IAEA to Barnwell could be required upon ratification of the U.S.-IAEA Safeguards Agreement, if there is Scientific Nuclear Material (SNM) present and if the IAEA, under the terms of the Agreement, chooses to apply safeguards there. Nevertheless, with respect to Barnwell, those safeguards may be improved through adoption of new techniques and instrumentation. Thus, no further consideration is given in the following analysis to the question of who performs safeguards responsibilities. Improvements in safeguards are discussed in Section 4.3.

The second factor relates to the market for Barnwell's services. The scope of Barnwell's market is a consideration of major importance. Whether Barnwell's customers are solely domestic or include foreign parties will have a fundamental impact upon the utility of Barnwell as an instrument of U.S. nonproliferation policy.

The scope of the market depends in part upon the nature of the institutional option. An institutional arrangement for the application of safeguards would not necessarily impose a responsibility upon the U.S. to offer fuel services at Barnwell to other than domestic customers. On the other hand, extension of the services to all countries participating in a multinational ownership arrangement would be a normal and expected feature. The size of Barnwell -- 1500 MTU/yr -- and the scale of projected domestic demand for plutonium under some scenarios may significantly limit the contribution Barnwell might make to meeting foreign demand for reprocessing.

Nevertheless, extension of fuel services to foreign customers would be an essential feature of any institutional option that had as a primary objective providing an alternative to similar facilities constructed elsewhere. Failure to do so, especially where lack of access to the service in question is a potential obstacle to nuclear power utilization, might be seen abroad as seriously prejudicial to energy security interests and might thus encourage construction of autonomous facilities.

The issue of foreign access to fuel services at BNFP raises obviously significant questions with regard to the responsibilities the U.S. is willing to assume vis-a-vis foreign parties. Whether the provision of fuel services to foreign customers is treated by the U.S. as an opportunity or as an obligation, and whether domestic customers are given priority, or both foreign and domestic are treated on a first-come-first-served basis, are questions of direct relevance to the ability of a particular option for BNFP to contribute to U.S. policy.

The seriousness of these questions may be considerable if materials or services with a high degree of proliferation sensitivity or environmental risk are involved. One issue in particular is whether provision of reprocessing services should be confined to countries with on-going advanced reactor R&D programs. The terms and criteria governing foreign access to BNFP, especially those determining which countries can utilize which kinds of services, have a direct relationship to the composition of any multinational group involved with Barnwell operations. While consideration of these terms involves discretion in granting foreign access and careful consideration of the appropriateness of that access at any specific point in time, denying all foreign access appears inconsistent with U.S. policy objectives and with the mandate for this study.

The relevance of the institutional arrangements to subnational diversion or seizure risks at BNFP and physical security responsibilities should be stated at the outset. Although subnational threats may be serious, the primary relevance of the institutional arrangements considered here is to national proliferation, which, in the case of Barnwell, would be by countries other than the U.S. Physical security is clearly a state rather than international responsibility, and it is assumed here that the U.S., as host country, would carry out the physical security function. Nevertheless, some institutional options, by improving detection capabilities for controlling or overseeing movement of plutonium, could reduce subnational risks, but that is not their main purpose.

Finally, not all of the institutional arrangements described here are at the same stage of either conceptual development or actual on-going international deliberation. For example, international plutonium storage has been under active study within the IAEA for over a year and has found considerable interest and support within INFCE as an important institutional step which could be adopted in the near-term. On the other hand, custody is a relatively new concept whose details have not yet been subjected to the same amount of scrutiny as the other concepts, and which may be a longer-term option. At the same time, Working Group 4 of INFCE has observed that institutions can evolve over time to include additional countries or facilities, and that multinational arrangements may be a desirable goal of this evaluation.²

5.2 OWNERSHIP ARRANGEMENTS

The ownership arrangements for a facility can affect both the energy and nonproliferation advantages and disadvantages attributable to that particular facility. This may be especially true of assurance of supply and proliferation risks occurring at the facility itself. At the same time, the ownership arrangements may be relevant to U.S. influence upon comparable foreign nuclear activities.

In considering institutional arrangements, it is important to distinguish between those arrangements tailored to a specific facility, and those constituting international or multinational systems in force at a number of facilities around the world. The class of arrangements considered here -- for ownership -- would be tailored to Barnwell. The second class -- for material control and oversight -- could be in force at a number of facilities.

5.2.1 Multinational Ownership and Management

A multinational approach to the ownership and management of a fuel cycle facility, in which a carefully selected group of countries owns shares in the facility and participates in decision making, provides

an opportunity to offer an alternative to nationally built and operated facilities and to strengthen the deterrent against seizure of sensitive facilities and materials or abrogation of nonproliferation undertakings on the part of any of the participants.

The ownership arrangement in this option would apply to Barnwell only and would not necessarily entail control of its product. Two specific options for control and oversight of sensitive products -- international plutonium storage and custody -- which could be combined with ownership arrangements, are discussed later in this chapter. The management structure of a multinational ownership arrangement could employ a two-tier organization, separating policy from business matters, or a lead-country arrangement, confining the multinational participation to ownership only.

The composition of the multinational group is crucial to the effectiveness and acceptability of the institution. A primary criterion governing composition is the incorporation within the group of an adversity of interest toward proliferation. This entails a genuine commitment on the part of the members as a whole against proliferation and a willingness and ability to enforce compliance with the nonproliferation undertakings of the arrangement and to take necessary steps to deal with violations of those undertakings. A high degree of political and economic interdependence among the members might reinforce the effectiveness of multinational ownership as a nonproliferation measure by raising the costs of violation. At the same time, the nonproliferation effectiveness of this institutional arrangement would be inherently limited if it did little to directly affect the potential for more proliferation-sensitive countries to build their own facilities. This implies that a priori exclusion of such countries from membership could be counterproductive.

The composition of the group also may have important consequences for the economic, operational, and political viability of the arrangement. Augmentation of the available market through the inclusion of additional ones in foreign partners might be a commercially attractive prospect. U.S. domestic demand alone in some cases could support Barnwell. At the same time, the inclusion of a diverse range of

economic and energy interests and circumstances in the management of the facility and in policy making could severely undermine the effectiveness of operating the facility under a multinational ownership arrangement. In this regard, the same interdependence that strengthens the proliferation resistance of this institutional option also might mitigate somewhat the potential in a multinational group for conflict over commercial questions by creating a high stake in efficient operation.

These considerations place considerable weight upon the careful selection of prospective participants, since this factor can have a marked impact upon their satisfaction with the arrangement and upon the perceptions of other foreign parties regarding its applicability and desirability in their own situations. Clear evidence of technical and managerial competence in the operation of a multinationally owned and managed facility would be essential to the economic credibility of the undertaking.

From a nonproliferation standpoint, the sensitivity of the facility in question is an important constraint upon the selectivity of composition. A less sensitive operation, such as spent fuel storage, might permit a less restrictive composition for the group, with need for this particular service as a criterion for selection, whereas a more sensitive use-option might circumscribe more narrowly the number of eligible participants. On the other hand, it must be recognized that a primary purpose of multinational ownership is to provide a means for potentially sensitive countries to have an alternative to reprocessing on their own or elsewhere, possibly under less rigorous nonproliferation conditions. Following this purpose through to its logical conclusion leads to the existence of a possible trade-off between effecting a delay in national reprocessing and providing access to the operation of a joint facility and its technology in a safe location. The timing of making this access available, in relation to the recipient country's legitimate need for plutonium, would be a major consideration in addressing this trade-off.

With regard to the nonproliferation benefits of multinational ownership for Barnwell, the principal gain may be in terms of the degree to which the foreign partners forego construction of indigenous facilities, thus reducing the overall number and location of such facilities. The magnitude of this benefit would increase as the sensitivity of the facility in question rises, although it is admittedly difficult to quantify this gain. The other primary nonproliferation benefit of multinational ownership -- deterrence of host country seizure -- would not be applicable in the case of Barnwell, except insofar as Barnwell might serve as a model or precedent for multinational approaches subsequently applied in non-nuclear weapon states.

At the same time, multinational ownership and management per se have no direct bearing upon the effectiveness of safeguards or other diversion detection capabilities, and may lead to unwanted technology transfer problems if the ownership arrangements create a presumption on the part of the partners towards eventual technology sharing or access. In general, with regard to the nonproliferation advantages directly attributable to ownership, the differences between the penalties of violating or abrogating an arrangement based upon property rights and, thus, the magnitude of the deterrent against such an act, and one based upon irrevocable rights of control over access and egress to and from sensitive facilities and over release of sensitive materials appear marginal.

Multinational ownership would provide a vehicle for countries otherwise confronted with the high investment demands of a national facility to share at less cost in the ownership of a multinational facility and to strengthen their claim, in an institutional sense, upon the services of that facility. Discussions in INFCE have indicated the existence of some foreign interest in multinational ownership for these very reasons, if participation is voluntary and if currently outstanding issues with regard to supplier behavior and the nature of export controls can be satisfactorily resolved.

There also may be several significant disadvantages from both economic and management points of view. Multinational, as opposed to national, ownership and management curtail national control over fuel cycle policy, involve foreign participation in proprietary matters, and may seriously detract from managerial efficiency insofar as decision making is by compromise among competing national prerogatives. The use of lead-country arrangements for management, or two-tier structures in which political matters are kept separate from technical ones, is becoming increasingly frequent in multinational ventures as the inherent problems of joint management are recognized. The consequences of inefficient management can be particularly serious if dissatisfaction with the arrangements encourages the independent efforts the institution is designed to prevent.

Multinational ownership and management also may pose problems of a public acceptability nature. In the wake of TMI, the competency and strength of the management of nuclear operations have become salient aspects of local acceptability problems, and any inefficiencies or weaknesses attributable to multinational ownership and management could introduce additional complications for public acceptability. Moreover, the extent to which foreign ownership might dilute the influence of local authorities in health and safety matters could directly affect public and institutional responsiveness to such an arrangement.

5.2.2 Multinational Staffing

In addition to ownership and management, multinational participation could be extended to the staffing arrangements as well. Staffing arrangements may have a direct bearing upon the detection of diversion. Whereas national staffing places the full burden of surveillance upon IAEA inspection, multinational staffing could provide a "built-in" inspection capability if multinational staff are at all sensitive points at all critical times, able and willing to perform a

surveillance task in addition to their normal operating responsibilities, and possess adequate channels for reporting violations. This feature could supplement, but not substitute for, IAEA safeguards.

The nonproliferation importance of staffing provisions depends to a great extent upon the type of facility in question and the potential of advanced safeguard techniques to achieve a real-time detection capability. Detection of diversion from a spent fuel storage facility is technically straightforward and can be achieved through instrumentation and inspection. Detection at a reprocessing plant is far more demanding and is more dependent upon containment (physical barriers to movement of sensitive material) and surveillance. The staffing arrangements may be more significant for the reliability of detection in the latter sort of facility.

As with other arrangements that entail access of foreign personnel to fuel cycle facilities, multinational staffing creates a potential for unwanted dissemination of information and technology. Although this potential exists with regard to IAEA inspection as well, it may be greater in the case of multinational staffing at the operational level because of the direct and hands-on experience the operating staff would have. The magnitude of this problem is not easily demonstrable. On the other hand, consideration may be given to whether, and to what degree, access to the plant's operations and technology might be granted to particular countries in exchange for deferral of national reprocessing activities and to the timing of this access in relation to that country's legitimate need for plutonium.

How to contain this potential without jeopardizing the effectiveness of surveillance is a serious matter. Limiting access to sensitive technology to nationals of countries with advanced capabilities in the sensitive area is one possible approach. Another is to rely more heavily upon control of the site perimeter and of access/egress rather than upon multinational staffing at the operating level. Finally,

careful consideration must be given to whether there exist other means of achieving real-time detection, as might be feasible with advanced safeguards instrumentation, which would provide an alternative to multinational staffing for this purpose.

Multinational staffing might also adversely affect operational efficiency if it introduces language and cultural barriers that would make the work force less cohesive than a comparably trained national one. The expense of overcoming such problems represents additional costs not encountered in a national plant. Although the prospect of multinational staffing might make an institutional arrangement more attractive to foreign participants, it figures far less prominently in terms of the overall acceptability of the institution than the core issues of who owns fuel cycle facilities and the terms upon which access to them is granted.

An important limitation of these and other arrangements for ownership, management, and staffing of facilities, from a nonproliferation point of view, is that they have no direct bearing upon the control and oversight of sensitive material, and thus the proliferation risks accompanying that material, at locations away from the multinational facility. This is especially serious, since releasing this material into a context within which safeguards are the only institutional arrangement in force would leave a major aspect of the proliferation problem unalleviated. Possible responses to this weakness involve integrating multinational or international control and oversight of material with a multinational ownership arrangement or establishing a separate institution for material control and oversight purposes only (see Sections 5.3.1 and 5.3.2). Ownership arrangements also do not directly address the question of whether, or how, the existing IAEA safeguards system should be strengthened.

An additional limitation on the efficacy of multinational ownership as applied to Barnwell is that its direct nonproliferation benefit,

e.g., reduction of host country seizure risks at the facility, is largely superfluous insofar as the host country is already a nuclear weapons state. The principal benefits achievable through multinational ownership in this specific instance are the persuasiveness of the possible precedent that might be set for others to follow and the reduction in the number of plants built elsewhere if other countries accept multinational ownership as an alternative to reprocessing elsewhere. However, INFCE indicates that the question of ownership may have less impact on foreign decisions about where to reprocess than might the terms and predictability of supply.

5.2.3 International Ownership and Management

Arrangements for international ownership and management differ from those for multinational ownership primarily in the composition of the membership. Whereas in the latter case the number of participants was limited, in an international group, all interested countries, or the IAEA, or both, would participate or be eligible to do so. International ownership and management raise many of the same issues as does a multinational arrangement for this purpose, but in a way aggravating many of the disadvantages of the latter. Consequently, an extended discussion of these problems is not presented here. Some attention should be paid, however, to specific issues arising from whether it is the IAEA or some other international collection of countries that is involved.

Although there may be a general preference for working with existing international organizations rather than for creating new ones for such a specific task as owning a fuel cycle facility, assumption of an ownership role by the IAEA, either as the sole owner or as partner with the host country, could result in several serious problems. International organizations like the IAEA may be ill-equipped to handle the financing, ownership, and management of complex facilities. Moreover, the politico-economic and energy resource diversity of its

members might severely handicap decision making, with adverse consequences for the IAEA's ability to operate a fuel facility efficiently. It is not evident that tinkering with the decision making apparatus can change the consequences of the composition of its membership. With a smaller and presumably less diverse membership, Eurochemic suffered from significant problems of indecision and member inability and unwillingness to meet financial obligations. The IAEA, as a result, would appear to be ill-suited for such a role.

Some form of "lead-country" management and operation would be even more urgent in the case of an internationally owned facility. This would be particularly so if the facility involved a complex and interdependent set of operations whose efficiency would be highly sensitive to the strength of management and operational competency.

A major consideration in regard to international ownership is the potential for significant and debilitating levels of conflict to be incorporated within the institution. Although conflict over business decisions would also occur in a multinational group, the greater range of interests in the international group, especially between industrialized and less industrialized countries, and the possibly more diffuse influence structure in the group could make the institution less manageable. Similarly, international staffing might present recruitment problems, especially if national quotas are demanded.

Finally, if INFCE is an accurate guide to foreign attitudes, there is little, if any, foreign interest in international ownership as an institutional option. This attitude does not extend, however, to multinational ownership, if implemented on a voluntary rather than exclusive basis.

The existence of such serious problems with international ownership and management, and the lack of interest in such arrangements, suggest that alternative international approaches might be more feasible

and attractive. One such alternative might be to bring a basically multinational arrangement into a relationship with the Agency. Whether this would be a special case of multinational ownership or a true international arrangement would depend upon the nature of this relationship and the Agency's authority within it. A simple reporting relationship in this regard is quite different in implication than one in which the Agency would set policy standards for the project or actually possess decision-making authority over it and administer controls governing use of the facility. Examples of the latter kind of arrangement are international plutonium storage and international spent fuel storage.

An international arrangement along the lines just considered would seek to provide an alternative to national facilities, and may be open to participation by a greater number of countries than a national or more narrow multinational arrangement. It would also broaden the financial base for fuel cycle projects. On the other hand, U.S. control over management and operation would be diminished, certainly as compared to national ownership, and even to a multinational group of more selective composition. There would be major concern at determining participation through self-selection. U.S. control over deposit and release of materials similarly might be diluted. The presence of foreign nationals, especially if the international character of the arrangement infringed upon host-country responsibility for health, safety, and environmental matters, could create serious local and even national opposition problems.

5.2.4 National Ownership and Management

Continued national ownership and management of Barnwell by either a private or government entity present an alternative to multinational or international ownership of the facility. At the same time, national ownership is not incompatible with other institutional arrangements, such as international plutonium storage or custody, which

have the potential for achieving significant nonproliferation benefits, but which do not involve foreign participation in the ownership and management of the facility. National ownership, within the framework of such arrangements, would not be inconsistent with the provisions of the NNPA calling for the establishment of "effective international auspices" to be applied at reprocessing plants. These provisions as noted earlier, are sufficiently flexible in intent as to entertain a range of possible arrangements not confined solely to foreign participation in ownership.

In general, national ownership and management present several advantages over alternative multinational or international ownership arrangements. The U.S. would have more direct control over activities in the facility than might be the case if foreign parties participated in decision making by virtue of their share in ownership. There would be less risk of technology transfer, since foreign ownership might entail, at a minimum, a presumption in favor of technology access or even foreign participation in staffing at operational levels. National ownership options might be established in less time than multinational or international options, which might be preceded by lengthy negotiations. Management would not be complicated by the inclusion of competing foreign interests in decision making, as might be the case in the multinational or international approaches. There may also be fewer complications posed for local acceptability, as established regulatory patterns and political relationships would not be broken if national ownership and management were retained.

National ownership, on the other hand, also suffers from several significant disadvantages. To the extent that an ownership share might be an incentive to forego national facilities elsewhere, national ownership would not provide this benefit. However, it must be questioned, in light of what INFCE has revealed of foreign attitudes, whether ownership per se, or the terms of access to services and materials, is of greater significance to foreign plans for sensitive facilities.

National ownership also would not offer an opportunity to set a precedent to the effect that the institutional circumstances of sensitive facilities, specifically the question of who owns them, demand special and careful consideration. Rather, national ownership might appear to legitimize similar arrangements for plants built elsewhere. The significance of this disadvantage depends upon the weight given to ownership in the establishment of legal and political barriers to proliferation risks.

Continued national ownership would not take advantage of the opportunity to strengthen assurances of supply of fuel services through ownership shares. On the other hand, the efficient provision of a fuel service on attractive economic terms, to the extent facilitated by national rather than multinational ownership and management, might make an important nonproliferation and energy contribution, especially if it discouraged construction of less economic facilities elsewhere.

Possible National Ownership Options

One can identify several options for national ownership:

- private ownership and management;
- government ownership and management;
- government ownership, contractor operation; and
- independent government corporation.

Each option is described in general terms below.

Private Ownership

In the private ownership option, either the present owners of Barnwell, AGNS, or another private U.S. corporation would hold all equity in the facility and would assume all normal commercial risks for existing and new facilities at Barnwell. Private ownership would not exclude government subsidy or debt guarantees.

The choice of a continued private ownership option could be based on the belief that, as a matter of principle, the government should not engage in activities that are essentially commercial or industrial. A second argument, supporting the first, would emphasize the importance of taking the first steps in establishing what could eventually become a competitive private industry that might better provide for potentially more appropriate market prices, greater technological innovation, and lower direct federal budgetary outlays.

The arguments in favor of private ownership, however, are contingent upon several assumptions. The economic efficiency attributed to private ownership may depend more upon the existence of competition rather than the private ownership itself. The pace of innovation, similarly, may depend upon the existence of incentives provided by a competitive market. The prospects for competition are affected by the size and growth of the market for the services and, thus, the number of companies able to enter the market. The market variable may be an underlying factor in determining whether the efficiency arguments in favor of private ownership will be borne out.

The arguments in favor of private ownership also assume that private companies are more willing to assume technological or market risks. However, this willingness may be affected by corporate financial stability, among other things, and certainly by corporate perceptions of the future of nuclear power. Any failure to provide services or complete a project because of the financial state of the corporation

could have seriously adverse political consequences if the service in question has an important bearing upon energy security or the state of nuclear power.

Finally, while private ownership would reduce or eliminate potential federal outlays for construction and would generate local and federal tax revenues, the government would not realize revenues from sales of the federally produced fuel services.

Government Ownership and Management

If demand for the fuel service failed to materialize at a level sufficient to support a competitive industry, or if prospective private companies proved reluctant to assume ownership and its attendant commercial risks, then the case for private ownership would be weakened. In such a situation, it would be less likely that the benefits of economic efficiency, fair market prices, and innovativeness attributed to private ownership would be achieved. If such developments are considered probable, then there may be significant reason to consider government ownership as an alternative to private.

Government ownership could be implemented through establishment of either a self-financed enterprise as a subdivision of an existing Department, such as DOE, or as a government corporation within a Department, and subject to OMB and Congressional approval of its budget. Both entities would be financed independently of government appropriations by reapplying revenues from sales and by borrowing from the Treasury, the public, or both. Both entities would be subject to government policy constraints on expenditures and debt management, depending on legislative limitations imposed at the time of establishment.

The argument for government ownership is further strengthened to the extent to which the economic inefficiency that can result from government enterprises can be avoided. Methods could be adopted to make

the price of government-provided services approximate the price that would be set by a private owner. Endowing the government enterprise with self-financing authority would relieve dependence upon the federal budgetary cycle, although recourse to the Treasury could be necessary when costs exceed revenues or where borrowing is necessary to finance capacity expansion.

Government ownership of Barnwell would offer several advantages over private ownership. The foremost of these might be greater U.S. freedom to use Barnwell as an instrument of policy. This advantage could manifest itself in greater flexibility in packaging fuel services to maximize their attractiveness to foreign customers, in adopting nonproliferation-related technical modifications for a fuel facility, and in facilitating various forms of foreign participation in the facility and related activities. Private ownership might constrain U.S. ability to do this.

Government ownership might enhance the credibility of the enterprise, especially if private sector parties are particularly averse to risk. The full resources and commitment of the federal government would support a government-owned venture and, consequently, might inspire greater consumer confidence in continued operation.

Government ownership also may have several disadvantages. Although self-financing might reduce dependence on the budgetary process, this might not be completely eliminated where construction of new facilities is required. Policy decisions regarding the facility might be more directly influenced by competing government interests and priorities than would be the case if the facility were privately owned. Government ownership also might discourage future private initiatives in this sector, especially if a government owner would have access to more attractive Treasury financing terms. A "guillotine" clause limiting the duration of government ownership, or mandating that all

future such facilities be privately owned, might be a means of addressing this issue, but the experience in the 1970s with arranging a transition from public to private enrichment suggests that such a step can be accompanied by serious uncertainties, at potential cost to consumer confidence in U.S. policy.

Government Ownership -- Contractor Operation (GOCO)

This option would apply to Barnwell the ownership management format long in force at such government facilities as enrichment plants and production reactors found at Oak Ridge National Laboratories, Savannah River plant, etc. In doing so, it would fit a proven organizational pattern while retaining many of the advantages cited with regard to government ownership (e.g., government ability to use the plant for policy purposes, control of sensitive technology, etc.) without requiring the establishment of a new entity within government to operate the facility. The selection of the contractor could be conducted on a competitive basis, although the enforcement of efficiency on the part of the contractor, once selected, in this case would rely upon regulation and government oversight rather than market competition.

This option, however, would not necessarily relieve all dependence upon the budgetary cycle. Moreover, it would take longer to establish such an enterprise, as compared to continuing private ownership, but less than would be necessary to establish an independent government corporation. The seriousness of this timing problem depends upon the urgency of the need for the particular fuel service in question.

Independent Government Corporation (IGC)

An independent government corporation, along the lines of the Tennessee Valley Authority or the Export-Import Bank, could be established

with self-financing authority to run the facility as a commercial enterprise. The board of directors would be selected on the basis of business competence, and decisions could be made in response to business conditions and market changes rather than an arbitrary appropriations cycle. A sizeable outlay of federal funds, however, would be required in all government ownership options to purchase the existing facilities and site from AGNS.

As with other government ownership options, an independent government corporation might provide a more direct means of using Barnwell as an instrument of policy than would private ownership. The resources and commitment supporting the project are those of the government itself, which might enhance foreign perceptions of the long-term nature of the undertaking. An independent government corporation also would be independent of the budgetary cycle.

A major disadvantage of this option is that it would employ an institutional arrangement that is as yet untried for sensitive material related activities. Although an independent government corporation may be able to take a more long-term perspective towards commercial risk, and may better integrate political considerations related to nonproliferation and energy security into its decision making than might a more risk-averse private company, it is nonetheless not free to disregard commercial considerations and, thus, may be less amenable to policy direction by the federal government than an ownership entity within an existing department.

An independent government corporation would be subject to the same regulatory constraints as would a private company. Finally, the very existence of an independent government corporation with preferential access to borrowing from the U.S. Treasury might deter subsequent entry into the industry by private firms.

5.3 MATERIAL CONTROL AND OVERSIGHT ARRANGEMENTS

A major weakness of institutional arrangements for ownership and management of sensitive facilities is that they do not necessarily improve diversion detection capabilities at the facility or reduce the proliferation risks accompanying sensitive material away from the facility. Multinational or international ownership thus represents an incomplete response to the full range of proliferation risks.

Institutional arrangements for international or multinational control and oversight of sensitive material could be established to address those risks unalleviated by ownership arrangements. In doing so, unlike ownership arrangements that might be developed for specific facilities, this class of institutions would relate the operation of an individual facility, such as Barnwell, to a broader international or multinational system for control and oversight of sensitive material, which might be in force at a number of similar facilities operated by the members of this institution.

5.3.1 International Plutonium Storage (IPS)

Article XII.A.5 of the Agency Statute gives the IAEA statutory power to operate a system for International Plutonium Storage (IPS) and to require deposit with the Agency of any excess of sensitive material over what is needed for peaceful purposes carried out under IAEA safeguards, and to return such material promptly at the request of the owner for subsequent peaceful use. The intent of IPS is to prevent stockpiling of these materials under national auspices and to provide improved international oversight of plutonium. Although XII.A.5. has never been implemented, an Experts Group convened by the Agency is currently studying institutional arrangements for the establishment of an International Plutonium Storage scheme. Working Group 4 (Reprocessing, Plutonium Recycle) of INFCE, moreover, has expressed considerable interest in IPS as a means of achieving a significant

level of proliferation resistance without intruding upon proprietary matters.

The rationale for IPS is that plutonium should be subject to special international control and oversight because of its proliferation sensitivity. Plutonium that is "excess" to national requirements would be deposited at storage facilities operated under international supervision. If a state wished to withdraw its plutonium from an IPS, it would have to submit an application for release. The IPS would authorize such release once it is satisfied that its release criteria and conditions of use will be satisfied. The timing of release would be consistent with the schedule of use.

The establishment of an IAEA-managed IPS arrangement would involve the Agency in several new official activities, including: the control of materials deposited in IPS stores; the taking of decisions on release; and verification of the use of released plutonium.

A range of IPS arrangements can be defined by the intensiveness with which these activities were carried out. At one extreme, IPS might be confined to storage, coupled with limited release criteria. At the other, IPS could involve a storage approach in which all plutonium is "born excess," highly rigorous release criteria, and extension of direct international control and oversight to transportation and usage. The actual form IPS takes will be determined by presently on-going deliberations on the arrangements.

To carry out these activities, the Agency would require additional manpower and financial resources. The additional costs incurred by IPS could be met through either increases in IAEA member financial contributions or user fees, possibly in conjunction with establishment of a revolving fund, imposed upon the direct participants in the scheme.

One of the central issues of an international plutonium storage scheme under Article XII.A.5 is "What is excess?" That question, in turn, raises the issue of immediacy of need, since a basic purpose of IPS is to prevent national stockpiling of unneeded plutonium. Article XII.A.5 provides limited guidance as to immediacy of need, in that it specifies that plutonium is to be used in research or for reactors in operation or under construction. While this criterion may rule out release requests for speculative programs, it does not define how far in advance of actual use material should be released. The inter-related concepts of excess, need, and immediacy are central to determining both what material must be deposited and when, and how much of it can be released. These matters are now under study by the IAEA Experts Group.

IPS's principal nonproliferation benefits are: the placing of unneeded plutonium in international storage; control over the release of that material from the international store; and improved international oversights over material that has been released. IPS would not aggravate risks of technology transfer, especially if IPS personnel are confined to the storage facility itself.

IPS would have the advantage of not interfering in proprietary (e.g., ownership and management) areas. A predictable and timely release mechanism in meeting release requests would minimize the potential for disruption of energy supply, though it must be recognized that the nonproliferation implications of any release approval are substantial and place great weight upon the relationship between thoroughness in the administration of release requests and the credibility of the nonproliferation assurances provided.

Organizationally, IPS could be quite complex, especially if approval of release requests requires decisions at several levels of the staff or IAEA bureaucracy, possibly up to the level of the Director General, or if the IAEA Board of Governors become involved. There may be a trade-off between the need to assure supply on a timely and reliable basis and the requirement to ensure that all nonproliferation considerations are being met and that release approval is not occurring too hastily.

The assumption by IAEA of release authority raises the question of how IPS controls relate to those exercised by supplier states. A suspension of bilateral controls in favor of those of IPS (assuming compatibility of supplier and IPS approval criteria), such as that that occurs in the safeguards area, would simplify this issue considerably. Retention of some bilateral supplier controls, in addition to those of IPS, or the establishment of a formal two-key arrangement for joint supplier-IPS approval, would make the administration of release controls less wieldy and could result in user dissatisfaction with the institution. A major incentive to institute IPS would be to rationalize national and institutional controls in order to establish a uniform system for the authorization of release and use of plutonium. The Agency would assign personnel to administer the IPS controls at facilities built by another party, without actual responsibility for physically operating them. Clear delineation of IAEA and operator jurisdictions would be necessary to minimize interference between the two. This situation might be encountered if the Agency designates as an IPS facility the storage depot that might be built as a normal adjunct of a reprocessing plant. For example, a collocated storage facility to hold Barnwell plutonium might be built and operated by the owner of the reprocessing plant, but IPS personnel would administer the IPS controls.

Whether IPS entails additional environmental or health considerations depends largely upon whether it involves construction of new facilities, or modification of the means or destination (e.g., to an intermediate stop in storage) of plutonium shipments, than might have been the case otherwise. These effects would be related to specific facilities, not to whether they are under Agency jurisdiction. For example, if a storage facility were to be built anyway, the environmental effects directly attributable to IPS would be minimal.

IPS itself may not have significant ramifications for public acceptability. The public acceptability issues would follow much more from the kind of fuel cycle operation, the competence of the operators, the strength of physical security measures, etc., than they

would from the presence of Agency personnel in a non-operational capacity, such as IPS entails.

A major factor governing institutional acceptability is the balance struck between assurance of supply, valued on energy security grounds, and the strictness of release criteria and the thoroughness of their administration, desirable for nonproliferation reasons. These concerns would be particularly prevalent at the national government and utility levels. IPS would not appear to pose novel or additional questions for state and local governments.

5.3.2 Multinational or International Custody of Sensitive Facilities and Materials

Custody would involve more extensive institutional responsibilities than improved safeguards, but would leave ownership, managerial, and operational responsibilities in national hands. In this option, the international or multinational organization would possess full authority over ingress and egress of sensitive material to and from sensitive facilities, such as Barnwell, and would have control of sensitive material within the perimeter of the facility site. It would also have similar control and release authority over sensitive materials in transit from Barnwell up to the point of insertion into the reactor. This authority would exist for both domestic and foreign reactors receiving such material from Barnwell. These two features of custody -- application to reprocessing plants, and extension of institutional possession and release authority over plutonium up to the point of insertion in the reactor -- distinguish this institution from IPS.

The rationale for the custody concept rests upon the premise that material control has more direct relevance to proliferation resistance than other institutional arrangements for ownership, management, staffing, etc., while avoiding potential problems with the political, economic, and operational acceptability of the latter arrangements. In exercising this control, the custody organization

would have the unrestricted right to account for, observe, and control material and the use of facilities for peaceful purposes within the Barnwell site.

Custody can contribute to proliferation resistance in several important ways. It can provide an effective means of dealing with the problem of undetected diversion, as the custody authorities would exercise complete control over egress at all points within the perimeter of the site. Deterrence of diversion, thus, would not depend solely upon ability to identify and guard conceivable diversion pathways. Custody would interpose a direct, although not invincible, obstacle to seizure, diversion, or abrogation. The extension of custody of sensitive material up to the point of insertion into the reactor would provide the same institutional protection to this material as it would obtain at a facility and, thus, ensure that nuclear material is under this protection at all points in the fuel cycle where it is sensitive. Last, custody would fundamentally change the political nature of violation by requiring that any would-be proliferator defeat or displace a politically highly visible obstacle in the form of the custody personnel, thus increasing the deterrent potential of the institution.

The incorporation of an element of physical control (in the form of physical possession of Pu and approval authority over its release) in the custody concept does not constitute a physical security role, as that term is understood as the responsibility for protection of nuclear installations and materials against unauthorized acts by the host state's own citizens or other parties acting in derogation of the state's responsibilities. As envisioned here, the institution's custody responsibility would be exercised not against citizens of the state seeking access to the facility or material, but in controlling movements of material that the state intends to carry out under its own authority. In the case of Barnwell, the U.S. would perform the physical security function.

A consideration of potentially major significance for the acceptability of such an institutional arrangement for both U.S. authorities and the customers of the facility is the relationship between the custody institution's authority to approve and control material movements and that of domestic licensing agencies that might be reluctant to surrender independent licensing power. Although concurrent control over releases by U.S. authorities, under a two-key arrangement, is conceivable, it may discourage participation by foreign customers. More likely, and more widely acceptable to all parties, would be possession of an independent release authority by the custody institution, with bilateral supplier controls suspended in favor of those of the institution.

A similar issue regarding the potential duplication of another entity's responsibilities could arise in connection with the custody organization's verification authority. Although it appears to overlap with the IAEA's responsibilities in applying safeguards, this authority is necessary to provide assurance against the existence of unknown diversion pathways, or unauthorized use of material once released from the institution's control. Close coordination with the Agency would be necessary to minimize any additional burdens placed upon the facility operator and its customers, and to ensure that custody arrangements do not interfere with IAEA safeguards.

A major feature of custody is the extension of the custody arrangements to both the facility and all related sensitive material, including that in transit, up to the point of insertion in the reactor. The rationale for this feature rests on several points. Failure to apply custody to the facility itself would leave a source of sensitive material and related proliferation risks unaddressed. Similar reasoning justifies extension of custody to all other points in the fuel cycle, including MOX fabrication and any fresh fuel stocks in the customer country where sensitive material is accessible.

From the standpoint of composition, the custody institution can be either international or multinational. As discussed earlier in this chapter, a multinational approach might facilitate earlier establishment of such an institution by reducing the number of potential participants and, by reducing the range of political and energy circumstances incorporated in the group, making the institution more manageable. More important, the nonproliferation commitment of the members would be a more prominent characteristic of a carefully chosen multinational custody group. At the same time, the relationship of the institution to the IAEA is an important point, as the Agency could be a major party to the institution in an international approach or as a de facto licensor (by satisfying itself of the technical and nonproliferation credentials of the group) of the institution in a multinational approach.

At the core of the custody institution are the criteria and authority governing the release of sensitive material to a customer. These criteria are needed, in as rigorous a form as possible, to provide maximum assurance of legitimate and immediate peaceful use and to ensure that appropriate release takes place without hindrance. These criteria would specify:

- the peaceful end-use of the material;
- the quantity of material to be released;
- the form in which the material is released;
- the timing of release; and
- return or other disposition of any material derived from the released quantities.

Implementing these criteria would necessitate establishment of procedures for submitting and verifying necessary data and for post-release verification of end-use.

In addition to the nonproliferation advantages already cited in this section, which commend the custody concept for careful evaluation, it should be pointed out that the technology transfer risk for custody, in general, appears to be no more serious, or different in character, than that arising in the context of safeguards inspection. Custody personnel would have no role in the operation of Barnwell.

In terms of economic and operational acceptability, the institution would not entail substantial additional costs. Nor would it interfere with proprietary responsibilities for ownership and management, although the concept of custody is fully compatible with arrangements for multinational or international ownership and management, should the participants consider these desirable.

Although the concept would involve a major change in the nonproliferation regime as it now exists, the changes are less drastic than other institutional approaches that multinational ownership, etc. would entail. Major points of potential controversy are the independent nature of the authority of the custodians vis-a-vis the U.S. to control material movements, and the energy security implications of multinational control over national access to a potential energy resource. As a result, the arrangement requires that careful attention be given to the relationship of assurance of supply to the nature and administration of release controls and that the arrangements be applied in a nondiscriminatory fashion, with the U.S. access subjected to the same control as that of possible foreign parties.

Custody, because it would not affect the management and operation of Barnwell, should not itself create any additional problems for public or local and institutional acceptability based upon managerial or operational concerns. Existing regulatory relationships would not be affected. Although the custody personnel would control ingress and egress of both material and personnel, this would not pose extraordinary difficulty where such considerations as access for local safety personnel, fire personnel, etc. are involved. The relationship between the European Community's Joint Research Center at Ispra

and Italian authorities may provide guidance in making provision for such contingencies.

REFERENCES

1. Senate Report No. 95-467. "Non-Proliferation Act of 1977". p. 25.
2. International Nuclear Fuel Cycle Evaluation. Working Group 4 (Reprocessing, Plutonium Handling, Recycle). Final Report. February 1980. p. 212.

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6.0 INTEGRATED INSTITUTIONAL-USE OPTIONS

6.1 INTRODUCTION

Of pivotal importance to the analysis of utilization options for Barnwell is the relationship between the use options, as defined and analyzed in Sections 3.0 and 4.0, and the potential institutional arrangements. Specific use options may pose particular institutional requirements and avoid or eliminate others. By the same token, specific institutional arrangements may enhance or detract from a use option. Together, they provide a basis for utilizing Barnwell to achieve particular purposes.

There are two levels of analysis in the integration of use options with institutional arrangements:

- the institutional implications of specific features of a use option; and
- the advantages and disadvantages of a particular type of institutional arrangement for that option.

The following analysis follows this structure.

In carrying out this task, it is important to distinguish between effects attributable directly to the use options themselves and those due to the relationship between institutional arrangements and use options, which are of principal attention here. Specifically, cost effectiveness, support for energy policy, and environmental effects are not considered in any detail here, since these are functions primarily of the use option. Nonproliferation and local and institutional acceptability, as well as managerial attractiveness, are more influenced by institutional arrangements and are given major attention in this chapter.

The use options considered here are:

- AFR
- Reprocessing
 - in support of breeders
 - in support of thermal recycle
- International Fuel Service Center (IFSC)
- Alternative Fuel Cycle Development

Other options considered in Section 4.0, e.g., safeguards development and training center, non-use, are not discussed here. A safeguards development and training center is treated as an add-on and would not appear to be particularly sensitive to institutional arrangements. Non-use is clearly not germane to the purposes of this chapter.

In order to identify where the institutional arrangements may be most directly relevant to achieving the benefits ascribed to the use option, the integrative analysis here concentrates on the impact of institutional arrangements upon:

- the credibility of the undertaking and, specifically, whether it makes the option more attractive to potential users;
- the nonproliferation characteristics of the option;
- the economic base of the undertaking;
- the opportunity to benefit from and influence foreign fuel cycle programs and activities;

- the timeliness of provision of the fuel service(s) involved in the option; and
- the local and institutional acceptability of the option.

In carrying out this analysis, an attempt is made to avoid repeating points already stated in the generic discussion of institutional arrangements. Rather, the emphasis here is on trade-offs and impacts specific to Barnwell.

One key parameter that would have considerable impact on the types of institutional arrangements appropriate or feasible for a particular option is the scope of the market, e.g., whether the market was domestic only or also included foreign customers. A change in the market could have an especially strong effect on ownership options, as multinational or international approaches to ownership and administration of BNFP would not be feasible where the market for an AFR or reprocessing was confined to domestic customers, or where the proportion of foreign use of the facility to overall use was sufficiently small (approximately 25% or less) to make national ownership the only viable option.

Institutional arrangements not involving ownership -- i.e., custody and international plutonium storage -- would be less sensitive to the market variable. This is so because they constitute international or multinational systems that could be in force at a number of reprocessing plants, not just Barnwell, whereas the ownership options would be tailored to the features of a specific facility. Even were Barnwell plutonium confined to domestic use, there might exist strong reasons to extend plutonium oversight arrangements to BNFP. Not the least of these would be to support a possible U.S. leadership role in implementing a system for the control and oversight of plutonium and

to enhance the international acceptability of such a system. The importance of U.S. acceptance of the same institutional arrangements it advocates for others has already been accepted by four Administrations in supporting the U.S. voluntary offer to accept IAEA safeguards on U.S. civilian nuclear facilities.

Subject to this important caveat about market, the following analysis is structured as if the BNFP market was international.

6.2 SPENT FUEL STORAGE FACILITY (AFR)

6.2.1 Introduction

Use of BNFP for spent fuel storage, regardless of whether foreign fuel was stored there, could entail the application of IAEA safeguards under the terms of the as yet unratified U.S.-IAEA Safeguards Agreement. Application of IAEA safeguards would offer an opportunity to demonstrate and test advanced safeguards techniques and instrumentation designed for spent fuel storage facilities and to conduct related training activities. Although the AFR is the primary use-option to be considered here, it is assumed that a program of advanced safeguards testing and training could be associated with this option.

Two institutional options -- custody and international plutonium storage -- are not directly relevant to an AFR-only option and, thus, are not considered here. This is because both of these institutions are designed for control of sensitive material; and spent fuel, due to its radiation barrier, would not, itself, be considered to be directly weapons usable. It should be pointed out, however, that as a practical matter, where the AFR served as the storage facility at the head-end of a reprocessing plant, it could be located within the reprocessing plant site perimeter at which the custody institution would control access and egress.

The ownership of the facility, however, does have a direct relationship to the achievement of the benefits of an AFR. Consequently, the following analysis of institutional arrangements for an AFR focuses upon the comparative advantages and disadvantages of ownership options.

6.2.2 Analysis

On nonproliferation grounds, the inclusion of foreign spent fuel in a BNFP spent fuel storage facility would be desirable, for reasons expressed in Section 5.1. Acceptance of foreign spent fuel, however, has potential implications for the nature of international involvement, beyond application of IAEA safeguards, in the institutional arrangements for such a facility. In particular, the ownership structure for the facility, and the nature of the controls governing deposit and release of spent fuel, might be significantly affected by acceptance of foreign spent fuel.

Assumptions as to the percentage of total AFR capacity used for storage of foreign spent fuel have a considerable impact upon which institutional options are feasible. If foreign fuel is no more than 10-20% of the total quantity stored, as projected in Section 4.2.1.1, ownership arrangements other than national ones are not particularly viable. Similarly, IAEA administration of deposit and release arrangements would not be especially relevant where the primary function of the facility was as a national AFR. The effect of this parameter -- foreign percentage of total quantity stored -- on the range of feasible institutional arrangements would become less constraining as the percentage increased significantly, or if construction of new pools to accommodate foreign fuel was to take place. It should be pointed out that a decision to adopt a multinational ownership for a Barnwell AFR would likely entail accepting greater amounts of foreign spent fuel than contemplated in Section 4.2.1.1, with direct consequences for the ability of a Barnwell AFR to address domestic needs.

Provision of storage services at an AFR would offer relief for potential congestion of at-reactor spent fuel storage facilities, thus alleviating a potential obstacle to nuclear power utilization and, where offered to foreign customers, might offer an alternative to early reprocessing where spent fuel management considerations would be the primary factor driving reprocessing decisions. These benefits, however, are directly attributable to provision of the AFR service itself, and would be present regardless of the institutional arrangement governing ownership of the facility. The institutional arrangements, nevertheless, may determine to what extent these benefits are realized, and whether the AFR option would be attractive to potential users.

Credibility: The credibility of the benefits of an AFR and, thus, the attractiveness of this use option to domestic and foreign customers, is directly affected by who owns the facility and by the terms upon which the service is offered.

Ownership:

- Multinational ownership might enhance the confidence of foreign customers and/or owners that their access to the material is more assured than if the facility were under national ownership. Confidence in retrievability could be of key importance to foreign interest in utilizing an AFR and, thus, to the achievement of its nonproliferation benefits. Allocation of storage space in the facility by size of ownership share similarly would mitigate concern over the availability of storage space.
- An international arrangement, most probably via IAEA leasing of the facility, might make the AFR service available to a larger number of countries than possible through multinational ownership. On the other hand, in addition to the disadvantages of international approaches identified in Section 6.3, allocation of space might be impractical because of the large number of countries involved. Storage space thus might be apportioned on a first-come, first-served basis. The principal IAEA function would be the administration of controls on deposit and release. The international arrangement

for an AFR would create serious problems for domestic utilities unless a portion of the capacity were set aside for domestic customers only. The applicability of IAEA deposit and release controls to domestic fuels and their relationship to U.S. arrangements similarly become a contentious point.

- National ownership would implement storage services essentially on a contract basis, although some portion of the facility might be set aside for foreign customers. Foreign perceptions of the strength of the contract would be the key to confidence in retrievability, while access to the service might be on either a first-come or a preferential basis, if national policy is to offer the AFR service to specific "target" countries as an alternative to reprocessing.

Deposit and Release Controls: Multinational ownership alone might be insufficient to improve foreign confidence in the reliability of a Barnwell AFR if the terms governing access and retrieval were not clearly defined and agreed upon prior to deposit and were not considered binding upon all relevant parties, including the host country. The discussion of spent fuel storage by Working Group 6 of INFCE indicates that the legal framework governing access and retrieval is the overriding concern of many countries on energy grounds, and would be of primary importance, regardless of who owns the facility. This framework is also key to the nonproliferation effectiveness of the option, as it might establish criteria determining when the facility may be used (e.g., when all at-reactor capacity is exhausted) and under what conditions spent fuel may be withdrawn (e.g., safeguards, specified destination) and might also determine who administers these controls. The criteria for, and administration of, approval authority over reprocessing presumably could be separate from those for spent fuel, although a more likely arrangement would be that release authorization would be directly related to approval of reprocessing or other means of ultimate disposition of spent fuel.

- In the case of multinational ownership, the owners could jointly establish this framework and might jointly administer the controls. U.S. domestic spent fuel, unless stored in a separate facility under national ownership, could be subject to the same arrangements as foreign spent fuel, which might have an adverse impact on domestic acceptability, depending upon the restrictiveness of the criteria. The value of multinational ownership in this case is that it gives foreign parties a voice in formulating and administering the legal framework, and, as a result, a diminution of U.S. control might occur.
- IAEA administration of the deposit and release controls would ensure identical treatment of all users of the facility and harmonization of controls if a number of IAEA-run spent fuel storage facilities were established internationally. The U.S. would not have a voice in the formulation of these criteria, except as a member of the IAEA, and no role in their implementation. Given the broader and less selective composition of the Agency membership, these controls may be more of a least common denominator character, especially with regard to withdrawal conditions.
- Under national ownership, with the service provided on a contract basis, the conditions and terms could be negotiated on a bilateral basis and would be administered by the U.S. Greater flexibility in using the AFR as an instrument of policy might result from the bilateral nature of the arrangements. At the same time, consumer confidence would demand that the strongest possible assurance be given that all contracts would be honored. Since the facility is nationally owned, the strength of the contractual arrangements could be the principal foundation for any successful use of the AFR as an instrument of policy, since the added assurance to foreign parties provided by multinational ownership would not be present.

Nonproliferation Effectiveness: The nonproliferation effectiveness of the AFR is a function of its ability to attract foreign customers and to serve as an alternative to early reprocessing, thus reducing

the impact of spent fuel management concerns as a factor driving reprocessing decisions. The proliferation risks of a Barnwell AFR could be effectively dealt with by safeguards. Consequently, the main consideration regarding the nonproliferation effectiveness of a Barnwell AFR is its credibility, as discussed above.

Economic Base: Ownership arrangements would affect the economic base of an AFR primarily in two areas: the allocation of financial requirements for construction and operation; and the size of the market.

- Multinational ownership would permit a sharing of financial requirements, though it must be pointed out that this argument is less compelling than it might be for a reprocessing plant. Although multinational ownership would build into the institutional structure direct access to foreign markets, it is not clear that, given strong contractual assurances, this access would be otherwise unattainable.
- If the basis for IAEA involvement is a lease rather than ownership title, the purported financial advantages of group ownership would not be realized. This option would lack the built-in market of the multinational option, but, on the other hand, would offer a larger number of potential customers.
- In the case of national ownership, the full investment burden would fall upon the U.S. With an attractive set of terms and conditions, that portion of capacity allocated for foreign spent fuel could be marketed aggressively on a selective basis to those countries at which the AFR service is targeted for nonproliferation purposes.

Influence Foreign Programs: The implications of institutional arrangements for U.S. ability to use an AFR to influence and benefit from foreign programs are particularly important in regard to: (1) carrying out technical exchanges in relevant areas; and (2) maximizing the impact of the AFR on foreign reprocessing decisions.

- The selectivity of multinational ownership with regard to composition would facilitate targeting the AFR service at key countries to provide an alternative to reprocessing or to remove spent fuel management obstacles to nuclear power utilization.
- Under international ownership or administration, the U.S. would not be able to target the AFR services at particular countries. Proprietary considerations might impede technical exchanges in an IAEA context.
- In the case of national ownership, the effectiveness of any "targeting" strategy would rest upon foreign perceptions of the strength of contracts, unreinforced by an ownership share. At the same time, the U.S. would retain maximum freedom of action to employ a "targeting" strategy, or to change it as circumstances warrant.

Timeliness of Service: In light of demand projections for the service, the implications of the institutional arrangements for the ability of the AFR to meet that demand are especially significant. Unnecessary complication or delay could seriously undermine the viability of the option.

- Since there is no ready institutional framework for implementing multinational ownership, multinational ownership arrangements, of the three options considered here, might take the longest time to put in place. This aspect of multinational ownership could be a serious problem in the face of near-term need for AFR services, but would be a less compelling constraint where construction of new increments of capacity, or expansion of existing capacity, in the future were contemplated.
- Establishment of an IAEA administration of Barnwell AFR would be constrained by the need first to negotiate the system for deposit and release of spent fuel and then to achieve member agreement.
- In the case of national ownership, the principal constraint would be determining whether the private sector or, more likely in the case of a stand-alone AFR, the government

would own the plant, and obtaining the necessary legislative authority in the latter case. In all three ownership cases, the time needed to satisfy U.S. regulatory authorities over the facility itself would be a relatively constant factor.

Local and Institutional Acceptability: The ownership structure may affect both outside perceptions of the competence and efficiency of the undertaking and the willingness of relevant parties to support the option. At the same time, ownership is less likely to be a source of controversy than different perceptions of the need for an AFR, its relationship with the viability of nuclear power, and the position of a Barnwell AFR as a potential precursor of reprocessing. The institutional arrangements may be a secondary factor, except perhaps to foreign customers concerned primarily with accessibility and retrievability.

- Multinational ownership may complicate local acceptability, but may enhance the attractiveness of the option to foreign customers.
- International ownership, or IAEA operation, would have a similar effect.
- National ownership would result in the least change to relations with state and local authorities, but would place the full weight of foreign acceptability upon the terms and conditions for deposit and release.

In summary, the advantages and disadvantages of multinational ownership are:

- Advantages
 - Improve the credibility of an AFR as an alternative to early reprocessing.
 - Establish precedent for multinational arrangements elsewhere.

- Greater ability to target service at sensitive countries than international approach.
- Facilitate exchange of information on spent fuel storage and related safeguards techniques.
- Expand market base of AFR.

- Disadvantages

- Less U.S. control over facility operations, especially deposit and release of spent fuel.
- Insufficient, in absence of agreement on legal framework of release and deposit, for making AFR attractive to foreign customers.
- Organizationally more complex and possibly less efficient than national ownership, whereas improvement of spent fuel management is important for timing of reprocessing.
- Incompatible with meeting near-term AFR need.

The advantages and disadvantages of international ownership (or, more likely, IAEA leasing of the facility) are:

- Advantages

- Least discriminatory, and thus the most widely acceptable, approach.
- Promotes international harmonization of deposit/release criteria by relying upon IAEA to establish and administer them.
- Facilitates testing of new safeguards technology and related training.

- Disadvantages

- Least amount of U.S. control over deposit and release.
- Controls likely to be less exacting than in multinational or national approach.
- Takes longer to implement than national ownership.
- Complicates lines of responsibility with local authorities.
- Foreign confidence in retrievability relies upon legal framework, and confidence in IAEA, without reinforcement by ownership share.
- If facility leased, U.S. must still provide capital for building AFR.

The advantages and disadvantages of national ownership of the AFR are:

- Advantages

- More U.S. control over facility operation, but still might entail establishment of binding criteria and agreements governing deposit and release prior to foreign usage of the facility.
- Permits AFR service to be targeted at selected countries.
- Shortest period for establishment of AFR, and thus more responsive to near-term needs.
- Single nation operation less administratively complex.
- Least disruption of relations with state and local authorities.

- Disadvantages

- All capital requirements and commercial risks fall on U.S.
- Lacks additional credibility to foreign parties that multinational ownership provided.
- No built-in opportunity for technical exchanges with other countries.

6.3. REPROCESSING

6.3.1. Introduction

Although one might distinguish the institutional consequences of a decision to reprocess per se from those deriving from a particular use of the material, the most fundamental decision is whether to reprocess, as the inevitable result is sensitive material. There may be some sensitivity of the institutional options to changes in purpose or to market scope, but there may remain certain unvarying institutional considerations that result from the act of reprocessing itself.

In particular, limiting reprocessing to support of on-going breeder development would confine the use of the resulting plutonium to a relatively small number of countries and might introduce smaller amounts of material into international commerce, at least initially, than might reprocessing for thermal recycle. Focussing reprocessing upon breeder support, as contemplated in use option 4.1.2, would appear to have the following institutional consequences:

- The number of countries eligible and potentially interested in participating in institutional arrangements would be small, making it difficult to conceive of what a multinational ownership option would consist of. International options other than ownership would be more feasible and appropriate in this case.
- Several of the advanced breeder countries otherwise eligible to participate in multinational ownership already have reprocessing facilities and, thus, have less need to participate. In general, advanced breeder countries may be unwilling to rely entirely upon a foreign source of plutonium.
- The intentions of non-breeder countries otherwise interested in thermal recycle or reprocessing itself would not be addressed by this particular use option and its associated institutional arrangements. Without access to the product, it is not clear that non-breeder countries would be strongly attracted to participating in an ownership scheme for reprocessing in support of breeders only. The weight of dealing with those countries would fall upon other use options (i.e., AFR) and other political and institutional initiatives (e.g., restrictions on technology transfer or on return of plutonium from spent fuel reprocessed under contract, assurance of low enriched fuel supply, or provision of LEU fuel credits).
- By restricting both the geographical distribution of plutonium and the number of countries likely to participate in the institutional arrangements, the task of implementing institutional arrangements may be facilitated, thus enabling a set of arrangements to be put in place capable of expanding to incorporate additional countries or being adopted elsewhere as the need arises.

The reprocessing use option considered here has several aspects. It is assumed that a safeguards R&D and training program, with IAEA involvement, could be established in order to test and demonstrate advanced safeguards techniques and instrumentation in a hot reprocessing plant and to assist the IAEA, through a related training program, to meet its safeguards manpower requirements. The advantages and disadvantages of such a program have been discussed in Section 4.2.2, and, as a result, primary attention here is given to the reprocessing part of the use option.

In this option, the AFR considered in the preceding section would now be at the head-end of the reprocessing plant. Although it is conceivable to have different ownership arrangements for the AFR and the reprocessing plant, bringing them under the same ownership regime would be more logical.

6.3.2. Analysis

Among the potential benefits of operating BNFP as a reprocessing plant are the support it might give to extending the viability of nuclear power as a source of energy and, where reprocessing services are made available to foreign parties, the provision of an alternative to national reprocessing in currently non-reprocessing states abroad. These benefits are directly attributable to operation in a reprocessing mode itself, and potentially could be available, regardless of the institutional arrangements for the facility. The institutional arrangements, however, as they were with the AFR option, would be relevant to the realization of these benefits, and nonproliferation benefits in particular.

Credibility: The principal consideration here is how the institutional arrangements affect customer confidence in the reliability and security of supply of reprocessing services, specifically that reliance upon Barnwell, as opposed to other alternative sources, would not jeopardize energy strategy and supply.

- The major contribution of multinational ownership would be to ensure access to a proportionate share of the plant capacity and to provide psychological reassurance of supply by virtue of whatever special status might accrue to the owners of the plant. However, while ensured access to the plant may be a major gain, the significance of the latter sort of assurance -- to the plant's product -- would be contingent upon the nature of export controls and their administration. The impact of multinational ownership alone might be of secondary importance in comparison to those controls. At the same time, fixed ownership shares might be in conflict with a U.S. desire to retain some flexibility in allocating plutonium between domestic and foreign customers.
- In the case of international ownership, as defined in Section 5.2.2, allocation of capacity by equity share would be impractical and incompatible with the constraints upon the Agency not to discriminate among customers. Thus, a major supply assurance benefit of ownership might be lost. This arrangement is likely to generate little, if any, interest as INFCE indicates.
- National ownership would be unable to take advantage of whatever confidence-building effects multinational ownership might provide. At the same time, the question of who owns the plant may be less critical to credibility than the terms and conditions governing supply. National ownership would not be incompatible with aggressive and selective marketing of services on attractive terms, and would provide flexibility in determining the relative shares of foreign and domestic customers in the overall allocation of the plant's production.
- The impact of IPS upon the credibility of the undertaking would be similar to that of custody.
- Although custody would not necessarily ensure access to plant capacity, because it does not involve ownership, it might clearly specify the criteria governing supply of the product and the means of their administration, depending on how U.S. export controls relate to those of custody. Greater reliance would be placed upon fuel assurance initiatives by the owner to attract foreign customers. Custody could also be combined with multinational ownership.

Proliferation Risk: One major aspect of the impact of institutional arrangements upon the magnitude of proliferation risks is their potential to reduce the number and geographical spread of reprocessing plants, a result that is very sensitive to the credibility of a BNFP reprocessing undertaking. However, a second aspect is that institutional arrangements, if applied to reprocessing carried out in advance of legitimate need, may serve to legitimize or encourage reprocessing, thus ensuring nonproliferation disadvantages. A third aspect is their direct impact upon the risks resulting from reprocessing at Barnwell itself.

- The primary effect of multinational ownership in the case of Barnwell would be to offer an alternative means of ensuring access to adequate capacity for countries otherwise unable to justify or afford large national facilities. Achieving this benefit would exclude any approach to composition that would confine participation in multinational ownership to other reprocessors. The other potential primary effect of multinational ownership -- deterrence against plant seizure by the host country -- would not be relevant in the case of Barnwell. In the absence of controls on the material, substantial proliferation risks would remain unabated.
- A similar observation could be made with regard to international ownership, with the added proviso that the ensured access, which might be an incentive to forego national plants, would be more problematic in this case.
- National ownership would rely principally upon attractive contract terms and bilateral fuel assurance initiatives to discourage the spread of national reprocessing. In the case of Barnwell, it also would avoid creating technology transfer problems. National ownership, like other options for facility ownership, would not have any bearing upon the magnitude of proliferation risks accompanying sensitive material.
- IPS would reduce the proliferation risk accompanying plutonium. As with custody, IPS itself would not offer an incentive to forego national reprocessing.
- Custody would address directly seizure or diversion risks both at the plant and at all points up to irradiation in the reactor. Custody would not necessarily affect incentives to forego national reprocessing, but it would rely upon other institutional arrangements to achieve this.

Economic Base: Institutional arrangements may affect the size of the economic base for the BNFP in two basic ways: (1) by influencing the allocation of economic risk and financial burdens; and (2) the size of the market and, thus, the potential to capture economies of scale through larger facilities.

- Multinational ownership would enable commercial and technological risks to be spread among the partners and would build in a market for the plant's services. At the same time, limiting plant operation to breeder support would sharply restrict the range of potential partners.
- International ownership, even if management and operation were on a lead-country basis, may be undesirable on organizational efficiency grounds. Furthermore, the financial demands that this arrangement would place upon the IAEA could render this approach impractical.
- Under national ownership, all risk would fall upon the U.S.
- The effect of IPS upon the economic base would be neutral, as it does not deal with either ownership or market factors.
- Custody similarly would have a neutral economic effect.

Opportunity to Influence Foreign Programs: The effect of institutional options for reprocessing upon foreign fuel cycle activities and programs is a particularly important aspect of those options' contribution to proliferation resistance. Two areas of potential influence are especially significant: (1) whether the institutional arrangements at BNFP will reduce or discourage the spread of reprocessing abroad; and (2) whether they provide an effective model for adoption where such expansion does occur. The first point has already been discussed under nonproliferation effectiveness.

- As a model for adoption elsewhere, multinational ownership may be desirable in some sensitive countries or regions. However, alone it is an incomplete response to proliferation risks due to the absence of controls on plutonium. Also, it may foster the impression that reprocessing, irrespective of need, is acceptable as long as it is done in a multinational framework.

- As a model for adoption elsewhere, international ownership, because of the lower cohesiveness and adversity of interest regarding proliferation in the membership, would be less desirable than multinational alternatives.
- As a model for use abroad, national ownership may be inappropriate in some sensitive countries, or where regional politics place considerable weight upon convincing demonstration of peaceful intentions or upon parity among regional rivals. In this regard, a disadvantage of national ownership might be the potential encouragement it might lead to similar arrangements elsewhere.
- As a model, IPS might inadvertently create the impression that any reprocessing operation is acceptable, so long as the plutonium is subject to IPS. A limitation of IPS is that it does not offer a means of controlling the spread of reprocessing.
- The same remarks may be made for custody as well. In the cases of both IPS and custody, other institutional arrangements would be necessary to control the spread of reprocessing.

Timeliness of Option: Of principal concern here is whether the time necessary to implement the institutional arrangement would result in undue delay in initiation of the use option. (The timing of this initiation is a matter of the actual energy need and the nonproliferation effects of the decision on when to start operation.) Unlike the AFR case, however, where there is a near-term need for storage, the longer time-scale associated with the start of reprocessing might permit some phasing of the institutional arrangements.

- The multinational ownership option could present a potential constraint due to the time necessary to organize groups of countries, negotiate the arrangement, and establish the necessary commercial entities. Initial ownership by the U.S. government, however, might enable work on the plant to begin, with multinational partners added subsequently.

- The international ownership option would appear to pose even more serious problems than the multinational approach in this regard because of the practical difficulties and political opposition involved in IAEA involvement in ownership.
- The principal constraint in the national ownership case would be the time taken to determine whether some form of government ownership should be established or private ownership continued.
- The implementation of IPS would not be required until plutonium was about to be produced in significant quantities. If one is already in place (at plants operating elsewhere), it could be extended to include Barnwell.
- Custody may be a longer term proposition, possibly an evolution of IPS. In this case, the prospects for custody would depend upon the level of satisfaction with IPS.

Local and Institutional Acceptability of the Option: Although major aspects of the acceptability issues are due to the use options themselves, of particular interest is the extent to which institutional arrangements affect those issues.

- Provision for multinational ownership might attract foreign participation, but such foreign participation in a nuclear facility might create major problems for state and local acceptability. Clear demonstration of strong management, which might require a lead-country management arrangement, would be necessary. At the same time, ownership may be less crucial to foreign acceptability than the conditions and controls governing foreign use of the plant.
- International ownership might aggravate these problems even more and might appear to present unnecessary complexities to both domestic and foreign parties. Moreover, INFCE indicates there is little or no interest in this arrangement.
- National ownership, coupled with strong assurances of supply for countries that satisfy criteria governing access to the plant, might minimize the addition of any unnecessary complications for state and local authorities while still addressing foreign concerns regarding supply from the plant.

- IPS should not present any new problems for state or local authorities, as it has no responsibilities for plant operations, nor does it entail additional operations that might otherwise not have occurred.
- Custody, likewise, should not create any serious additional problems itself, as it would not affect plant operation.

In summary, the advantages and disadvantages or limitations of multi-national ownership, as applied to reprocessing, are:

- Advantages
 - Improve confidence in access to capacity.
 - Establish institutional precedent for application abroad.
 - Enable sharing of financial burden and expansion of market base.
 - Provide an alternative to national reprocessing abroad.
- Disadvantages
 - Does not reduce proliferation risks accompanying sensitive material or improve diversion detection capability.
 - May legitimize premature reprocessing.
 - Addresses secondary issue -- ownership -- when primary foreign concern is terms and conditions of supply and their administration.
 - Intrudes upon proprietary responsibilities.
 - May create local acceptability problems.

The advantages and disadvantages of international ownership are:

- Advantages
 - Appeal to wider range of countries.
 - Provide an alternative to reprocessing abroad.
- Disadvantages
 - Less credible assurance of access than in multinational ownership option.
 - Potentially less rigorous controls over access and release.
 - Greatest loss of U.S. control over facility.
 - Places substantial, if not unacceptable, burdens on IAEA.

The advantages and disadvantages of national ownership are:

- Advantages

- Preserves U.S. control over facility and policy flexibility.
- No foreign interference with proprietary matters.
- Requires that primary foreign concerns -- controls on use and export -- be directly addressed.
- Does not create local acceptability problems of its own.

- Disadvantages

- Does not address proliferation risks, other than technology transfer.
- Places full reliance upon terms and conditions to attract foreign customers, rather than offer ownership share as incentive to forego reprocessing elsewhere.
- Sets potential precedent that may not be appropriate to some foreign circumstances.
- Full financial burden falls upon U.S.

The advantages and disadvantages of IPS, as applied to BNFP, are:

- Advantages

- Addresses proliferation resistance concerns for plutonium.
- Establishes criteria for release and use of plutonium, thus addressing foreign concern on export controls.
- Compatible with all ownership options.
- Avoids unnecessary local acceptability problems.

- Disadvantages

- Does not affect incentives for national reprocessing.
- Does not address foreign concerns at access to plant services.
- Incomplete arrangement where facilities located in more sensitive areas.

The advantages and disadvantages of custody are:

- Advantages

- Responds to proliferation risks at all points in back end of fuel cycle.
- May address concerns over substance and administration of export controls, if national controls are harmonized with those of custody.
- Links BNFP to multinational/international control system.
- Compatible with all ownership options.
- Not a constraint upon timeliness of use option.
- By avoiding operational responsibilities, should not create local acceptability problems.

- Disadvantages

- Does not address foreign concerns of access to plant services.
- Does not affect incentives for national reprocessing.
- Not a complete institutional arrangement for facilities in more sensitive geographical areas.

6.4 INTERNATIONAL FUEL CENTER

6.4.1 Introduction

The concept of using Barnwell as the site for an international fuel service center represents a special case of the reprocessing option. All activities included in that option would be incorporated in the IFSC, with the addition of fuel refabrication facilities and indefinite storage of solidified HLW resulting from foreign as well as domestic spent fuel. The output of the IFSC would be fully fabricated MOX fuel elements.

There is no necessary reason why these facilities, especially refabrication, could not also be constructed as part of a reprocessing option in support of either breeder development or thermal recycle, although the IFSC concept, as defined in this study, makes facilities for fuel refabrication and HLW storage no longer optional for a reprocessing complex. The inclusion of HLW storage in particular, however, can be expected to create additional public and state/local acceptability problems for the IFSC option, as discussed in Section 4.2.4.

Institutionally, the IFSC differs significantly from the basic reprocessing options in the following areas:

- The IFSC concept, as it is widely understood, entails either multinational or international ownership. National ownership is no longer an option.
- It may emphasize regional composition of the membership.
- It may entail a degree of multinational or international staffing.
- It may impose an HLW storage responsibility upon the host country.
- It specifies the form of the end-product, thus eliminating this as a potential area of variability in any release criteria that might be established.

The IFSC represents a particular form of multinational or international reprocessing plant, with several added responsibilities (fabrication, HLW storage). As formulated by the IAEA, it does not involve a multinational or international system for controlling sensitive material comparable to custody or IPS.

6.4.2 Analysis

As the IFSC is a special case of a reprocessing option, rather than repeat the detailed analysis of institutional arrangements for that option, the analysis here will focus upon those arrangements specific to the the IFSC option itself. Many of the remarks made in the previous section with regard to reprocessing are applicable here.

Credibility: The primary rationale for multinational or international ownership is that such arrangements provide an alternative to national reprocessing and improve foreign confidence in the ability to make use of the facility. This argument, however, is subject to

several qualifications, as discussed in Section 5.2. Taking discussions in INFCE as a guide, foreign concern remains focussed upon the terms and conditions of supply and their administration, as much as it does upon ownership. Given a satisfactory solution to problems in the area of export controls, some countries may be interested in multinational ownership, if entered into on a voluntary basis. On the other hand, resolution of these problems might increase customer willingness to rely upon the market as the primary source of supply assurance and to place relatively less weight upon ownership. Moreover, the complexity of the system of operations at an IFSC, including fabricating fuel to meet customer specifications and to safely store HLW, places great weight upon the competence and efficiency of management and staff, whereas the IFSC concept contemplates arrangements less efficient than national ones.

A strong regional character has been a prevalent feature of the IFSC in many studies of the concept. This entails both regional composition and market. While this feature might increase participant confidence in the measure by dedicating the facility's operations to a specific group of countries, it is not clear that geography provides a useful or desirable basis for determining the composition of this group. Moreover, if the purpose of reprocessing is to support breeder development only, the global framework of breeder activity makes regional composition impractical. The regional character carries with it the implication that sensitive material will be used, possibly on a wide scale, in that region.

Nonproliferation Effectiveness: Specifying that plutonium would be exported in fabricated fuel elements might simplify safeguards accountability after release and might permit shipment to be timed to correspond closely to refueling schedules, thus avoiding national stockpiling. These may constitute significant nonproliferation improvements, but the means by which they are achieved -- confining fabrication to the IFSC -- poses several problems, not the least of which is a potential adverse impact upon existing fabrication industries elsewhere (possibly in potential participants or supporters of

the concept). Multinational staffing could create serious technology diffusion risks, while it is not clear, given improvements in safeguards technology of the sort envisaged in Section 4.2.2, that the putative surveillance benefits of multinational staffing would be necessary.

The most serious nonproliferation limitation of the IFSC concept is the same for any arrangement limited to ownership only: it does not address proliferation risks at all points in the fuel cycle where sensitive material is present. Once away from the IFSC, the level of proliferation resistance of the plutonium would be that attributable to safeguards, unless institutional arrangements for international oversight of the material were also established.

Local and Institutional Acceptability: Whereas other use options may provide greater flexibility regarding HLW storage, the IFSC, as defined in Section 4.2.4, assigns to the host country responsibility to store HLW on an indefinite basis. Although the purpose of this arrangement is to maximize the attractions of relying upon the IFSC rather than utilizing an alternative source of reprocessing, it places a considerable burden upon the host country. Without clear specification of responsibility for final, ultimate disposal, or for the maximum duration of onsite HLW storage, this feature of the institutional arrangements for the IFSC could create serious acceptability problems at all levels of the U.S.

In other areas of concern, such as the economic base and timeliness of the option, the advantages and disadvantages of the institutional arrangements would be the same as those for a multinationally or internationally owned reprocessing plant. The inclusion of an HLW storage responsibility, because of its controversial nature, could be expected to complicate the establishment of this option. In summary, the advantages and disadvantages of the institutional arrangements for an IFSC are:

- Advantages

- Greater assurance of access to plant capacity.
- An alternative to national reprocessing.
- Greater economic base.

- Disadvantages

- Incomplete response to proliferation risks.
- Potentially less efficient multinational or international groups required to operate complex system of facilities.
- Potentially serious local acceptability problems.
- Regional composition inappropriate for some purposes.
- Multinational staffing creates technology transfer risks.

6.5 ALTERNATIVE FUEL CYCLES

Several modifications of the base-case reprocessing process -- high decontamination and complete partitioning -- have been considered in Section 4.2.3. A primary purpose of these modifications is to improve the proliferation resistance of the product of the facility. This could be achieved through the addition of a radiation barrier, a chemical dilution barrier (in the case of a mixture of PuO_2 and UO_2 or their nitrate solutions), or both, in order to complicate the task of a would-be proliferator in obtaining plutonium.

As a variant of the reprocessing use option, the alternative fuel cycle option shares many of the same institutional issues with the reprocessing options, especially regarding ownership. Consequently, the reader is referred to Section 6.3 for a discussion of those issues. In order to avoid repetition, no further analysis of those points is included here.

There is, however, an area of potentially major sensitivity of the institutional arrangements to the nature of this use option: the possible existence of a trade-off between the proliferation resistance of the material and the need for institutional measures for oversight of the material, in the form of either IPS or custody.

Were the inherent proliferation resistance of the material to be sufficiently high, the controls on that material could be relaxed some. For example, continuing international or multinational oversight over the plutonium up to insertion in the reactor might not be as compelling if the material had a high intrinsic proliferation resistance. Nevertheless, other features of an institution for oversight of plutonium would be retained (e.g., release controls, automatic deposit of all plutonium). It must be kept in mind, however, that BNFP might not be the only facility involved in an IPS or custody system, and that unless all participating reprocessors adopted the same measures, the nature of the system would not be affected by adoption of alternative fuel cycles at BNFP only.

The actual nonproliferation efficacy of these measures, though, was found in Section 4.2.3, to be uneven, especially production of MOX as opposed to a pure plutonium product stream, and to vary considerably with the technical sophistication and resources of the adversary. The existence of these limitations on the nonproliferation gains achieved through alternative fuel cycles suggests that the trade-off between these modifications and institutional arrangements is not an extensive one, and that a requirement for strong institutional controls over plutonium would remain in any case.

Moreover, the need for international controls on plutonium derives from the act of reprocessing itself and is not changed by the adoption of alternative fuel processing. Even were these technical measures to produce greater nonproliferation gains than they actually do, there would still be a strong argument in favor of participating in international controls over plutonium. Though there may be some flexibility in choosing the ownership arrangements for BNFP, the need for such plutonium controls to be established to protect the output of all reprocessing plants, not just Barnwell, places a corresponding political demand upon the U.S. to facilitate their establishment and,

in particular, to bring its facilities into a proper relationship with these international or multinational control systems.

International plutonium controls, whether IPS or custody, differ in one fundamental aspect from ownership arrangements. They constitute an international or multinational system to which Barnwell, as well as other reprocessing plants abroad, would be brought into a relationship. They are not facility-specific options to be tailored to the characteristics and features of that facility. This fact alone limits the sensitivity of these arrangements to the process options for BNFP.