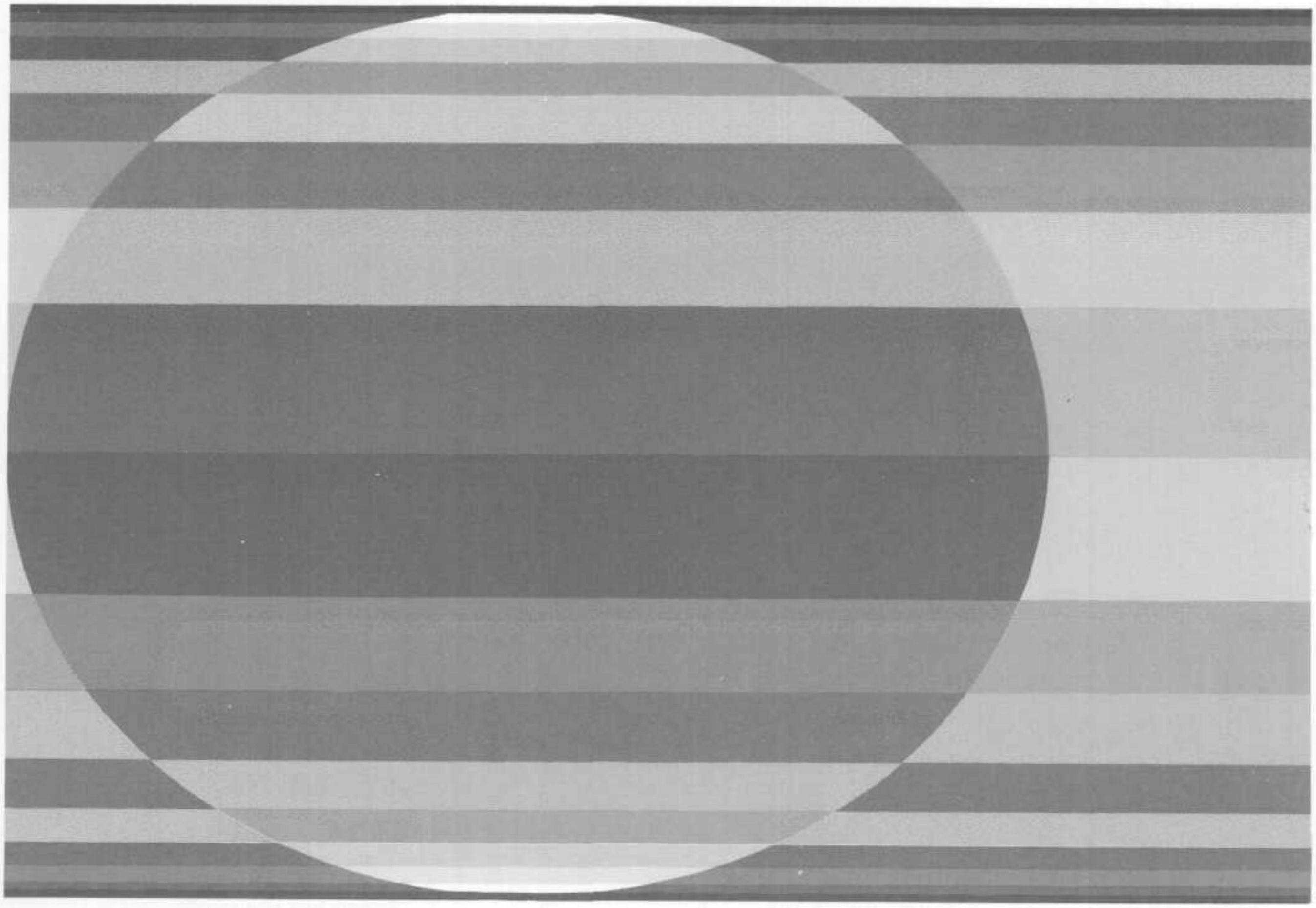
BACKGROUND PAPER

Nuclear Reprocessing and Proliferation: Alternative Approaches and their Implications for the Federal Budget

May 1977



Congress of the United States
Congressional Budget Office
Washington, D.C.

NUCLEAR REPROCESSING AND PROLIFERATION:
ALTERNATIVE APPROACHES AND THEIR IMPLICATIONS FOR THE FEDERAL BUDGET

The Congress of the United States
Congressional Budget Office

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PREFACE

Nuclear Reprocessing and Proliferation analyses and provides background information on the relationship between reprocessing of spent nuclear fuel and the proliferation of nuclear weapons. Choices of alternative approaches to domestic reprocessing can influence the approaches appropriate to containment of proliferation and the development of the breeder reactor. These alternative approaches can have important budget impacts, especially in the long run, and the provisions that could be made in the fiscal year 1978 budget for at least some preliminary activities, will set a pattern for larger expenditures in future years.

This study was prepared in response to an informal request from the staff of the Senate Budget Committee. In keeping with the mandate of the Congressional Budget Office to provide objective, nonpartisan analysis of budget issues, this report contains no recommendations. The budget options presented in this report do not represent policies advocated by the Congressional Budget Office. They are simply alternatives chosen to illustrate the broad range of options available to the Congress.

The paper was prepared by Richard M. Dowd of CBO's Natural Resources and Commerce Division with the assistance of Katharine Terrie Bateman under the direction of Raymond C. Scheppach and Nicolai Timenes, Jr. The author wishes to acknowledge the assistance of Sheila Fifer of the National Security and International Affairs Division. The manuscript was typed by Angela Z. Evans.

Alice M. Rivlin
Director

May 1977

TABLE OF CONTENTS

TABLES

FIGURES

SUMMARY

Plutonium does not exist as a natural element. It exists only as manmade material, created during the fissioning process that takes place in the present generation of light water nuclear reactors. The spent fuel removed from these reactors contains plutonium.

Through a technique called reprocessing, the plutonium in this spent fuel can be recycled back through the nuclear reactor, thus generating additional energy. The reprocessing of plutonium can greatly extend the life of natural uranium, which is a natural element, but exists in finite, nonrenewable quantities.

Another kind of reactor--the liquid metal fast breeder reactor--depends almost exclusively on plutonium for fuel. It is called a breeder because it produces more useful fuel (plutonium) than it consumes, therefore breeding additional fuel, and extending much further the life of the original uranium source.

So far, it would appear that plutonium is a useful product of nuclear fission, and that processes to recover that plutonium would greatly enhance the ability of the nuclear fuel cycle to become one of the most important worldwide sources of energy.

But, plutonium is the stuff of which most nuclear weapons are made. The plutonium created through reprocessing of spent nuclear fuel and in the breeder could be stolen or diverted from its intended purposes and used in nuclear weapons. This theft or diversion could take place during transportation or storage of the plutonium. Therefore, opposition to reprocessing and to the breeder has focused most directly on the fact that the generation of plutonium greatly increases the threat of proliferation of nuclear weapons.

Hence, an inherent conflict exists: The promise of large increases in the energy that can be created from nuclear fission versus the realization that the same processes that produce this energy can also enable countries not now in possession of nuclear weapons--or even terrorist groups--to obtain them.

The U.S. government--through legislative, administrative, and regulatory decisions--will soon decide the approaches the United States takes on the issues of reprocessing, the breeder, and on proliferation. While the federal government can determine policy for domestic reprocessing and breeders, it cannot set policy for other nations. We can only hope that decisions made domestically will influence those made in other countries.

It is important to note that the decisions made by the federal government will affect the federal budget--although some of those effects will not be immediate. Furthermore, these decisions are intimately related, and the choice of approaches with respect to reprocessing, for example, will constrain the options and effectiveness of decisions on the breeder and on the general issue of proliferation.

A further decision must also be made regarding the storage of highly radioactive waste which, without reprocessing, would include spent fuel rods from light water reactors. This waste cannot be disposed of in the sense that it can be absorbed into the environment. Therefore, it must be permanently stored. At issue are the sites for such storage and the form in which the waste should be stored. Decisions on storage issues will have to be made regardless of the decisions on whether to reprocess. At present, there is a large amount of military nuclear waste material--greater in quantity than the waste from commercial facilities--awaiting permanent storage.

However, even though the issue of waste storage will certainly affect the federal budget, it is not a critical determinant in the resolution of the issues surrounding reprocessing, etc., and will not be discussed at length in this paper.

CARTER POSITION ON NUCLEAR POWER

Both the Ford and Carter Administrations have thoroughly reevaluated the issues involved in reprocessing, the breeder, and their effects on the proliferation of nuclear weapons.

On April 7, 1977, President Carter issued in the following statement:

> ...We are now completing an extremely thorough review of all the issues that bear on the use of nuclear power. We have concluded that the serious consequences of proliferation and direct implications for peace and security--as well as strong scientific and economic evidence--require:

-- a major change in U.S. domestic nuclear energy policies and programs; and

-- a concerted effort among all nations to find better answers to the problems and risks accompanying the increased use of nuclear power.

In essence, the Carter Administration is calling for an indefinite delay in commercialization of reprocessing and breeder facilities, and a search for alternatives to the existing nuclear fuel cycle that would not "involve direct access to materials usable in nuclear weapons."

However, the ultimate decisions on these issues will be for the Congress to decide. This paper will attempt to shed some light on the issues involved in making those decisions.

THE BREEDER REACTOR AND ITS IMPLICATIONS

Arguments for the breeder are based on estimates of future energy consumption, the exhaustion and limitations of existing resources, and the way in which breeding can extend the life of existing uranium resources.

Arguments against the breeder are based in large measure on the threat of proliferation inherent in the widespread use of plutonium, and also on claims of questionable economics, high costs, safety, and the fact that the breeder is dependent on reprocessing for fuel supplies.

There are no commercial breeders today. The Energy Research and Development Administration (ERDA) is sponsoring a smaller-than-commercial-scale breeder demonstration plant at Clinch River, Tennessee, which has, itself, been the focus of much of the controversy surrounding breeder development.

The currently suggested approaches to dealing with the issue of the breeder are:

1. Sequential development, which would require that a larger, closer to commercial-size-breeder (known as a prototype large breeder reactor) not be constructed until the Clinch River Breeder Reactor (CRBR) had been operational for one full year; and that no commercial-size breeders be

built until the prototype breeder had been operational for one year.

2. Parallel development would permit the design and construction of the prototype breeder to begin before the Clinch River breeder became operational; and that design and construction of a commercial-size breeder could begin before the prototype became operational.

3. No further development would mean simply that all further development of the breeder would stop either before or after Clinch River is completed. This approach is similar to the approach suggested by the Carter Administration.

REPROCESSING AND ITS IMPLICATIONS

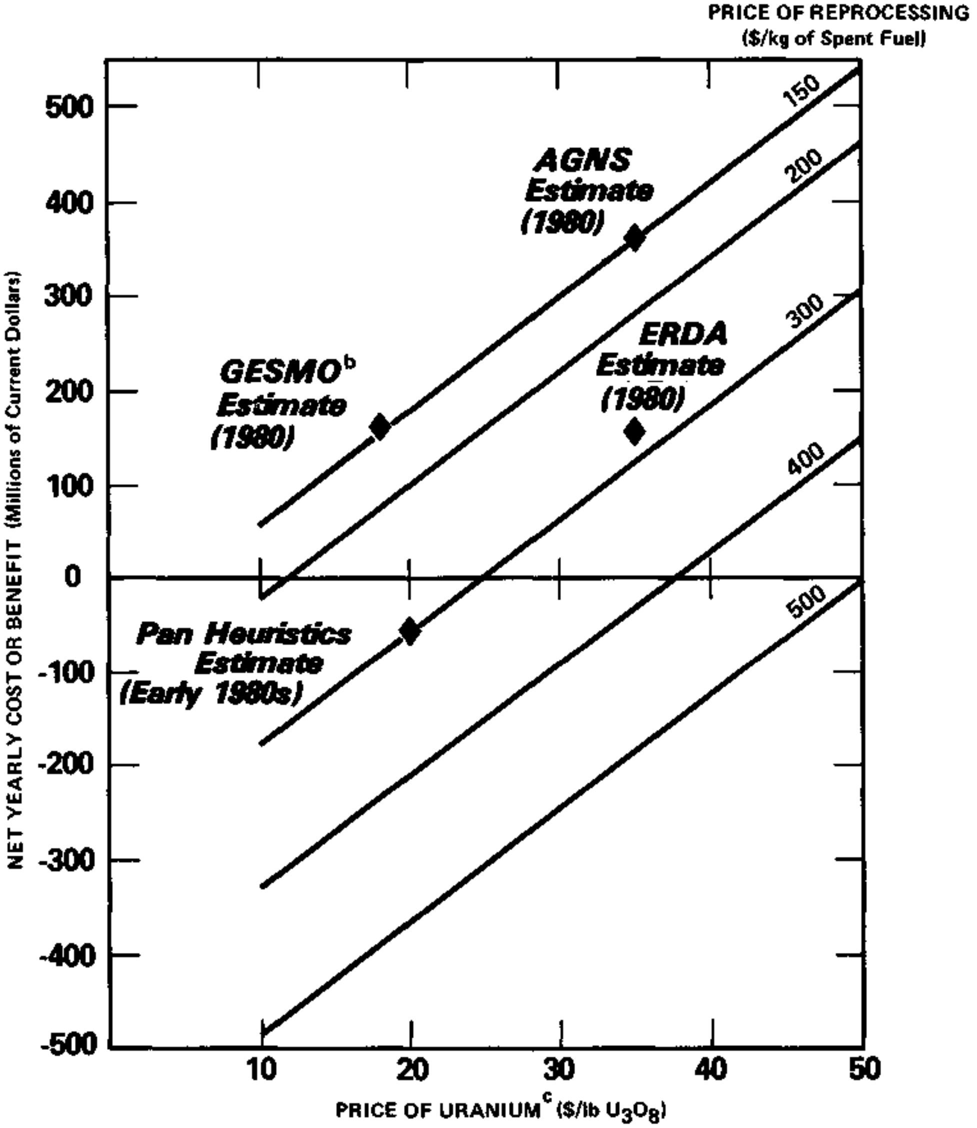
The arguments for reprocessing, like those for the breeder, are based on the expected growth in demand for energy generally, and nuclear power in particular, coupled with the exhaustion of uranium resources. Reprocessing is of course essential for the implementation of the breeder, but it could be advantageous even if the breeder were not developed. Economic benefits are claimed for reprocessing, although that issue is the subject of some controversy.

The arguments against reprocessing are similar to those surrounding the breeder. The widespread use of plutonium raises the specter of proliferation. Further, the cost advantages of reprocessing have been questioned.

The following figure shows the calculated net benefits or costs of reprocessing uranium and plutonium using a range of prices for mined uranium (U_3O_8), compared with a range of prices for reprocessing services (represented in the figure by the diagonal lines). For example, if reprocessing costs $150 per kilogram of spent fuel and natural uranium is selling at $10 per pound, a yearly net benefit of about $50 million will be derived from reprocessing. However, if it turns out that reprocessing costs $300 per kilogram of spent fuel and uranium costs $10 per pound, a net cost of about $175 million will result from reprocessing.

The figure also shows estimates of net costs or benefits derived from reprocessing spent fuel based on assumptions used in several pertinent studies on the subject of reprocessing.

Net Yearly Benefit of Reprocessing Resulting From Different Uranium and Reprocessing Prices[a]



[a] Based on a 1500 metric ton/year facility.

[b] The ◆ denotes estimated prices for uranium and reprocessing used in these various studies. These are detailed in Appendix A.

[c] For comparison, note that the range in prices for 1977 was estimated to be $7-$30 per pound with an average of about $12 per pound; the estimated range for 1980 is from $12 to $56.

Currently available approaches to dealing with the issue of reprocessing are:

1. No reprocessing. The implementation of this approach would stem from a determination that the benefits were either negative or not large enough to outweigh the risks of proliferation. This alternative is favored by President Carter.

2. Reprocessing with the recycling of plutonium. The implementation of this approach would stem from a determination that the advantages of reprocessing--restored resources, cost effectiveness--outweigh the threats of proliferation.

3. Reprocessing with no recycling of plutonium. The implementation of this approach would stem from a determination that the risk of proliferation is too great to permit full reprocessing, but that recovery of uranium only is still worth the effort.

There are a variety of technical varients of the second two options, all of which are designed to prevent the traffic in plutonium to exist. The cost of such options generally would be reflected in both reduced economic benefits and in reduced life for existing uranium resources.

The final option is one of timing. A decision on reprocessing need not be made now, since various temporary expedients exist for storage of spent fuel rods, and the need for additional nuclear power is not yet pressing. Yet the problems which suggest reprocessing increase with every passing day, and costs are associated with the virtues of delay.

PROLIFERATION AND ITS IMPLICATIONS

In 1953, the United States instituted its Atoms-for-Peace policy which called for the sharing of nuclear technology for peaceful uses with developing countries. In return, these countries agreed to forgo the use of this technology for weapons manufacture. However, since that time, the distinction between nuclear power and nuclear explosives has been eroded by advances in nuclear technology. A country that has acquired a nuclear power facility has also acquired much of the information and materials necessary to manufacture nuclear explosives.

The spread of nuclear technology to developing countries has clearly increased, rather than decreased, the prospects for nuclear proliferation.

The concerns regarding proliferation take the form of two major threats:

> Diversion (essentially the act of placing plutonium in weapons) of nuclear materials by nations that do not have nuclear weapons, but do have the other elements of the nuclear fuel cycle; and
>
> Theft of weapons-usable materials by terrorist groups.

Subordinate concerns include the need for and effectiveness of safeguards to protect against diversion and theft and the limitations on civil rights imposed by those safeguards.

Technical considerations attending proliferation include a variety of techniques for safeguards and the possibility of redesigning the methods of reprocessing to eliminate weapons-usable material.

The approaches to coping with proliferation depend on the potential for international cooperation, since the attitudes of nations now in possession of nuclear weapons; nations with nuclear technology that have so far chosen not to build weapons; and nations with no nuclear technology all will influence the ultimate decisions on proliferation. The United States, as a major potential supplier of nuclear technologies or services, is in a position to influence, but not determine, these decisions by its own action. It should be noted, however, that there may be other reasons why nations wish to acquire nuclear weapons. These reasons are beyond the scope of this paper.

Depending on the extent to which proliferation is considered a major threat, several approaches are available to counteract that threat: Decisions could be reached that would (1) simply prohibit further development of nuclear power; (2) permit continued development of nuclear technologies but prohibit reprocessing (and hence the breeder); (3) permit reprocessing and enrichment only by nations now in possession of that technology (thus enabling nations without major reprocessing capabilities to receive reprocessed fuel, but not the technology); (4) permit reprocessing only under the auspices of an international authority employing strict safeguards. There are two additional possibilities regarding proliferation: (5) that any nation be able to buy reprocessing and enrichment capabilities, which would follow from a conclusion that the benefits from reprocessing outweigh the threats to proliferation; or (6) no coherent international agreement on proliferation, which would be the result of a failure to agree on other courses of action.

DECISIONS BEFORE THE CONGRESS AND THEIR EFFECTS ON THE BUDGET

Each of the possible approaches to reprocessing, breeder development, and proliferation has implications for the other approaches. While the basic decisions that the Congress is likely to make on these issues will deal primarily with domestic reprocessing and breeder development, the results of these decisions will affect the positions taken by other countries on reprocessing and their general attitudes toward the issue of proliferation.

For example, a decision made by the United States to reprocess fuel immediately on a commercial basis would be consistent with further commercial breeder development and a multilateral decision that reprocessing would be done only by supplier nations, or under international authority, or by all nations without restriction.

On the other hand, a decision by the United States to allow no domestic reprocessing would be inconsistent with further development of the breeder and could probably reduce U.S. influence on multilateral decisions regarding the question of shipping plutonium and the development of adequate safeguards, if a position were taken internationally that supplier nations should do all reprocessing.

Summary Table 1 shows a full range of approaches to domestic reprocessing, approaches to containment of proliferation, and the consistency or inconsistency of these alternative approaches to the issues. This table also shows which of the approaches would be consistent with development of the plutonium breeder.

It is important to note that even though U.S. involvement in international efforts to contain proliferation can only be nurtured through diplomatic initiatives, some of the decisions made by other countries may ultimately have budgetary consequences that the Congress may have to deal with. For instance, an international decision that reprocessing would be done only under the

SUMMARY TABLE 1. RELATIONSHIPS BETWEEN APPROACHES TO CONTAINMENT OF PROLIFERATION AND APPROACHES TO DOMESTIC REPROCESSING AND THEIR CONSISTENCY WITH BREEDER DEVELOPMENT

INTERNATIONAL APPROACHES TO CONTAINMENT OF PROLIFERATION RELATING TO REPROCESSING

APPROACHES TO DOMESTIC REPROCESSING

	No Additional Nuclear Power	No Reprocessing	Reprocessing by Supplier Nations Only		Reprocessing Under International Authority	Reprocessing Permitted By Any Nation
			Without Plutonium	With Plutonium		
No Reprocessing	Approaches would be consistent; however alternative energy sources would be necessary.		Approaches would be directed toward different goals, hence inconsistent. If the United States chooses to forgo nuclear power, and other nations do not, the United States would probably lose the ability to influence the decisions on the use of nuclear power, especially those concerning reprocessing, made by other nations.			
No Additional Nuclear Power			These approaches could be consistent. However, the ability of the United States to influence international decisions on shipping plutonium and on development of safeguards could be considerably reduced.		Approaches could be consistent if safeguards were effective.	Approaches would be inconsistent. Such a situation would indicate lack of coherent international policy.
Immediate Reprocessing Without Plutonium	Major inconsistencies would occur among these approaches. The United States would be pursuing courses of action rejected by other nations. Thus, no coherent international agreements could be reached.		Approaches would be consistent. International agreements could be reached.	Approaches would be inconsistent on the issue of plutonium. Presumably, no international agreements could be reached.	Approaches could be consistent provided agreements did not allow shipping of plutonium	Approaches would be inconsistent on the issue of plutonium. Presumably, no international agreements could be reached.
Immediate Reprocessing With Plutonium			Approaches would be inconsistent on the issue of plutonium. Presumably no international agreements could be reached.	Approaches would be consistent. International agreements could be reached.	Approaches would be consistent. International agreements could be reached.	
Indefinite Delay in Reprocessing	Approaches would be consistent until the United States made its final decision on reprocessing. Then, if the United States decided to forgo reprocessing, major inconsistencies with approaches to proliferation allowing reprocessing would develop.					

APPROACHES CONSISTENT WITH BREEDER DEVELOPMENT

APPROACHES CONSISTENT WITH BREEDER DEVELOPMENT auspices of a multilateral authority might possibly require financial support. The amount of any such support would be decided by the Congress. But these decisions may be somewhat more long term than the domestic reprocessing and breeder issues.

In sum, the Congress will probably have to make the following decisions in the near future:

- Whether to reprocess spent fuel, and if so, when and how;
- Whether to continue with the development of the liquid metal fast breeder reactor on a commercial basis, and if so, when and how;
- And, if the answer is yes to any of the above questions, how much federal money, over what period of time, should be spent on these ventures.

In the past, these issues have been reflected in the federal budget through line items for energy research and development, with the breeder receiving the bulk of support and attention. It is, in fact, difficult to separate the budgetary requirements of various approaches to reprocessing and proliferation from other larger items.

However, the Congressional Budget Office has estimated the potential levels of expenditures that could result from decisions to follow any one of the various approaches to reprocessing, the breeder, or proliferation. These estimates appear in Summary Table 2. The amount of money authorized for any of these approaches is small at the inception of the project, but grows over time and could increase to $4.6 billion by 1986 if the Congress decided to implement the breeder on a commercial basis (the parallel development approach discussed earlier).

Compared to other items in the budget, federal money for any of these approaches is not large. However, the economic consequences of these expenditures for the country could be quite large indeed.

In any event, the final choices are likely to come down to assessments of how critical containment of proliferation is, compared with the economic benefits of further development and implementation of new nuclear technologies such as reprocessing and the breeder on a worldwide basis; and how U.S. decisions on domestic reprocessing and breeder development will affect these choices.

SUMMARY TABLE 2. POSSIBLE BUDGET EFFECTS OF ALTERNATIVE APPROACHES TO THE BREEDER, REPROCESSING, AND CONTAINMENT OF PROLIFERATION, IN BILLIONS OF DOLLARS

Alternative Approaches	1977-1986	Beyond 1986
Approaches to Breeder Development		
Parallel Development	4.600	similar
Sequential Development	3.500	similar
Prohibition	0-(1.00)	
Approaches to Reprocessing		
No Reprocessing	small**	small**
Reprocessing with plutonium		
Immediate	0.500	***
Delay	0.500-0.900	***
Approaches to Containment of Proliferation		
No Additional Nuclear Power	*	*
No Commercial Reprocessing	**	**
Reprocessing by Supplier Nations		
with plutonium	0.250	0.750
without plutonium	0.500	1.300
Reprocessing Under International Authority	small	1.300
No Restrictions	*	*
No Coherent Policy	*	*

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* In many of these approaches, additional support would be required for IAEA inspection and safeguards. It is difficult to determine amounts but they would not be large.

** These approaches would have to include a substantial revision of present R&D priorities, to focus on nonfission alternatives.

*** The budget effects of these approaches would depend upon the extent to which processing facilities were funded and constructed by private industry.

CHAPTER I. INTRODUCTION

The dream of turning atomic power to peaceful uses has motivated men since that power was first harnessed. This dream has resulted in attempts to develop and share information, materials, equipment, and technology for the generating of electricity with nuclear power. It now appears that some aspects of commercial nuclear power production and the attendant facilities--notably those for enriching uranium and for reprocessing spent fuel--have the potential for creating materials which could be used directly as nuclear explosives. Plutonium is an important component in the manufacture of nuclear weapons, and it is through reprocessing that plutonium becomes available.

Plutonium can also be recovered from the fast breeder reactor--another facility for harnessing nuclear power. Thus, the risks of the breeder are also discussed in this paper.

The risks of reprocessing, of the breeder, and what these new technologies mean for worldwide proliferation of nuclear weapons are viewed in the context of issues and budget decisions before the Congress.

Of crucial importance in making these decisions is the fact that policy regarding domestic implementation of both reprocessing and the breeder are within the power of the U.S. government to make or change. However, global policies involving proliferation are at the discretion of the nations having or willing to sell nuclear capabilities. The United States can only encourage caution. It cannot dictate policy to foreign powers. Therefore, domestic decisions must be viewed with the complexities of international relationships in mind.

Both the Ford and Carter Administrations have thoroughly reevaluated the issues involved in reprocessing, the breeder, and their effects on the proliferation of nuclear weapons.

The Ford Administration acknowledged clear problems of proliferation, and urged caution and careful study, particularly with respect to reprocessing.

In essence, the Carter Administration is calling for an indefinite delay in commercialization of reprocessing and breeder facilities and a search for alternatives to the existing nuclear fuel cycle that would not "involve direct access to materials usable in nuclear weapons."

However, the ultimate decisions on these issues will be for the Congress to decide. This paper will attempt to shed some light on the issues involved in making those decisions.

BACKGROUND--THE NUCLEAR FUEL CYCLE

The nuclear fuel cycle includes all facets of the process of obtaining uranium, converting it to a fuel form, using it, and then converting spent fuel for reuse and/or permanent waste storage. For the past 20 years, the mining, milling, conversion, enrichment, fabrication, and use--known as the front end of the cycle--have received most of the attention and money for research, development, and implementation. Furthermore, it has been assumed that the back end of the fuel cycle would eventually be developed, and would include reprocessing and permanent storage of reprocessing wastes.

The idea of permanent waste storage without eventual reprocessing has not been considered seriously as part of the fuel cycle until recently, as the inherent dangers of reprocessing have begun to be addressed.

It is important to understand that nuclear waste cannot be disposed of in the sense that it can be absorbed in the environment. Thus, it must be permanently stored. Since some nuclear waste is highly radioactive, sites and the form in which it is stored must be carefully considered.

The existence of large quantities of military nuclear waste, indeed greater in volume than the waste created by commercial reactors, makes the question of waste storage relevant no matter which way the decision to reprocess goes.

A process is being developed that will stabilize nuclear wastes into a kind of glass. Furthermore, the most promising sites for permanent waste storage would seem to be granite or salt deposits, although final decisions on the acceptability of these kinds of sites have not been made.

Stabilization and storage of nuclear waste may cost over $10 billion by the year 2000. But these budget issues, although critical, are separate from the issues regarding reprocessing and are not discussed in this paper.

Reprocessing 1/

The currently available technology for reprocessing is known as the Purex process; it was developed for production of weapons-usable plutonium and has been used extensively by the military for this purpose. The process, as adapted to spent fuel from commercial reactors, includes: storage of spent fuel rods; chopping the rods; dissolving the uranium, plutonium, and radioactive products in acid; separating the radioactive wastes and storing them; separating uranium nitrate from plutonium nitrate; converting uranium nitrate to uranium hexafluoride; converting plutonium nitrate to plutonium dioxide; and solidifying the highly radioactive wastes. The plutonium oxide and uranium hexafluoride can then be prepared for further processing into new fuel rods, and the radioactive solid wastes can be taken to a final storage site.

It is this recovery of plutonium that has engendered much of the controversy surrounding reprocessing because the separation and commercial use of plutonium present the opportunity for stealing or diverting the plutonium, necessary for the construction of nuclear weapons. The availability of reprocessed plutonium in a commercial setting raises the threat of proliferation of nuclear weapons by nations presently without that capability, or by terrorists with similar motives.

At the heart of the controversy is the question of whether reprocessing is indeed necessary to enjoy the full benefits of nuclear energy and, if it is, whether commercial use of plutonium as a fuel will increase the risks of further proliferation of nuclear weapons among nations to unacceptable levels.

INTERNATIONAL, INDUSTRIAL, AND REGULATORY HISTORY

International

Between the end of World War II and 1953, the United States shrouded all aspects of nuclear technology--military as well as

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1/ For a complete description of Purex reprocessing, see diagram at the end of this paper.

industrial--in tight secrecy hoping to avoid any proliferation of nuclear weapons by nations not already possessing nuclear capabilities.

However, this approach failed with the Soviet development of nuclear weapons. The Atoms-for-Peace program announced in 1953 redirected U.S. policy and attempted to encourage the peaceful use of nuclear energy through multinational energy agreements that allowed a sharing of knowledge about industrial applications, including that of reprocessing, but without the further spread of nuclear weapons.

This change in U.S. policy set the stage for the creation of the International Atomic Energy Agency (IAEA) in the late 1950s. The IAEA was established to encourage the use of nuclear energy for peaceful purposes and to provide safeguards against proliferation; the safeguards attempt to detect, rather than prevent, the diversion of nuclear materials. And it is hoped that the threat of detection will prevent the spread of nuclear weapons.

The second major international response to the Atoms-for-Peace plan was the Nonproliferation Treaty (NPT) which was ratified in 1968 and became operational in 1970; there are now over 100 parties to the treaty. The NPT provides for the right of each nation participating in the treaty to engage in peaceful nuclear activities (including reprocessing), and obligates weapons nations (those now in possession of nuclear weapons) to contribute to peaceful nuclear development; it also provides that nations not in possession of nuclear weapons agree not to develop them and to accept IAEA-directed safeguards for all peaceful nuclear activities under their control.

In keeping with this agreement, 12 countries have already built larger-than-laboratory scale reprocessing facilities; 6 countries are major developers of the technology at a commercial scale (France, Germany, Japan, United Kingdom, United States, and USSR). In addition, France and Germany have agreed to sell parts of nuclear fuel cycle systems (including reprocessing plants) to Pakistan and Brazil respectively. However, both France and Germany have imposed a moratorium on future sales of reprocessing facilities for the time-being.

Industrial

The earliest commercial reprocessing facility in the United States was the Nuclear Fuel Services plant at West Valley, New York. Although a relatively small plant (300 tons spent fuel reprocessed each year), it operated from 1966 until 1972. During this period, regulatory requirements became stricter. When it shut down in 1972, the intention was to increase capacity and alter the facilities to meet potential new requirements. However, difficulties were subsequently encountered in retrofitting to these requirements, and in September 1976 it was announced that the plant would not reopen.

A second plant (also 300 tons per year) built by General Electric at Morris, Illinois, at a cost of $64 million, has been unable to operate due to design problems and likely never will open.

In 1970, Allied-General Nuclear Services (AGNS) began to construct a much larger facility (1500 tons per year) at Barnwell, South Carolina. This plant (which was designed to produce uranium hexaflouride (UF6) for further enrichment, liquid plutonium nitrate, and highly radioactive liquid waste) has been completed at an estimated capital cost of $250 million. Additional facilities for conversion of the plutonium nitrate to plutonium dioxide (PuO2) and for solidification of the highly radioactive wastes could cost an additional $250 million to $500 million. However, regulatory decisions are necessary before such facilities can be planned or built, and before any fuel can be reprocessed.

In January of 1976, Exxon applied for a license from the Nuclear Regulatory Commission (NRC) to construct a large reprocessing plant. No final action has yet been taken on that application.

Regulatory

The Nuclear Regulatory Commission has the responsibility for regulating and licensing nuclear facilities in the United States. As part of this responsibility, NRC is in the process of deciding whether to permit the use of mixed oxide fuel (a mixture of recycled plutonium dioxide and uranium dioxide) in the present generation of light water reactors on a widespread basis. This process involves the preparation of a Generic Environmental Impact Statement on the Use of Recycled Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors (for purposes of brevity, this document is referred to as GESMO) which has been completed, with a supplement to address safeguards yet to come. A final decision on GESMO by the Commissioners is planned for late 1977. However, the Carter policy statement may alter this timetable. The issues addressed in the GESMO decision will include spent fuel storage, reprocessing, fuel fabrication, enrichment of recovered uranium, conversion of highly radioactive wastes to a form suitable for storage and disposal, and transportation of all products and wastes. Obviously, all decisions regarding the licensing of individual reprocessing facilities await a decision on GESMO.

When the overall issue of whether to allow any new reprocessing is resolved, issues involving the individual components of a reprocessing facility can be addressed. Although some regulatory decisions have already been made in allowing for the construction of the Barnwell plant, other issues include the storage of spent fuel, the separation facility, the facility for converting plutonium to plutonium oxide, and the facility for solidifying highly radioactive wastes. Since no commercial facilities are currently operating, the licensing process may be quite extensive, particularly for the plutonium oxide and waste solidification facilities. In addition, if a decision is made not to allow widespread use of plutonium oxide, some modifications to the reprocessing design may be necessary, particularly for the final disposition and storage of the plutonium to allow for recycling only the uranium.

The NRC, along with other agencies, is involved in deciding whether or not to allow the sales of nuclear materials (such as enriched uranium or recycled plutonium), or nuclear technologies, or facilities such as nuclear reactors or reprocessing facilities to foreign nations. The present U.S. policy is not to permit exports of sensitive technologies such as reprocessing and enrichment.

PROBLEMS

Several issues that are affected by the reprocessing/proliferation debate will need resolution at about the same time. These include:

- Inadequate facilities for permanent storage of spent fuel from the present generation of nuclear reactors. In the absence of reprocessing or some other disposition of spent fuel, some action must be taken quickly to store the increasing quantities of spent fuel being generated by existing reactors.

- The form in which radioactive waste should be permanently stored. At present no method for permanently transforming highly radioactive wastes to a stable form for storage has been licensed.

- The sales of reprocessing facilities to foreign countries. Although reprocessing technology is not secret, the construction of a large-scale commercial plant is very expensive and requires the ability to implement extremely sophisticated technology. The question of whether the United States should assist in foreign reprocessing initiatives needs to be resolved, regardless of the decision on domestic reprocessing.

- The extent and ownership of uranium enrichment facilities. Although money has been appropriated to construct one additional government-owned gaseous diffusion enrichment plant, the question of further additional facilities remains: how many are needed and for what customers? Who should own and operate them? For example, foreign access to U.S. enrichment could reduce interest in plutonium as a fuel, but would presumably increase the number of enrichment facilities needed. Obviously, these questions will be partially resolved by the decisions on reprocessing and further proliferation.

- Whether and how the federal government should support the partially completed reprocessing facility at Barnwell, South Carolina. If reprocessing and recycling of either uranium or plutonium are permitted, a decision must be made about how much, if any, federal support to provide for those portions of the facility not yet designed, and whether it should be a multinational facility or a domestic one.

GOALS

The resolution of the issues related to reprocessing and proliferation must be related to broad goals regarding energy policy. Not all of the goals often articulated for energy policy--and nuclear energy policy in particular--are consistent with one other. Therefore tradeoffs must be made. However, one overall goal pervades all discussion of U.S. energy policy objectives:

1. To provide adequate supplies of energy for domestic economic health and to reduce or mitigate U.S. dependence on disruptable energy supplies.

Within the reprocessing and proliferation arena, there are several other goals and these goals have been alluded to earlier in this introduction:

2. To reduce the threat from further nuclear proliferation. If this goal is the single most important worldwide issue, then a policy of restrictions on the use of nuclear energy could be the result and the additional goals enumerated here would become obsolete. If it is an important goal, but not the dominant one, then different approaches can be taken to mitigate or delay proliferation, some of which might compromise proliferation goals to avoid aggravating others.

3. To insure that nuclear activities are safe and do not endanger the environment. Meeting this goal will have implications for both facets of the back end of the fuel cycle: reprocessing and permanent storage.

4. To encourage nuclear technology that is economical in terms of money spent and resources used. The ability to meet this goal will depend largely on estimates of future prices for most facets of the entire fuel cycle.

5. To the extent possible, improve the conversion of uranium into useful energy. Since at any price level, only a finite amount of uranium exists, it is prudent to maximize the useful energy gained. Reprocessing does make available some of the energy remaining in spent fuel rods. Other avenues can also improve the energy conversion; the breeder, lowering the tails assay (waste) in enrichment, and increasing the efficiency of light water reactors.

ISSUES

Thus to recapitulate, the issues take the form of several questions:

- How to reduce the threat of international proliferation?
- Whether and how to reprocess spent fuel?
- Whether to support private initiatives in reprocessing?
- Whether and how to develop the breeder reactor?

In the remainder of this paper, these issues will be discussed in order.

Chapter II discusses the breeder reactor and its development and suggests approaches to decisions on its future.

Chapter III addresses reprocessing spent fuel and suggests approaches to the issue of whether or not to reprocess.

Chapter IV addresses proliferation of nuclear weapons and suggests approaches to the containment of proliferation.

Chapter V addresses the decisions before the Congress in the context of the relationships among approaches to containment of proliferation and approaches to reprocessing and the breeder, and discusses the implications for the federal budget of decisions on all of these issues.

CHAPTER II. THE BREEDER REACTOR AND ITS IMPLICATIONS

The breeder reactor produces energy that can be used for the generation of electricity just as a light water reactor (LWR) does. It differs from an LWR in many respects, but the most important one is its ability to produce more isotopes that can be used as fuel than it burns, thus breeding fuel. The breeder presently under intense development in the United States and abroad is called a liquid metal fast breeder reactor; it uses fast (as opposed to slow) neutrons emitted during nuclear fission to transform U238, which cannot fission, into plutonium which can. However, the present design requires reprocessing to make the plutonium available for new fuel elements.

There are several possibilities for developing other kinds of breeders. One such concept does not use plutonium, but rather converts thorium, a relatively abundant element, into U233, which is a fissionable isotope useful as fuel in the same way U235 or plutonium are. Although U233 can be used to make weapons, technical considerations make it easier to safeguard against diversion or theft than plutonium.

Decisions on the breeder are closely related to decisions on reprocessing. Thus, the future of the breeder is an important part of any broader decisions with respect to reprocessing and proliferation. While reprocessing does not require the breeder, the breeder cannot breed without reprocessing.

NEED

The breeder has been developed to alleviate two restrictions on present energy sources: (1) the continuing growth of energy consumption in the face of declining petroleum supplies, and (2) inherent limitations in the existing light water reactor as a source of energy because of insufficient uranium resources.

1. Energy Growth. Until recently the overall production of energy from fossil fuel has been keeping pace with or exceeding increases in the world population. At present, worldwide consumption of energy has increasd faster than the population. Moreover, reserves of natural gas and petroleum still in the ground are not sufficient to remain a major energy source for many more years.

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The decline in fossil fuel resources, as well as the large price increases associated with them, has accelerated efforts to find new energy sources less tied to limited natural resources.

A case in point: The consumption of electricity is growing faster than the traditional fuel (oil or gas) available to generate that electricity. One relatively new fuel source for generating electricity is uranium. But, because uranium is also a finite fuel source, costs here will eventually rise also. And, emphasis will shift to nonuranium sources or to methods of perpetuating uranium supplies. For this reason, the breeder has been the subject of intensive research, as has the use of solar energy and the use of more abundant fossil fuels such as coal. In fiscal year 1977, over $400 million was appropriated for research on coal, $290 million for solar energy research, and over $680 million for research on the liquid metal fast breeder reactor.

If the very recent reductions in energy growth are a more accurate forecast of future trends, the need for alternative sources to petroleum and natural gas may be somewhat delayed, but this need will not be eliminated. However, this delay may provide more time for research efforts to resolve remaining uncertainties.

2. Limitations in the Light Water Reactor. The physics of nuclear reactors using uranium restrict the production of energy to one specific element in the uranium--the U235 isotope. 1/ Although the fissioning of U235 releases a great deal of energy, U235 makes up only 0.7 percent of all natural uranium.

Depending on growth projections, the amount of uranium available domestically may or may not permit expansion of a U.S. nuclear power industry much past the turn of the century. The Federal Energy Administration report, National Energy Outlook for 1977, suggests that reasonable and probable domestic categories of uranium resources known today would provide a lifetime (approximating 30 years) supply of uranium for over 300 large power plants, 220 of which will probably be operable by 1990. 2/

1/ For a more complete explanation, see diagram on the nuclear fuel cycle at the end of this paper.

2/ National Energy Outlook, draft 1977, Federal Energy Administration, January 15, 1977 pp. III-88 and VI-35.

These resources, recoverable at costs up to $30 per pound could provide for expansion of the nuclear industry roughly until the turn of the century. As additional resources are discovered (estimates conclude that resources in the possible and speculative categories are as large as those in the reasonable and probable categories), and as market pressures push prices higher making the recovery of uranium costing more than $30 per pound economical, the resource base should allow for some expansion beyond the turn of the century. These resources could maintain light water reactors as an appreciable energy source, albeit at higher costs, well into the next century. However, even with more efficient reactors and fuel cycles, the amount of energy available from present nuclear technology is limited. The use of nuclear energy can be viewed as a way of buying time for the transition from the present dependence on oil and gas to other alternative sources of energy.

The breeder program is often seen as an essential element to strengthen and expand the nuclear industry, and to provide an alternative source of energy. Most of the justification for the breeder program is made from this vantage point. Development of the breeder can be avoided only by using increasingly more expensive (because of lower concentration) uranium resources or by developing other alternative sources that do not use fission, such as coal, fusion, or solar energy.

CONCERNS

The major impediments to implementation of the breeder reactor are unresolved questions of the cost of power generated by such a reactor and the environmental effects of its development. In addition, major concerns have been raised regarding the issue of proliferation, and safety of the breeder.

1. Cost. This issue is of particular importance because of the history of the Clinch River Breeder Reactor (CRBR)--the first breeder to be built at close-to-commercial scale. The early estimate for the cost of this project was $700 million, but has now risen to close to $2 billion for a plant with a capacity of 350 megawatts (MWs). Thus, even if the cost of breeder fuel is reduced to below the cost of uranium when produced at commercial scale, unless capital requirements are much less for the next generation of breeders, the cost of power from such a source could be considerably above that of an LWR or of a coal-fired power plant. While the breeder is only now in development and the cost undoubtedly will change, these cost issues do create cause for some concern.

2. Effects on the Environment. The primary environmental concerns relating to the breeder reactor involve the production, containment, and emission of radioactive material. In most respects, these materials are similar to those generated in an LWR. Whether the breeder can utilize environmentally safe emission systems for these materials, similar to those used in the LWR, remains to be seen. The CRBR will attempt to implement an emission control system; and the effects on the environment can then be assessed. The effects of other critical aspects of the breeder system, including reprocessing and waste storage, must also be assessed. However, these particular components will not be specifically tested by the CRBR.

In addition, concern has been voiced over the large quantities of plutonium that will be generated, transported, and processed. Since plutonium is a highly toxic material, even very small amounts could create a danger to human health and have a deleterious effect on the environment. The toxic character of plutonium will necessitate its being handled very carefully during all stages of the breeder fuel cycle. Many opponents of the breeder feel that there is no assurance yet that any protective system could be adequate.

3. Proliferation. The present plans for breeder reactors call for fast breeders that use either U235 or plutonium as a source of energy and U238 as a raw material which, in the reactor, is changed to plutonium (hence breeding plutonium). The fuel rods then need to be reprocessed to isolate the plutonium, which is fed back into the reactor to fission and generate both energy and more plutonium.

Therefore, a system of fast breeders that makes more fuel than it uses requires the processing and storage and use of the excess plutonium for new breeders and LWRs. Consequently, large inventories of plutonium have to be maintained, processed, and transported.

These large amounts of plutonium in commercial settings create a situation that could encourage proliferation, because of the existence of many shipments of weapons-usable material. It would not be necessary to have all of the plutonium actually placed in bombs; but, rather, it is the creation of the opportunity for diversion of small amounts of materials at a time that causes concern. This issue is discussed more completely in Chapter IV.

4. Safety. In the past several years, the issue of the safety of present commercial reactors has been explored. Although the "Rasmussen" study sponsored by NRC concluded "that the risks to the

public from potential accidents in nuclear power plants are comparatively small," 3/ safety remains as an issue. These concerns are most directly related to the effects of radioactive emissions on the environment, as well as to the possiblity of serious accidents at a reactor site. These same issues are germane to the implementation of a breeder industry.

The CRBR will demonstrate the levels of emissions that can be expected during operation. These levels can then be evaluated and should add information that will be useful in making decisions on the safety of the breeder, since the systems for emitting and holding wastes implemented for CRBR can be very similar to those implemented for commercial breeders.

Accidents that suddenly could release substantial and dangerous quantities of radioactive material are of a somewhat different nature. The working coolant in a breeder is liquid sodium, rather than water, which is used in an LWR. The temperature is much higher in a breeder core than in an LWR, and the configuration and design of fuel elements are quite different. As a result of these changes, the nature of the accidents of principal concern and of the emergency system for coping with such possibilities differs in many respects from those involving an LWR. For example, although unlikely, it is possible for the fuel in a breeder to achieve a critical configuration leading to a runaway situation. While not an atomic bomb, and while it can be contained within the structure, it could release quite a large amount of energy. This sort of accident could not occur in an LWR. Consequently, engineered safeguards may be more costly than those for an LWR. While breeder safety experts do not believe that these problems are insoluble, the issue is debatable and of importance.

5. Reprocessing. The breeder reactor requires, as an essential element of its fuel cycle, reprocessing of spent fuel to reuse the plutonium produced during operation. Without reprocessing there can be no continued operation of breeders. Although present plans for the liquid metal fast breeder reactor require the separation of plutonium from uranium, it is possible that alternative breeders could utilize cycles in which plutonium separation could be minimized. The concerns with reprocessing are discussed in Chapter III.

3/ Reactor Safety Study, "An Assessment of Accident Risks in United States Commercial Nuclear Power Plants," Wash 1400, United States Nuclear Regulatory Commission, October 1975, p. 1.

ALTERNATIVE APPROACHES TO BREEDER DEVELOPMENT

The possible approaches for dealing with the new breeder technology can be delineated as follows: (1) sequential development, (2) parallel development, and (3) prohibition. The Carter Administration is delaying the commercial breeder program and has reduced its request for the liquid metal fast breeder reactor program for fiscal year 1978 to roughly $200 million less than the Ford request.

1. Sequential Development. This approach would require a series of sequential steps.

   (a) Construction and operation of the CRBR

   (b) Construction of the next near-commercial breeder (the prototype large breeder reactor [PLBR])

   (c) Construction and operation of the first commercial breeder reactor (CBR).

The justification for this sort of approach is that information on one stage should be available before final commitment is made for the next. Thus, construction for subsequent stages would not begin until the previous stage had been in operation for one full year. If this approach were followed, the CRBR would begin operating in 1983, the PLBR in 1991, and the CBR--if all goes well--in 1999.

2. Parallel Development. This approach would prepare designs and begin construction for one demonstration stage before the previous stage had begun operation. This kind of approach could be justified under the assumptions that the need for the technology is pressing, that the major work accomplished in a demonstration is in the design, that failures are not likely to occur, that relatively little information is going to be obtained in the demonstration other than hands-on experience, and that the industrial infrastructure needs to be built up and maintained. This is essentially the approach that had been proposed by ERDA. It would lead to the CRBR beginning operation in 1983, the PLBR in 1988, and the CBR in 1993.

3. Prohibition. This approach would simply stop the development of the breeder reactor, either before CRBR or when CRBR is completed, because of the enormous uncertainties associated with cost, safety, and proliferation.

The Congress has already authorized the money for the completion of the CRBR, but the Carter Administration has suggested the reviewing of that situation.

The choice among these approaches will affect the extent and timing of commercial utilization of the breeder and, hence, the extent and timing of the need for reprocessing facilities. These choices will also depend on decisions regarding proliferation.

CHAPTER III. REPROCESSING AND ITS IMPLICATIONS

This chapter will explore the three major areas of discussion specific to reprocessing:

1. The need for reprocessing in the context of the expanded use of nuclear power, finite uranium sources, problems with disposal of waste, development of new technologies, and the implications of dealing with the reprocessing issue with other nations.

2. Concerns expressed about reprocessing such as the ratio of costs to benefits, and the possibility that other alternatives could achieve the same end.

3. Possible courses of action for the Congress to consider in dealing with the reprocessing issue.

NEED

Expanded Use of Nuclear Power

As discussed in Chapter II, projections of the imminent depletion of conventional fuel sources such as oil and gas have inspired the search for new energy sources. A way of reprocessing spent nuclear fuel was sought for the same reasons. Projections of the growth of nuclear power as a primary energy source coupled with the realization that just so much uranium was available to produce nuclear power made the ability to reprocess (and hence use nuclear fuel again) appear to be a necessity. However, those projections have changed recently, altering that urgency somewhat.

1. Growth in Nuclear Power. At present, there are 62 commercial nuclear plants with a total capacity of about 45,000 megawatts (MW) in operation in the United States. Several years ago, it was anticipated that by 1985, at least 225,000 MW of electric generating capacity would be nuclear powered. Recent estimates

greatly reduce that estimate. The 1977 draft of National Energy Outlook estimates that only about 126,000 MW would be in operation by 1985, and only 220,000 MW by 1990. 1/

While some estimates still show larger capacity in 1985 than does FEA, it is more likely that unless the political and licensing climate improve, continuing uncertainty about the future of nuclear power in general will push future capacity below rather than above the FEA estimates. 2/ In particular, since it is now taking about 10 years for a nuclear plant to become operational, it is possible that only those already with construction permits can be operating by 1985. This would suggest an upper limit of about 121,000 MW by 1985 if no delays were to occur.

Each 1,000 MW reactor produces about 30 tons of spent fuel each year. That spent fuel is radioactive and contains energy, but not in an immediately usable form. Ultimately, something must be done with the spent fuel, which is now normally stored in pools at the reactor site. Until recently, it has been assumed permanent storage of this spent fuel was not a pressing issue since this spent fuel would eventually be reprocessed.

Since a typical commercial reprocessing system--such as the Allied-General Nuclear Services (AGNS) plant being built at Barnwell, South Carolina--is designed to process approximately 1,500 tons of spent fuel each year, such a plant could service about 50 power plants of 1,000 MW each. Given the number of light water reactors (LWRs) operative now and scheduled to be operative in 1990, spent fuel would be available to feed two to three reprocessing plants in 1985 and three to five by 1990.

Reprocessing for LWRs would be economical only if the costs associated with reprocessing did not exceed the costs of obtaining nuclear fuel by other means, such as mining new ore. Thus the economics of reprocessing are central to estimates of demand. If

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1/ National Energy Outlook, Table III-22.

2/ For example, a recent analysis done by ERDA indicates for a base case about 180,000 MW and 290,000 MW in 1985 and 1990, respectively, and a low growth case of about 150,000 and 250,000. See Benefit Analysis of Reprocessing and Recycling Light Water Reactor Fuel, Energy Research and Development Administration, 76/121 December 1976.

the economics of reprocessing were marginal, some utilities with contracts to purchase higher priced uranium would find it profitable to reprocess, but others would find it more profitable to use new uranium, and the demand for reprocessing would be somewhat less than that implied by the rate of growth of nuclear power. Presumably, the cost of uranium in these calculations would rise to reflect its increasing scarcity. The economics of reprocessing have been the subject of debate, and are treated in the next section of this chapter.

Needless to say, changes in the rate of growth of nuclear power would, of course, change the need for reprocessing.

Finally, there is the question of timing. Spent fuel need not be reprocessed immediately upon removal from the core of a nuclear reactor. Indeed, most fuel that has been removed from cores of operating reactors remains in temporary storage pools at the reactor site. Since the energy value of spent fuel does not degrade during temporary storage, it can be subsequently sent to reprocessing facilities or to alternative processes that may be proposed.

Even if the decision were made to move ahead with commercial operation of reprocessing plants, long lead times for construction and testing would mean that massive inventories of spent fuel and the high costs associated with the storage would be a reality for some time. In fact, the temporary storage plants provided for some domestic nuclear power facilities will soon be filled to capacity and other provisions will have to be made.

The Nuclear Regulatory Commission (NRC) estimates that the costs of five additional years of storage capacity might be about $2 million for a typical 1,000 MW reactor, although different designs could cost more.

Thus, the need for reprocessing is a somewhat flexible concept depending on present uranium sources, economics, and the storage of spent fuel. But it is clear that two to three plants operable by 1985 and three to five by 1990 are the maximum number feasible, if reprocessing is determined to be the best way to extend uranium sources.

2. <u>Depletion of Uranium</u>. A second important factor in determining the need for reprocessing is the limited nature of uranium resources. It is clear that the amount of uranium in the earth is limited. Thus, the amount of the fissionable isotope U235 (which makes up 0.7 percent of natural uranium) is also limited. The

United States is fortunate to be one of the major sources of uranium in the world (with 35 percent of reasonably assured commercial resources). The United States has 640,000 tons of estimated reserves of well-defined deposits of known extent plus 140,000 tons of by-products from other mining, making 780,000 tons of yellowcake (U_3O_8) in a known reserve category. There are an additional 1.1 million tons of probable resources which are estimated to exist. These probable resources and known reserves, amounting to 1.8 million tons, are the most reliable estimates of the uranium resources available domestically. An additional 1.8 million tons of resources may exist in possible and speculative categories, making a total of 3.7 million tons. As the price of uranium goes up, exploitation of the less concentrated reserves may become economical.

According to FEA, by 1985 the cumulative requirement by the nuclear industry will be 0.7 million tons, and by 1990 1.1 million tons. While the cumulative 1990 requirements fall well within the estimated resources available, it is not clear that the lifetime requirements of the industry will be satisfied. A typical 1,000 MW reactor will use about 6,000 tons in its life of about 30 years. Thus, the 1.8 million tons will fuel over 300,000 MW for a full lifetime. If the possible and speculative categories prove accurate, over 600,000 MW could be fueled, thus carrying the nuclear industry well into the next century. In addition, imports and any new discoveries would extend the life of the industry further.

Reprocessing of nuclear fuel will act to extend the uranium resources either in terms of the lifetime of the nuclear industry or in number of plants fueled. When placed in the reactor initially, a typical fuel rod contains about 3.2 percent of the fissionable isotope U235. When removed, a spent fuel rod contains about 0.8 percent U235 and perhaps 0.7 percent of fissionable plutonium. Thus, nearly half as much potential energy is in the fuel when it is removed as when it was inserted in a reactor.

If the recycled uranium and plutonium can be used instead of an equivalent amount of natural uranium, then the recycled uranium can reduce the natural uranium requirements by about 10 percent and the recycled plutonium can reduce the requirements by about 20 percent over a reactor's lifetime. This would mean that the same uranium resource base above could provide fuel for the lifetime of about 440 power plants rather than about 300. A further conservation of present sources of uranium would result from changing the percent of U235 in the uranium enrichment wastes from 0.25 percent to 0.2 percent. This action would extend present resources by about 10 percent.

However, there is an uncertainty about the effect of the buildup of U236, which is an isotope of uranium also generated in the reactor. This isotope will reduce the usefulness of the recycled uranium; thus the total reduction of uranium requirements due to recycling might be from 20 to 30 percent. 3/

3. Breeder. The breeder poses an issue for reprocessing since, if the breeder is to be developed, reprocessing will be an essential link in its fuel cycle, unlike that of the LWR. Thus without reprocessing, there can be no sustained breeder operation. While a firm prohibition of reprocessing would abort commercial introduction of the present breeder design, it would not close off development of other types of breeder reactors; initial and subsequent fuel loadings for a breeder demonstration do not require commercial facilities, since other sources of plutonium and facilities are available.

4. Foreign Growth. Other nations face the same kinds of issues regarding the growth of nuclear power and projections of future needs that the United States does. And, as with the United States, early estimates of the extent of foreign nuclear capacity have been revised downward. In 1975, ERDA projected that foreign nuclear capacity would reach 385,000 MW by 1985 and 780,000 by 1990 The most recent projections by FEA have reduced this expectation substantially to 126,000 MW in 1985, and 323,000 MW in 1990. The importance of the forecasts is not in their accuracy, but rather that a re-evaluation of the relative benefits of nuclear power has resulted in lower forecasts.

The above revised estimates on foreign nuclear capacity would indicate a maximum need for approximately two large reprocessing plants in 1985 and six by 1990 outside of the United States. Existing plans for constructing foreign reprocessing facilities call for at least two large plants by 1985. Plans are being studied to add more capacity in the late 1980s. A list of reprocessing plants presently in operation, and those that will be operational by 1990, is shown in Table 1.

It is important to note that there are countries aside from the United States, Japan, and those in Europe that are developing facilities for generating nuclear power. Together, those other

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3/ Nuclear Fuel Cycle Closure Alternatives, Allied-General Nuclear Services, April 1976, pp. 8-11.

TABLE 1.   NUCLEAR FUEL REPROCESSING PLANTS

Country	Type of Fuel	Start of Operation	Feed Capacity (Ton U/yr)	Pu Product/ year at Capacity (kg)	Comment
Argentina		1968	200 kg/yr	--	
Belgium (Mol)	Metal/LWR		80	516 (1077)b/	167 tons U have been processed
Eurochemic	MTR a/	1966	40	--	Eurochemic is not expected to process any more fuel
France					
Marcoule	Metal	1958	500	2,150	French military and civilian reactors
La Hague	LWR	1975/78	400	2,580	Will increase production gradually until 1978
Germany					
WAK, Karlsruhe	LWR	Sept 1971	36	232 (206)	32 tons U have been processed
KEWA	LWR	1983/84	1400	9,030	
India					
Trombay	HWR	1967	100	230	
Tarapur	HWR&LWR		150	968	Assume all LWR fuel
Italy	MTR	1970	5	--	
Eurex 1	LWR	1975	10	64	
Japan					
Tokai-Mura	LWR & Nat U	1976	200	1,290	Assume all LWR fuel
Spain					
Moncla	MTR		100 kg/yr	--	
Taiwan					Small pilot plant
United Kingdom					
Windscale 1	Metal Nat U	1964	2,500	10,750	
Windscale 2	LWR	1970 (76)	400	2,580 (645)	Shut down 1973 after processing 100 tons; will restart 1976 at 200 tons/yr and 1977 400 tons/yr
		1982	400	2,580	
Dounreay	Highly Enriched U and Pu		1	--	

a/ MTR – Materials Test Reactor uranium aluminium alloy fuel. Usually enriched to 20% or higher in 235U, normally produces very little Pu.

b/ Assumes all 167 tons of uranium that have been processed were LWR fuel.

SOURCE: Albert Wohlstetter, et al, Moving Toward Life in a Nuclear Armed Crowd, Pan Heuristics, December 1965; pg. 265-266.

countries expect a 25,000 MW capacity by 1985. However, many of these facilities are as yet only planned, and expectations about growth and economics could alter these plans. But it is probably these countries, just beginning to focus attention on nuclear power or in the process of greatly expanding their nuclear potential, that could pose the most serious threat for proliferation of nuclear weapons.

For the most part, these countries do not have the existing technology but rather must import all elements of the nuclear fuel cycle. Export agreements with two such countries, Pakistan and Brazil, have caused much international concern.

CONCERNS

Two principal issues affecting the acceptability of reprocessing are (1) the relative costs and economic benefits, and (2) the possible advantages of technical alternatives to existing reprocessing methods.

1. Costs and Benefits. Considerable controversy surrounds the economic justification for reprocessing. The issue is significant because if reprocessing were ultimately deemed uneconomical, the pressure to initiate reprocessing would be greatly reduced both domestically and abroad. On the other hand, if reprocessing were determined to be economically feasible, the pressure to build and operate facilities would increase.

The debate over future benefits results from two major uncertainties: (1) How much will a reprocessing facility cost? (2) How much will uranium cost? Subsidiary questions include the costs of fabrication of mixed oxide fuel, the penalty that should be assigned to the presence of the contaminating isotope U236, the price of uranium enrichment, and the cost of waste storage.

In general, those who favor reprocessing tend to foresee rapid escalation in real terms of the price of yellowcake (U_3O_8) perhaps from $35 per pound in 1976 to $50 per pound in 1985, but do not see capital costs for a 1,500-ton-per-year reprocessing facility increasing substantially (from $700 million to $900 million). Those who oppose reprocessing tend to see yellowcake prices remaining fairly steady and capital costs of a reprocessing facility rising rapidly.

In the analysis presented in the Appendix, the costs for various stages of the nuclear fuel cycle will generally agree with those in GESMO 4/ except that both capital costs of reprocessing facilities and uranium prices are allowed to vary. The benefits (or costs) for one year are calculated for a hypothetical 1,500 tons per year facility assuming that it is able to operate at full capacity. In addition, 20 years of benefits will be calculated discounted at 10 percent.

The economic benefit of reprocessing is the net cost saving to the electric utilities, if any, of reprocessing spent fuel as opposed to not reprocessing spent fuel. Stated alternatively, it is the difference between the estimated fuel costs (over the entire natural fuel cycle) for reactors using reprocessed fuel as opposed to using only natural uranium. Depending on the assumptions concerning uranium and reprocessing prices, this difference ranges from a net benefit of $500 million per year per reprocessing plant to a net cost of $500 million per year. Viewed in terms of a typical 1,000 MW generating plant, the different assumptions concerning uranium and reprocessing prices yield annual savings to electric utilities ranging from a gain of $10 million per generating plant to a loss of $10 million per plant.

Estimated 1977 uranium prices fall in a range from about $7 per pound to $30 per pound. Future estimates have even wider ranges--from $12 per pound to $56 per pound. In addition, estimates for the cost of building a reprocessing facility range from $600 million for the Barnwell facility to $1.2 billion estimated by ERDA. This is roughly comparable to reprocessing charges ranging from $150 per kilogram of spent fuel to $350 per kilogram. Additional waste storage costs resulting from spent fuel could make the reprocessing costs as high as $500 per kilogram. Thus the benefits are calculated using reprocessing costs ranging from $150 per kilogram to $500 per kilogram, and uranium costs ranging from $10 per pound to $50 per pound.

Figure 1 shows the calculated net benefits or costs of reprocessing uranium and plutonium using a range of prices for mined uranium (U O) compared with a range of prices for reprocessing services (represented in the figure by the diagonal lines). For example, if reprocessing costs $150 per kilogram of spent fuel and

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4/ Final Generic Environmental Statement on the Use of Recycled Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors, U.S. Nuclear Regulatory Commission, August 1976.

natural uranium is selling at $10 per pound, a yearly net benefit of about $50 million will be derived from reprocessing. However, if it turns out that reprocessing costs $300 per kilogram of spent fuel and uranium costs $10 per pound, a net cost of about $175 million will result from reprocessing.

The figure also shows estimates of net costs or benefits derived from reprocesing spent fuel based on assumptions used in several pertinent studies on the subject of reprocessing.

One of the ways to analyze a set of yearly benefits such as those possible from reprocessing is to compare the present value of the stream of future benefits with the present value of the stream of future costs. If the present value of the benefits exceeds the present value of the costs, there is a net benefit. If the present value of the costs exceeds the present value of the benefits, there is a net cost. In calculating the net benefits (or costs), an annual discount rate of 10 percent per year (the same rate used by the Nuclear Regulatory Commission) was assumed. Also, it was assumed that whatever the initial reprocessing price, it remained constant over the 20-year life of the facility. In contrast, whatever initial uranium price is chosen, it is assumed to increase by 3 percent per year. Table 2 illustrates this for several choices of reprocessing and uranium prices.

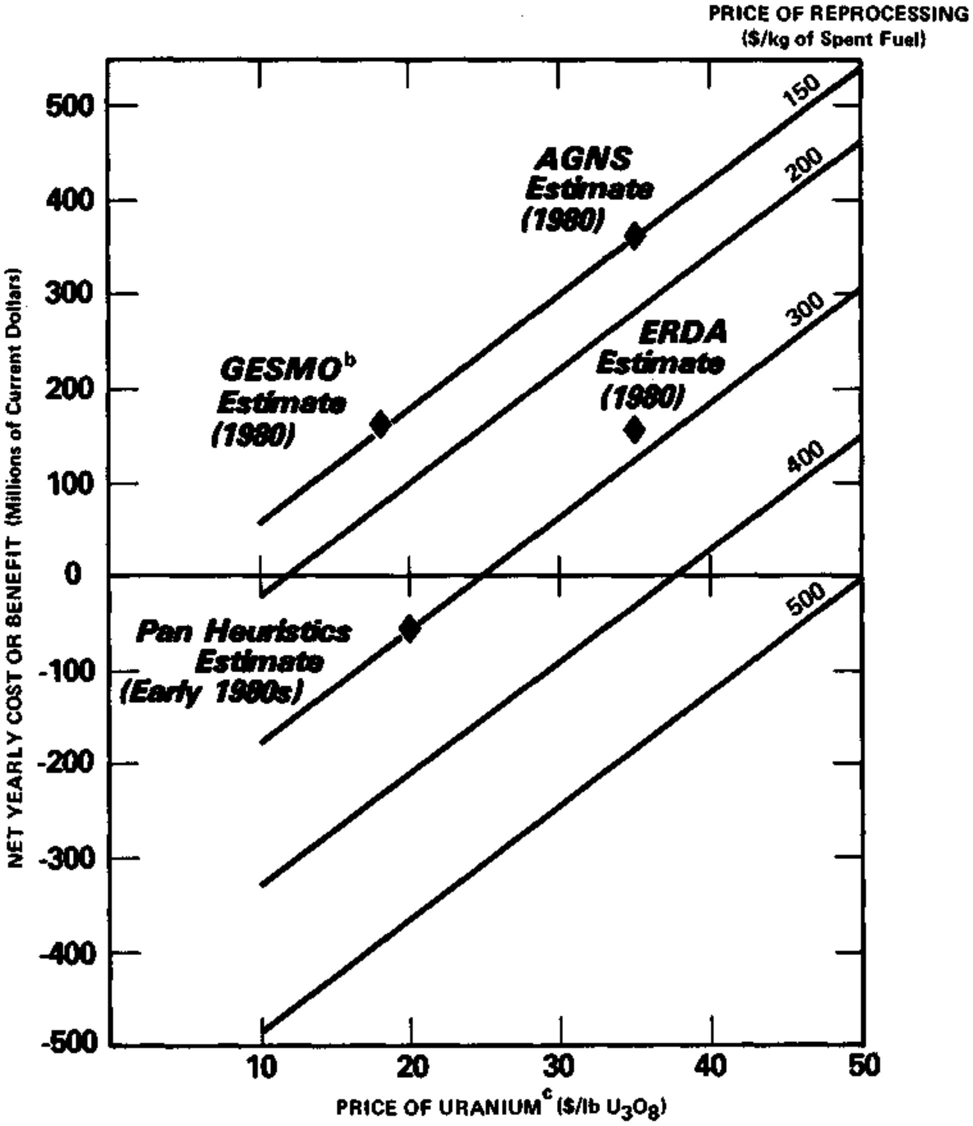
If the reprocessing price is kept low (at $150 per kilogram), there is a net benefit over 20 years as long as uranium prices stay at their presently estimated levels. If the reprocessing prices are higher in real terms ($300 to $400 per kilogram), then a positive benefit depends on uranium prices also rising in real terms to $20 to $30 per pound.

If an average yearly benefit at a reprocessing facility were about $200 million (uranium prices $25 to $35 per pound and reprocessing prices in the range of $200 to $300 per kilogram), it would amount to about a $4 million yearly saving for each 1,000 MW generating plant. Assuming a 65 percent capacity factor, this is about 0.7 mills/kwh which compared with an average price of electricity of about 27 mills/kwh is about 2.5 percent. Such a benefit would be significant for an individual power plant but somewhat less in terms of costs to consumers.

2. Technical Alternatives. Another concern that has been raised is whether there may be better ways of recovering the energy that remains in spent fuel than the existing Purex process. The Purex process is well understood; information on alternatives is sketchy.

Figure 1

Net Yearly Benefit of Reprocessing Resulting From Different Uranium and Reprocessing Prices[a]



[a] Based on a 1500 metric ton/year facility.

[b] The ◆ denotes estimated prices for uranium and reprocessing used in these various studies. These are detailed in Appendix A.

[c] For comparison, note that the range in prices for 1977 was estimated to be $7-$30 per pound with an average of about $12 per pound; the estimated range for 1980 is from $12 to $56.

TABLE 2. NET PRESENT VALUE OF REPROCESSING FOR 20 YEARS, MILLIONS OF DOLLARS

	Reprocessing Price			
Uranium Price at Beginning	$150 per kg	$300 per kg	$400 per kg	$500 per kg
$15 per lb.	1,400	-690	-2,080	-3,490
$25 per lb.	2,730	640	-770	-2,180
$35 per lb.	4,050	1,960	550	-860
$50 per lb.	6,030	3,940	2,530	1,120

Purex. 4/ The Purex process was developed after World War II to recover plutonium for use in weapons. The process yields highly radioactive waste and useful products (uranium and plutonium). In addition, the Purex process includes a step separating the plutonium and uranium. Broadly speaking the process involves dissolving the spent fuel rods in a series of acids and organic solvents and then using the chemical activity of the various materials to enforce the separation. The result is a highly radioactive liquid waste and stream of plutonium nitrate and uranium nitrate. The present process includes subsequent conversion of the uranium nitrate to uranium hexafluoride which is fed to enrichment plants and conversion of plutonium nitrate to plutonium oxide which is fed back through the fabrication process. This results in relatively pure plutonium and uranium material which may be recycled. 5/

4/ The Purex process is described in detail in a diagram at the end of this paper.

5/ A complete description of the entire nuclear fuel cycle and the reentry points in it for reprocessed uranium and plutonium appears at the end of this paper.

Co-processing. Co-processing is a term that has been applied to any of the several alternatives to the Purex process which would not separate the plutonium and uranium completely, but rather would result in a final product that would be a mixture of all of the plutonium and as much uranium as is appropriate for reuse in mixed oxide fuel. The product could also be altered by leaving in some of the highly radioactive wastes.

The potential advantage to this system is that at no point would there be a flow of relatively pure plutonium. This would presumably reduce the threat of diversion (although subsequent chemical separation could purify the plutonium). The addition of radioactive waste would futher reduce this threat.

Problems with such a process include the need to adjust the reprocessing facility in a way that has not been done commercially, and to determine the required characteristics of the mixed oxide fuel fabrication facility, which has been designed on the basis of a pure plutonium fuel. If radioactive waste is left in the plutonium stream, the difficulty of final handling would be increased. All of these problems presumably have solutions; however, to find the solutions will require substantial new research and development--and hence time.

Tandem Cycle. The tandem cycle alternative would provide for the use of spent fuel from LWRs in nuclear reactors that presently use natural uranium (designed in Canada and known as CANDU reactors). The basis for the idea is that the U235 concentration in spent fuel is slightly above that in natural uranium, and thus might be substituted for it. The advantage is that plutonium would not be separated, thus, the risk of proliferation would be lessened. Presumably, much of the fuel value would be recovered--perhaps as much as in the Purex process.

There are several disadvantages: Tandem cycling has not been done and its feasibility is unclear. The dimensions of the fuel rods in the two kinds of reactors at present are incompatible; thus, some reworking of the spent fuel--perhaps even a form of reprocessing--or a redesign of the reactors themselves would be required. One CANDU reactor would be required to consume the spent fuel from roughly four LWRs. At present there are very few CANDU reactors in existence. U.S. companies do not manufacture CANDU reactors, and none has been licensed here. Much of the nuclear industry feels the tandem cycle is not feasible on either technical or economic grounds.

Uranium Only. A further possibility is reprocessing to produce only uranium. The plutonium would be kept with the radioactive waste or would be stored alone; but, in either case, would not be transported or used. Hence, the threat of plutonium diversion would be considerably reduced. A major disadvantage to this approach is that most of the economic benefit (perhaps over 80 percent) results from the plutonium reuse and would be forgone, making the entire reprocessing capability much less attractive from the point of view of costs. In fact, without plutonium, all economic benefits might be lost. In addition, substantial safeguards would be required for the stored plutonium.

These problems, like those associated with co-processing, presumably could be solved. But it is not known if these solutions could be cost effective. However, very little work has been done to investigate this alternative.

ALTERNATIVE APPROACHES TO REPROCESSING

Several courses of action could be followed in response to the reprocessing dilemma. These are basically: (1) no reprocessing, (2) reprocessing with plutonium recycling permitted, and (3) reprocessing without plutonium recycling. The issue of recycling of plutonium is chosen as a partial determinant of the various approaches because of its central role in the issue of proliferation. The possibility of alternatives to the Purex process is included in each of the approaches allowing reprocessing, but only if delay is chosen because only then can an evaluation of alternatives take place.

1. No Reprocessing or Indefinite Delay. This approach would result from a determination that the benefits from reprocessing were either negative or not large enough to outweigh the risks from proliferation. If such an approach were chosen, it might be accompanied by efforts to increase energy production from existing uranium resources. Such efforts might include investigating the tandem cycle (which would not require reprocessing), or investigating ways of increasing the yield of enriched uranium from each kilogram of natural uranium. This approach is favored by President Carter.

2. Reprocessing with Recycling of Plutonium. Within this general category reprocessing could be begun quickly or delayed.

A. Immediate: This approach would result from a determination that:

   (1) reprocessing would provide large and necessary benefits both in terms of restoring depleted resources and because it was found to be cost effective;

   (2) breeder reactor development is essential and the timing is such that reprocessing must begin now;

   (3) reprocessing is the only reliable method of spent fuel treatment, and,

   (4) appropriate safeguards can be designed.

Generally, such an approach would probably require federal support of commercial facilities, such as the one at Barnwell, South Carolina, to assure that reprocessing was able to begin quickly. In addition, substantial research on safeguards would provide additional assurance against proliferation.

B. Delay: This strategy would result from a determination that:

   (1) the slowed growth in nuclear power and uncertainties concerning the future of the breeder will not require reprocessing immediately; and

   (2) alternatives to the Purex process should be investigated in advance of a final decision on reprocessing.

If such an approach were deemed appropriate, the rationale for it would probably be based on the assumption that not enough is presently known about the effects of reprocessing. Delay would buy time to explore alternatives and to try to determine if reprocessing is worth the risks involved. As in the case for immediate reprocessing, considerable research on safeguards and support for the IAEA would undoubtedly be necessary.

3. Reprocessing Permitted with No Recycling of Plutonium. This approach would result from a determination that, the risk of proliferation is too great to permit recycling of plutonium in any form but that reprocessing to recover the energy values remaining in uranium would be both acceptable and desirable. Again, there are options with respect to timing.

A. Immediate: This approach would be reasonable only if the benefits from recycling uranium alone were so great that they could not be forgone; such a situation would require both extremely high uranium prices and extremely low reprocessing costs. In addition, the need to conserve existing uranium resources would have to be perceived as great.

Under those circumstances a demonstration effort would be in order since no such facility exists and the present AGNS (Barnwell) plant would have to be modified. Somewhat less work on safeguards would be necessary since separated plutonium would not be available off the reprocessing site.

B. Delay: This approach would be appropriate if the same conditions prevailed as above except that they would be delayed for some time. In addition, time could provide some alternative processes such as the tandem cycle which does not involve the separation of plutonium during reprocessing.

Since there are fewer options to investigate if the delayed approach were followed, some what less research and development would be necessary.

CHAPTER IV. PROLIFERATION AND ITS IMPLICATIONS

In deciding upon domestic reprocessing policies, the Congress may wish to consider the prospective international consequences of sponsoring reprocessing plants in the United States. The relationships among development of the U.S. nuclear industry, of nuclear industries of other countries, and nuclear proliferation have changed radically over the past 10 years. It was originally assumed that the United States would simultaneously expand its own nuclear industry, provide nuclear energy facilities to developing countries, and prevent the spread of nuclear weapons and explosives. These three objectives were believed to be mutually supportive. The U.S. Atoms-for-Peace policy was based on the presumption that if the United States shared civilian nuclear resources with developing countries, these countries would be willing to forgo nuclear military resources. This presumption was the basis for the 1968 Nonproliferation Treaty (NPT) in which the United States and other nations with nuclear capabilities agreed to provide nuclear power technology to those countries that pledged not to acquire nuclear weapons.

While this agreement has been successful as a means of increasing developing countries' access to nuclear power, it is questionable whether it has been successful as a means of restraining nuclear proliferation. Since the treaty was signed, the distinction between nuclear power and nuclear explosives--the key to its success--has been eroded by advances in nuclear energy technology. A country that has acquired a nuclear power facility has also acquired much of the information, laboratory facilities and access to nuclear materials necessary to make crude nuclear explosives. Hence, the effect of this agreement may have been the reverse of its initial objectives: The spread of nuclear power to developing countries has clearly increased, rather than decreased, the prospects for nuclear proliferation.

As new nuclear power technologies, such as reprocessing, become available, they further blur the distinction between nuclear power and nuclear explosives capacities. The argument is now advanced that these technologies should be restricted, since reprocessing would increase the amounts of plutonium held in inventories or reactor cores, and which must be transported to and from power plants and reprocessing facilities.

It should be clear that the initiatives available for restricting domestic nuclear development, or international commercial reprocessing involving either diffusion of facilities or of plutonium products, cannot affect clandestine military efforts by a nation determined to obtain nuclear weapons.

Even without reprocessing, nuclear technology and nuclear materials are now too widely available to be withheld from developing countries intent upon acquiring nuclear explosives. The United States, moreover, is not the only source of reprocessing facilities for countries developing nuclear power. If the United States decides not to develop reprocessing facilities itself, other nations with nuclear technologies may still make reprocessing available to those countries (including developing nations) who want to buy this technology. While a decision to proceed with reprocessing in the United States would seem to increase the prospects for proliferation, there is no assurance that a decision against U.S. reprocessing will substantially slow the pace of nuclear proliferation, without considerable diplomatic initiatives as well.

Nonetheless, it is possible that a concerted international effort to avoid reprocessing could prolong the period in which some nations do not/cannot attempt programs to construct nuclear weapons, therefore delaying further extensive nuclear proliferation for a time.

This chapter will discuss the threats implied by proliferation, technical considerations, and alternative approaches for attempting to control proliferation.

THREATS

The major threats associated with proliferation of nuclear weapons can be divided into four specific categories:

1. Diversion of nuclear materials by nations not now in possession of nuclear weapons,
2. Theft of nuclear material by terrorist groups,
3. Threats to civil liberties posed by measures taken to prevent proliferation, and
4. The reactions of certain countries to the possibility that adjacent countries might develop weapons.

1. Diversion. Essentially diversion is the act of taking weapons-usable plutonium and placing it in a weapon. One of the responsibilities of the International Atomic Energy Agency (IAEA) is to monitor nations with the capabilities to divert plutonium and to sound an alarm if it detects diversion taking place.

Various countries such as Germany, Canada, and Japan are now in possession of quite sophisticated nuclear technology and thus have the capability to create nuclear weapons in a relatively short period of time and at little cost, if they choose to do so. So far, they have not.

However, the threat of proliferation involves a large group of countries that does not have advanced nuclear capabilities.

In general, development of weapons depends on access to reactors and the expertise to build reprocessing or enrichment facilities. Building these facilities could take several years at costs of from $50 million to $200 million. If the large group of countries mentioned above gained access to this sophisticated technology, the situation regarding the possibilities for weapons development would change greatly.

As stated in the previous chapters, the key word here is plutonium. Spent fuel from nuclear reactors contains plutonium; the present method of reprocessing spent fuel separates the plutonium from the uranium and thus makes it available for weapons. Therefore, something of a dilemma exists: If nations, not having nuclear capabilities, are encouraged to buy them for peaceful purposes; then these nations will also have been given the opportunity to create weapons.

Based on present estimates, by 1986 nearly 40 nations will have on hand, in spent fuel, enough plutonium for a few (three to six) bombs each, and of these nations, as many as 35 would each have enough plutonium for a large number (over 30) of weapons.1/ However, the plutonium cannot be used unless it is more concentrated, which can take place through reprocessing. By 1985, five of the countries with very large inventories of plutonium plan to have reprocessing facilities, while an additional eight with smaller inventories plan

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1/ Wohlstetter, et al., Moving Toward Life in a Nuclear-Armed Crowd? Pan Heuristics, Los Angeles, California, April 1976.

to reprocess. At present, at least six nonweapons nations have reprocessing facilities, some at laboratory scale. Two of these nations--Spain and Argentina--are not signatories of the Nonproliferation Treaty. Thus, the potential for indigenous production and separation of plutonium is present.

A further threat involves the possibility that nations with reactors, but without reprocessing facilities, could send their spent fuel elsewhere for reprocessing and subsequent return. If this practice becomes widespread, as many as 25 nations could have extremely large quantities of plutonium, in the form of mixed plutonium and uranium oxide fuel, on hand.

It is a substantial step from an inventory of plutonium for use in a reactor to weapons capability. But as this worldwide inventory grows, the number of nations with a substantial inventory grows; and the possibility increases that one or several of these nations might decide to undertake a program for developing weapons technology up to but not including assembling and testing a weapon--which is not diversion. Standards set by IAEA really cannot address this kind of program. Only when an actual diversion of materials takes place, can the IAEA detect such a program, if its monitoring is sufficiently accurate.

The real importance of the new knowledge and advanced nuclear capabilities of these nations will depend on several factors and the perceived effect that such development will have on international stability. It is not the purpose of this paper to discuss in depth the effects of proliferation on the international scene. However, the threat will result from the growth in the use of nuclear power and from the increasing sophistication of nations in handling such technologies as reprocessing and enrichment. It is clear that without widespread use of reprocessing, and of mixed oxide (plutonium) fuel, the opportunity for obtaining weapons-usable material within the constraints of the existing Nonproliferation Treaty system will be reduced.

Nonetheless, nuclear weapons can be constructed and tested--and the worldwide balance of power changed--by a few actions and facilities; the facilities need not be widespread nor commercial. India's test of a device that was produced using only a heavy water reactor and a small pilot reprocessing plant is a perfect illustration.

Within this context, the leverage of U.S. domestic policy toward both proliferation and reprocessing must be carefully assessed. Diplomacy and systems of alliances may have as much impact on ultimate proliferation as will the widespread availability of commercial nuclear technologies. There are two contrasting views on the effects of U.S. policy on proliferation and on reprocessing. One holds that the economic and resource incentives to reuse uranium and plutonium are so great that nations will be drawn to the use of reprocessing whether or not the United States approves such use. The other argues that a decision by the United States on reprocessing will be so effective as to convince other nations to follow the same path (whatever it is). What appears most plausible is that a U.S. policy can influence but not determine the decisions of other nations.

2. Theft. A concern only recently articulated has been the potential threat of theft of weapons-usable material by terrorist groups.

Nuclear material is most vulnerable to theft when it is relatively low in radioactivity (safe to handle) and highest in concentration of weapons-usable material. It would be low in radioactivity as a fuel rod prior to use in a reactor and also after reprocessing, before reuse. It would be relatively high in concentration of weapons-usable material after reprocessing, if plutonium is separated for reuse. Although spent fuel is also vulnerable to theft during shipment, it is highly radioactive and, unless it comes from a breeder, low in concentrations of weapons-usable material.

Using a mixture of plutonium and uranium, rather than plutonium alone, provides little protection, since it is relatively easy, though risky, to separate plutonium from uranium and only small quantities (about 10 to 15 pounds of plutonium) are needed to manufacture an atom bomb. Other nuclear fuel cycles not using plutonium could potentially reduce the threat (e.g., in the U235-thorium cycle, not in widespread operation). The weapons-usable material can be diluted with natural uranium thus requiring enrichment technology for separation--a more difficult procedure to arrange.

While building a nuclear device is not easy, it would not be outside the technical competence of a dedicated group with some sophistication, particularly if the group members were not concerned with protecting their own lives. 2/ In any event, a threat backed by possession of plutonium would have to be taken seriously.

3. Civil Liberties. It has been suggested that the measures taken to counter the proliferation threat will pose a grave danger to civil liberties. As the opportunities for diversion grow, the concern about avoiding both theft and diversion may cause an increase in safeguards. Such safeguards could require large increases in police surveillance, and could interfere with the freedom of citizens to apply for and accept jobs in public utilities, for example. These safeguards could, over time, extend considerably beyond the bounds of the nuclear industry.

If a theft of weapons-usable material did take place, the urgency for recovering the material would probably call for unprecedented measures on the part of authorities (i.e. civilian and military police) to recover the material. This action could interfere with the civil liberties of many people only peripherally connected--or totally unconnected--with the theft.

4. Foreign Experience. Development of a weapons capability--or the potential for it--by one nation could trigger concern, and possibly competing development, in nations that are adjacent or that are involved in regional rivalries. While it is impossible to assess the potential of such interactions, they are likely to exert considerable influence on the attitudes of a number of states toward reprocessing and weapons technologies, particularly in areas of the world where stability is tenuous.

TECHNICAL CONSIDERATIONS

1. Safeguards. A principal technical issue raised by proliferation is the necessity of safeguarding facilities and nuclear materials. Domestic safeguards are designed to prevent the theft or diversion of nuclear materials that could be used in nuclear weapons. The safeguards generally combine physical security measures (fences, isolation, etc.) with surveillance of personnel and monitoring of material flows. New technical methods to protect nuclear

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2/ See for example, Willrich and Taylor, Ballinger, Nuclear Theft: Risks and Safeguards, Cambridge, Mass., 1974, pp. 5-28, and especially p. 21.

material may be developed from research efforts underway. Although physical security measures are likely to resemble those for other secret or dangerous materials, the surveillance and monitoring methods that may be developed are designed specifically for dealing with nuclear materials.

International safeguards are of a quite different sort. Current safeguards are designed to provide assurance that a diversion will be detected and reported to the IAEA and possibly to the United Nations. Thus, the key is credible information and means for detecting material unaccounted for. At issue is the adequacy and reliability of present methods and necessary improvements.

The objective is to provide timely warning that a significant diversion has taken place and that a nation might be planning to use this material in a way to contravene its agreements with suppliers, with the IAEA, or under the NPT. It is hoped that such detection will deter diversion or make it more difficult, slow, or costly.

It is still not clear whether safeguards can be designed that can prevent a nation from converting an already existing stockpile of plutonium fuel to weapons quickly and easily.

2. Redesign of the Process. The objective here would be to make changes in processes and material composition that would render nuclear materials less usable or unusable.

Essentially, these changes involve mixing the plutonium with other materials that would then require further processing to produce weapons-usable material; the simplest change being the dilution of plutonium with uranium. While such a mixture could not be fabricated directly into a weapon, the techniques for the necessary chemical separation are widely known, the facilities required would not have to be large or expensive, and the time delay from diversion to weapons capability would likely be days or weeks rather than months or years.

To make weapons capability more difficult, the plutonium could be diluted with materials contaminated by highly radioactive wastes. While separation is still possible, the facilities for accomplishing the separation would have to be larger and more sophisticated, such as those used for normal reprocessing. The time delay in obtaining the weapons-usable material would presumably also be somewhat longer.

ALTERNATIVE COURSES OF ACTION TO CONTAIN PROLIFERATION

Any effort to contain nuclear proliferation will require international cooperation. An assessment of whether such cooperation is possible is not the purpose of this paper. It is clear, however, that the stance the United States takes regarding proliferation will influence, but not dictate, the decisions made by other countries on this issue.

International efforts to contain proliferation could range from a restrictive attitude advocating no additional nuclear power and a requirement that all presently generated fuel be accounted for to a laissez-faire approach, which in essence would mean no effort at all.

1. No Additional Nuclear Power. This effort represents the most restrictive course of action to reduce the threat of proliferation addressed in this paper. The justification for it would be based on the conclusion that as long as spent fuel containing newly generated plutonium exists; then the opportunity to recover this plutonium and create weapons-usable material also exists. If there is no more fuel, there can be no more weapons; and the threat to proliferation would be eliminated.

However, it is extremely unlikely that this effort will be carried out in the near future. Many nations have plans for a large expansion in the use of nuclear energy, in part to compensate for growing dependence on limited supplies of oil and natural gas. The economic pressures are strong to continue with nuclear technology. In order to forgo nuclear energy, alternatives would have to be developed. And these alternatives will require time.

2. No Reprocessing. This approach and its variant, a delay in reprocessing, are predicated on the assumption that it is the inventories of plutonium in separated form (the result of reprocessing) that make proliferation possible. If reprocessing were eliminated, the plutonium would not exist in an accessible form. Without reprocessing, safeguards would be necessary only for transporting fuel during the various processes before it is inserted in the reactor (when no plutonium is present) and to storage sites. Safeguards would also be necessary at spent fuel storage facilities; but, because spent fuel is highly radioactive, it is unlikely it would be tampered with.

The obvious disadvantages to this approach are (1) no reprocessed fuel for LWRs, and (2) the plutonium breeder reactor could never be implemented, although it could continue to be developed for the time being. Some countries, (e.g. France) have extensive plutonium breeder programs and are unlikely to want to make a decision which will eliminate this sort of breeder entirely.

A variant would ban reprocessing only for the present generation of reactors, but not necessarily for the breeder. This approach would have the advantage of eliminating recycled plutonium from the world's economy--at least until the breeder was implemented--at which time a further decision would need to be made. If the development of the breeder leads to implementation of present plans which require plutonium reprocessing, there would be no loss to the breeder program, since the plutonium value in the spent fuel will not degrade. Research efforts on reprocessing technology would presumably continue to assure its availability when needed. While this approach would delay some proliferation risks, those same risks would exist if the breeder were later put into widespread use.

A major drawback to these first two approaches for containment of proliferation is that, if either were implemented, all the important advantages of reprocessing would be forgone: Providing additional energy from uranium and thus extending uranium resources, reducing the dependence on oil and on the supplies of other nations, and trying to keep energy prices low. There is, however, enough uranium to continue the expansion of commercial nuclear energy through this century, particularly with the recent reduction in estimates of energy growth rates. Thus, as long as the spent fuel is stored retrievably, any residual energy value could be recovered if reprocessing were eventually deemed necessary.

3. Reprocessing/Enrichment Only by Nations Now in Possession of Reprocessing Technology. This approach would attempt to continue the inequality that the NPT recognizes and attempts to preserve: some nations have and some do not have nuclear weapons. Restricting access to reprocessing technology to nations already possessing nuclear weapons or reprocessing technology limits the opportunity for others to develop weapons capability. This approach, of course, would be inconsistent with one of the premises of the NPT--that all countries should have access to commercial technology. The difficulty with such an approach may be that, while energy value is recovered and uranium resources are extended, consumer nations (those without reprocessing capabilities) will still be dependent on supplier nations (those with reprocessing capabilities) for that energy value. Clearly, strong assurances would have to be given that fuel would not be cut off.

There are two possibilities for dealing with the return of recycled fuel if this approach were implemented. The first is to return only the equivalent fuel value in low enriched uranium, and the second is to return the recycled material itself, including plutonium.

Returning only low enriched uranium (no plutonium) has the advantage that only the supplier nations would then have weapons-usable material. While low enriched uranium can be converted to weapons-usable material, it requires isotope enrichment which, in the United States, is classified technology, and requires considerable technical sophistication. Thus significant, but not insurmountable, barriers to weapons are presented.

Returning the plutonium as a fuel ready for the reactor would present many of the same problems as reprocessing itself. As discussed above, the chemical separation necessary to create weapons-usable material could be accomplished without much difficulty, if the plutonium fuel were available.

4. Reprocessing Under International Authority. This approach could be carried out under the auspices of an organization such as the IAEA, or a multinational or regional authority. It could include the reprocessing, fuel fabrication, delivery of fuel, and storage of spent fuel.

The advantage of this approach is that reprocessing technology would not generally be available to nations not already possessing nuclear weapons, and that the processes for recovering plutonium would be under a central authority with the ability to prevent as well as detect diversion. The difficulty is again that consumer nations would have to depend on others for fuel, although agreements with an international agency might be preferable to bilateral arrangements.

Some significant problems include the selection of politically stable sites for the reprocessing facilities and that the technology would still spread, through the operation by an international staff. Furthermore, the question of whether to ship back plutonium or uranium or both to the consumer nations would still exist.

5. Reprocessing/Enrichment By Any Nation. Unlimited access to reprocessing and enrichment technologies would follow from a decision that either proliferation is not a problem or that international safeguards can be made sufficiently strong to deter any diversion or theft. This approach would require significant emphasis on the development and support of safeguards.

6. No Coherent International Action. This is not really an approach to containment of proliferation, but, rather the absence or failure of the other approaches. It would reflect an inability to achieve an international consensus on antiproliferation issues.

The consequences of such a situation would presumably be a growth in the use of nuclear power spurred on by the growth and spread of reprocessing and enrichment facilities. This growth in the use of nuclear power could mean energy self-sufficiency for some nations. But it could also mean the desire for weapons capability on the part of these same nations.

CHAPTER V. DECISIONS BEFORE THE CONGRESS AND THEIR EFFECTS ON THE BUDGET

The Congress has before it now, and will have in the near future, various decisions regarding stages of the nuclear fuel cycle that will affect the stance the United States will take ultimately for or against the proliferation of nuclear weapons.

Because of the disparate nature of these decisions, it is difficult to fashion one cohesive approach to solving the problems surrounding reprocessing, the breeder, and proliferation in general. However, there are important linkages within these issues. This chapter examines some of those linkages and illustrates how different approaches to resolving the issues affect each other, discusses the timing of Congressional decisions, evaluates the budgetary consequences of these decisions over the longer term, and, finally, discusses the potential consequences for the fiscal year 1978 budget.

As was pointed out earlier in this paper, decisions about domestic reprocessing and implementation of the breeder can be made unilaterally by the U.S. government, while other decisions, chiefly issues affecting proliferation with international implications, are at the discretion of the governments of the various nations involved. The United States can only urge cooperation.

RELATIONSHIPS AMONG THE BREEDER, REPROCESSING AND PROLIFERATION ISSUES

Of all the decisions involving the nuclear fuel cycle facing the Congress, the ones regarding reprocessing will probably have the most far reaching effects.

The discussion in this paper has been restricted to those aspects of proliferation and reprocessing that are closely interrelated. There are many other international considerations such as mutual security treaties, the use or threat of force, and international assurances that may affect a nation's desire to acquire nuclear weapons. While critical, those considerations are beyond the scope of this paper.

Table 3 indicates some of the ways in which resolution of the reprocessing and proliferation issues complement or contradict one another and relate to the breeder. In the table, the various international approaches to the proliferation issue have been chosen with the various approaches to reprocessing in mind, so that the two overall issues have similar structures. However, the approaches to reprocessing are restricted to domestic issues on which the United States can make unilateral decisions.

As pointed out in Chapter IV, the United States does not have a monopoly on enrichment and reprocessing technologies worldwide, and is in no position to force an international initiative to contain proliferation. Such an initiative will be directed by concerted action--or by inaction--of the nations that possess enrichment and reprocessing technologies.

The United States can, depending on its approach to reprocessing and by diplomatic action, influence, but not determine, the international approach taken on proliferation. The table shows which pairs of approaches (domestic reprocessing and international approaches to containment of proliferation) would be consistent with each other and which would be consistent with breeder development. The table also illustrates the inconsistencies that would develop if certain pairs of approaches were implemented.

Clearly, commercial implementation of the present breeder reactor is consistent only with the approaches that include reprocessing with recycling and use of plutonium. Thus, if this breeder is considered necessary, the decision on reprocessing is limited to a question of timing; it might still be possible to delay the decision on reprocessing for a very few years, depending on the schedule for introduction of the breeder. If the breeder is not considered a necessary source of energy, then the reprocessing decision can be made on the basis of its impact on the LWR fuel cycle and proliferation.

TIMING OF REPROCESSING AND PROLIFERATION DECISIONS

President Carter, in his statement on nuclear proliferation, has proposed no commercial reprocessing of spent fuel either in the United States or abroad, and that the development of a breeder dependent on recycling plutoninum be slowed. If the Congress agrees and does not further fund these technologies, domestic reprocessing of spent LWR fuel will have been terminated. If the Congress decides to support commercial reprocessing, the decision made after the GESMO hearings are concluded will be critical.

TABLE 3. RELATIONSHIPS BETWEEN APPROACHES TO CONTAINMENT OF PROLIFERATION AND APPROACHES TO DOMESTIC REPROCESSING AND THEIR CONSISTENCY WITH BREEDER DEVELOPMENT

INTERNATIONAL APPROACHES TO CONTAINMENT OF PROLIFERATION RELATING TO REPROCESSING

		No Additional Nuclear Power	No Reprocessing	Reprocessing by Supplier Nations Only		Reprocessing Under International Authority	Reprocessing Permitted By Any Nation
				Without Plutonium	With Plutonium		
APPROACHES TO DOMESTIC REPROCESSING	No Reprocessing	Approaches would be consistent; however alternative energy sources would be necessary.		Approaches would be directed toward different goals, hence inconsistent. If the United States chooses to forgo nuclear power, and other nations do not, the United States would probably lose the ability to influence the decisions on the use of nuclear power, especially those concerning reprocessing, made by other nations.			
	No Additional Nuclear Power			These approaches could be consistent. However, the ability of the United States to influence international decisions on shipping plutonium and on development of safeguards could be considerably reduced.		Approaches could be consistent if safeguards were effective.	Approaches would be inconsistent. Such a situation would indicate lack of coherent international policy.
	Immediate Reprocessing Without Plutonium	Major inconsistencies would occur among these approaches. The United States would be pursuing courses of action rejected by other nations. Thus, no coherent international agreements could be reached.		Approaches would be consistent. International agreements could be reached.	Approaches would be inconsistent on the issue of plutonium. Presumably, no international agreements could be reached.	Approaches could be consistent provided agreements did not allow shipping of plutonium	Approaches would be inconsistent on the issue of plutonium. Presumably, no international agreements could be reached.
	Immediate Reprocessing With Plutonium			Approaches would be inconsistent on the issue of plutonium. Presumably no international agreements could be reached.	Approaches would be consistent. International agreements could be reached.	Approaches would be consistent. International agreements could be reached.	
	Indefinite Delay in Reprocessing	Approaches would be consistent until the United States made its final decision on reprocessing. Then, if the United States decided to forgo reprocessing, major inconsistencies with approaches to proliferation allowing reprocessing would develop.					

APPROACHES CONSISTENT WITH BREEDER DEVELOPMENT

APPROACHES CONSISTENT WITH BREEDER DEVELOPMENT

At the same time the existence of plans by supplier nations to build and sell reprocessing technology and the substantial interest in buying reprocessing services on the part of countries such as Japan makes diplomatic initiatives timely. If too many nations make unilateral decisions, the opportunity for any sort of multinational effort may pass. The existence of tangible commitments on the part of several countries to build reprocessing facilities could foreclose options for concerted international action. Present plans call for several reprocessing facilities to be built abroad by the mid 1980s. Thus, if no multinational decision on reprocessing is made by the early 1980s, it may be too late for such a decision.

POTENTIAL BUDGET ISSUES

There are no separate budget categories or appropriations line items for reprocessing or proliferation. Certain research and development (R and D) expenditures can be identified for reprocessing and for safeguards, and, of course, research on the breeder is an important identifiable item in energy research and development. However, the Congressional Budget Office has estimated the potential levels of expenditures that could result from decisions to follow any one of the various approaches to reprocessing, the breeder, or proliferation. These estimates appear in Table 4. The amount of money authorized for any of these approaches is small at the inception of the project, but grows over time, and could increase to as much as $4.6 billion by 1986, if the Congress decided to implement the breeder on a commercial basis.

The discussion that follows illustrates the potential effects on the federal budget of various approaches to the issues of breeder development, reprocessing, and proliferation.

Approaches to Breeder Development

Parallel Development. This approach, formerly being pursued by ERDA, but which would be eliminated if the Carter plan were implemented, would require that, in addition to the Clinch River Breeder Reactor (CRBR) work begin on the next prototype large breeder reactor (PLBR) before the CRBR is operable. These projects could easily amount to about $4.6 billion in budget authority in

TABLE 4. POSSIBLE BUDGET EFFECTS OF ALTERNATIVE APPROACHES TO THE BREEDER, REPROCESSING, AND CONTAINMENT OF PROLIFERATION, IN BILLIONS OF DOLLARS

Alternative Approaches	1977-1986	Beyond 1986
<u>Approaches to Breeder Development</u>		
Parallel Development	4.600	similar
Sequential Development	3.500	similar
Prohibition	0-(1.00)	
<u>Approaches to Reprocessing</u>		
No Reprocessing	small**	small**
Reprocessing with plutonium		
Immediate	0.500	***
Delay	0.500-0.900	***
<u>Approaches to Containment of Proliferation</u>		
No Additional Nuclear Power	*	*
No Commercial Reprocessing	**	**
Reprocessing by Supplier Nations		
with plutonium	0.250	0.750
without plutonium	0.500	1.300
Reprocessing Under International Authority	small	1.300
No Restrictions	*	*
No Coherent Policy	*	*

* In many of these approaches, additional support would be required for IAEA inspection and safeguards. It is difficult to determine amounts but they would not be large.

** These approaches would have to include a substantial revision of present R&D priorities, to focus on nonfission alternatives.

*** The budget effects of these approaches would depend upon the extent to which processing facilities were funded and constructed by private industry.

1977 dollars by 1986. 1/ Efforts after 1986 to initiate a commercial industry could require as much additional money. In addition, experience with the CRBR and other projects suggests that the federal share for the prototype large breeder reactor could be larger than the 50 percent assumed here, which could increase the federal share of breeder development substantially.

Sequential Development. This appraoch would delay final design work on the PLBR (and associated facilities) until the CRBR becomes operational. While the $4 billion estimated above would be required eventually if this approach were followed, a substantial portion of it would not be spent until after 1986. Budget authority for this approach is estimated at about $3.5 billion until 1986. In addition, it would seem less likely that a large percent of federal support for the PLBR would be needed, because if the CRBR proved to be cost effective, there would be incentive for private investment at the next stage.

Prohibition. This approach would require no additional expenditures for the plutonium breeder reactor beyond Clinch River. And if the Clinch River project were slowed as requested by President Carter or ended by Congressional action, a reduction of perhaps $1 billion from what was originally estimated for completion of the program on schedule is certainly possible. If other breeder programs are accelerated--such as the thorium cycle or the molten salt breeder--it is quite possible that a sizable fraction of this $1.0 billion reduction could be required over the next few years.

Approaches To Containment Of Proliferation

No Additional Nuclear Power. The impetus for implementing this approach would be a concerted worldwide campaign to discover alternative non-nuclear energy sources through major research and development (R and D) efforts. Furthermore, in the short term, imported oil would be relied on even more heavily than it is at present as a major energy source, and substantial commercial incentives would be introduced for the implementation of new or expand-

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1/ See Energy Research: Alternative Strategies for Development Of New Energy Technologies and Their Implications for the Federal Budget, CBO Background Paper No. 10, July 15, 1976.

ed energy sources. This approach could cost an estimated $1 billion to $3 billion in subsidies by 1986 to implement competitive energy sources. 2/

No Reprocessing. The major impact of this approach would not be felt in the federal budget; it would be felt in the private sector. Alternative methods of recovering the energy value in spent fuel (i.e. the tandem cycle) could also be explored.

It is not likely that federal budget costs would be higher for permanent storage facilities than they would be for reprocessing facilities. However, giving up the plutonium breeder (the subsequent result of no reprocessing) would mean that more federal money would have to be spent on R and D to find alternative energy sources, although the LWR would still be an important energy source as long as it was economically feasible to mine uranium.

Reprocessing and Enrichment by Supplier Nations Only. If each supplier nation were able to handle its own reprocessing, the major expenditures for this approach would be for facilities to reprocess the spent fuel from consumer nations. Returning both reprocessed uranium and plutonium to consumer nations would be less expensive than returning the equilavent in enriched uranium. It is presently estimated that half of the capacity of a large (1,500 ton per year) reprocessing plant will be the maximum needed to do reprocessing for consumer nations by 1985; and the capacity of one and one half plants will be the maximum needed by 1990.

Assuming that the United States would pick up half of the costs of such a venture, $250 million in federal money would be required by 1985 and $750 million by 1990.

A second possibility that would also utilize the facilities of supplier nations would be to return an equivalent in enriched uranium to consumer nations. This approach would be more expensive than full reprocessing of plutonium because the value of the plutonium would be forgone and would necessitate the purchase of new uranium. As stated in Chapter II, this value depends on the price of uranium and the cost of reprocessing services. By 1985 the payments could be $75 million per year and by 1990 over $150 million per year.

2/ Financing Energy Development, CBO Background Paper No. 12, July 26, 1976.

In addition to these costs, the spent fuel would then have to be stored or reprocessed and any costs would have to be assumed. Costs for permanent storage could equal the payments of $75 million to $150 million estimated above. If the U. S. share were 50 percent, the costs for permanent storage and for additional reprocessing facilities could total nearly $500 million by 1985 and perhaps $1.3 billion by 1990.

Reprocessing Under International Authority. If this approach were followed, most of the additional reprocessing facilities would be constructed under international auspices (either IAEA or a special multinational entity). It is unlikely that such an entity could have a reprocessing facility operating before 1985. However, by 1990, nuclear power capacity to support roughly eleven 1,500 ton per year reprocessing plants could be in existence. Such an effort carried out internationally could require a large capital investment--as much as $11 billion in world capital costs.

If the international authority restricted its effort to reprocessing spent fuel from consumer nations, the costs would be roughly as shown in the preceding approaches. Costs would have to be apportioned to supplier nations in some manner and the costs to the United States would be similar to those of processing under an international authority.

No Restrictions. If this approach were implemented, the only budget impact would be for increased support of IAEA and for safeguards.

Approaches to Domestic Reprocessing

No Reprocessing. A prohibition on reprocessing would lead to some budgetary increases and some decreases. The money allocated to reprocessing R and D could be completely cut, as could additional plutonium breeder development. As a result of forgoing the breeder, R and D on nonfission alternatives would have to be emphasized.

In the short run, this strategy would not require additional enrichment facilities, although after 1985 there would be such a need.

Reprocessing with Recycling Plutonium. There are two possibilities, both related to timing.

1. Immediate reprocessing would probably require federal support of a demonstration facility. The minimum federal cost would be about $500 million for the plant at Barnwell, South Carolina. Since it is nearly completed, such a demonstration would begin operation quickly.

2. Delay to allow for accelerated efforts on alternatives to the Purex process, that could total $100 million for evaluation, feasibility design, and pilot plants. If the resulting design were substantially different from the Purex process, a demonstration facility could cost the federal government as much as $1 billion.

If the alternatives resulted in changed requirements for associated facilities (e.g., mixed oxide plants), some of the increased costs might be carried by the federal government.

Reprocessing without Recycling Plutonium. The budget impacts for immediate and delayed approaches would be very similar to reprocessing with recycling plutonium, with one major exception. Since plutonium is the source of most of the benefit of reprocessing, elimination may make the reprocessing facilities unprofitable. If this proves true, and there is still a reason to reprocess, the facilities may have to be built by the federal government. This might reduce individual construction costs to $750 million, but the cumulative costs could still be quite high--as much as $2 billion by the late 1980s, if three plants were needed.

IMPACT ON THE FISCAL YEAR 1978 BUDGET

The major budget impacts for fiscal year 1978 will be related to decisions on reprocessing and breeder development, rather than on proliferation. Although the approaches to containment of proliferation are at least as important, the processes of international negotiation will require time before substantial budget effects are felt.

This paper uses, as a starting point, the fiscal year 1978 budget request for nuclear energy made by President Carter. This request includes $656 million in budget authority and $651 million in outlays for the liquid metal fast breeder reactor. Included in this budget authority figure is $150 million for work on the Clinch River breeder reactor.

An additional $611 million in budget authority and $474 million in outlays are requested for the nuclear fuel cycle and safeguards, of which $380 million in budget authority and $282 million in outlays are earmarked for fuel cycle R and D. It is important to note, however, that President Carter's request is only one of the options that the Congress could choose. Furthermore, President Carter's April 7 policy statement on nuclear energy may result in alterations to this budget request.

The approach to the issue of breeder development chosen by the Congress could lead to a substantially different funding level than that chosen by the President. Parallel breeder development would not be consistent with reducing the Clinch River funding below $150 million and could require additional money for follow-on commercial development for which roughly $100 million was included by President Ford but eliminated by President Carter. Sequential development would be consistent with the budget request proposed by President Carter, thus allowing breeder development to be stretched out. Prohibition of further development of the plutonium breeder could involve a further reduction of the CRBR funding below $150 million. However, if the prohibition of further breeder development is also to involve additional initiatives on other breeder concepts which would not require large scale plutonium reprocessing (for example, the thorium breeder), then reductions in present breeder funding could be offset by increases in support for other breeder development.

The various approaches to reprocessing could have significant impacts in fiscal year 1978 particularly considering the addition or elimination of support for a private demonstration of reprocessing. The $380 million in budget authority for the nuclear fuel cycle originally included about $140 million for continuation of efforts to develop the final stages of the Purex process and for evaluation of alternative technologies. Immediate commercial reprocessing which included major federal support of a private demonstration would require the determination of how much budget authority was necessary in fiscal 1978 for an eventual $500 million to $700 million federal expenditure.

An approach that had no support for commercial reprocessing could presumably eliminate any federal support and much of the $140 million mentioned above. However, if it were to include alternative technologies, the evaluation and development efforts would have to continue, possibly at a lower level.

Thus, alternative methods of reprocessing could cost an additional $250 million, depending on the method pursued.

APPENDIX. ANALYSIS OF NET BENEFITS FROM REPROCESSING

In the analysis that follows, the fixed costs for various processes will generally agree with those in GESMO, with some exceptions noted. The benefits (or costs) for one year will be displayed for a hypothetical 1,500 ton per year facility operating at full capacity.

The major assumptions include the use of material flows as calculated by Allied-General Nuclear Services for their base case.1/ These assumptions may result in overstating the ability to substitute recycled uranium for natural uranium, since they do not take adequate account of the build up of the contaminant U236. Unless otherwise noted, all values are assumed in 1975 dollars.

With three exceptions the costs are the same as the best estimates used in GESMO for UF6 conversion, uranium fabrication, spent fuel storage, permanent storage and transportation of spent fuel, plutonium storage, mixed oxide fabrication, and final waste treatment and storage. 2/ The cost of uranium enrichment is valued in GESMO at $75/Separatie Work Unit; in this paper a charge of $100/SWU was assumed based on ERDA estimates of costs for new plants. GESMO uses reference values of $28.50 per pound of yellowcake (U_3O_8) and $150 per kilogram for reprocessing spent fuel. To illustrate the variations that are possible, these two prices are allowed to vary.

The yearly economic benefit of reprocessing is the difference between the full estimated fuel cycle costs for those reactors having fuel reprocessed and the full estimated fuel cycle costs for those same reactors without recycling. The difference could range from a benefit of $500 million to a cost of $500 million, depending on uranium and reprocessing prices.

1/ Allied-General Nuclear Service, <u>Nuclear Fuel Cycle Alternatives</u>, April 1976, pp 8-9.

2/ GESMO, pp. XII-35.

The assumptions concerning uranium and reprocessing prices are thus critical to the economic justification for reprocessing. One of the problems of estimating the cost of reprocessing is that no complete domestic, commercial-sized reprocessing facility now exists. To complete the AGNS facility at Barnwell, South Carolina, would require the addition of a plutonium conversion facility, and a high level waste solidification facility, which would cost $345 million. Added to the $250 million already expended, this would result in a total estimated cost of $595 million in 1976 dollars. In GESMO, NRC estimates between $500 million and $600 million in 1975 dollars; ERDA's best estimates is a cost of $1 billion in 1978 with a range of plus or minus $250 million. This results in estimates of reprocessing charges that also vary from $150 per kilogram for AGNS and NRC to $280 per kilogram for ERDA's best estimate and $340 per kilogram for ERDA's high-cost scenario. A range of charges from $150 per kilogram to $400 per kilogram corresponds to a range of construction costs roughly from $500 million to $1.5 billion. Additional waste storage costs could increase the range to $500 per kilogram.

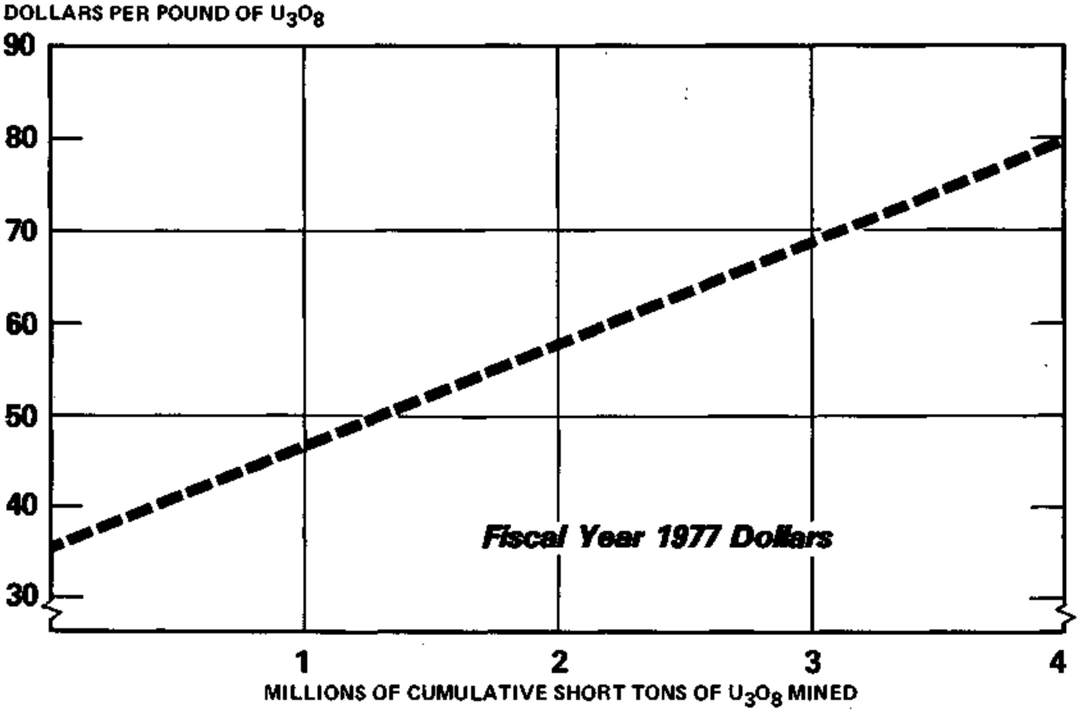
Since the Barnwell facility has been under construction for a number of years, the replacement cost would be higher than the current AGNS estimate of total costs. The low figure might, however, be appropriate for follow-on facilities incorporating technological improvements. The higher figure would be appropriate if new safeguards and the requirement to solidify highly radioactive wastes are deemed necessary, therefore further increasing costs.

The price of uranium is also subject to large uncertainty. The most recent ERDA survey of uranium marketing activity shows a range of prices in 1975 from $5 per pound to $30 per pound with an average of $11 per pound. The wide range of prices makes this assumption of single price for uranium extremely hazardous. In addition, the ERDA survey reports that an increasing number of contracts for future delivery will be at market prices at the time of delivery. The 1977 FEA draft, National Energy Outlook estimated a 1980 price (in 1977 dollars) ranging from $12 per pound to $23 per pound. In GESMO, NRC uses a range from $14 per pound to $56 per pound. They estimate initial prices in 1980 at about $18 per pound and rising at 3 percent to 3.5 percent each year, with a best estimte of $28 per pound.

ERDA has estimated the price schedule based on the cumulative amount of uranium mined. The Appendix figure presents this estimate. This schedule and FEA's latest estimates of nuclear power growth shows a real growth in uranium prices of about 3 percent each year. The major question, then, is what the average price of uranium will be when a reprocessing facility opens. If growth of nuclear power continues to slow, prices may not rise as rapidly; if the growth increases the pressure of additional mining requirements may force prices up. For these reasons Figure 1 in Chapter III includes uranium prices ranging from $10 per pound to $50 per pound and reprocessing costs from $150 per kilogram to $50 per kilogram.

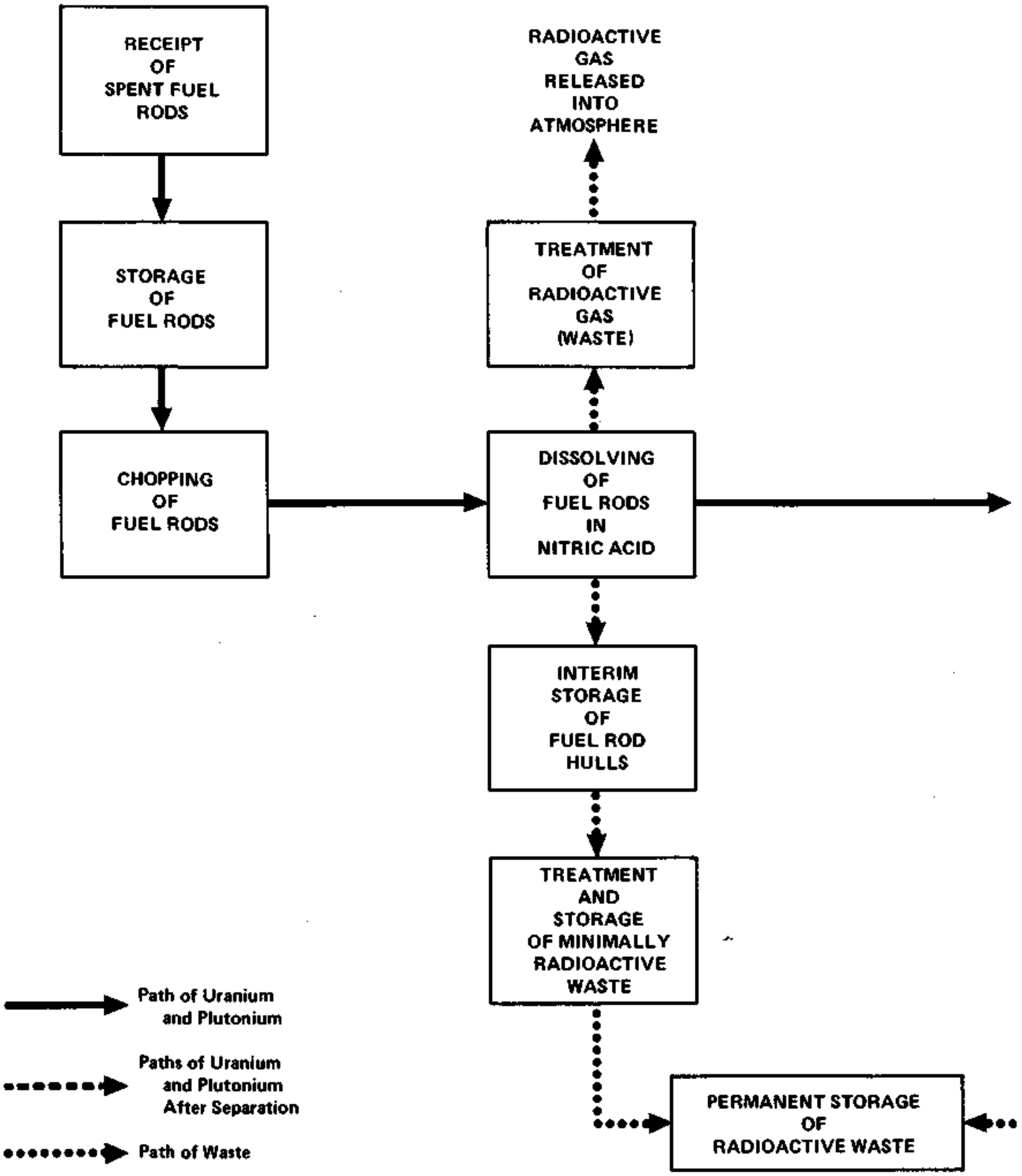
Appendix Figure

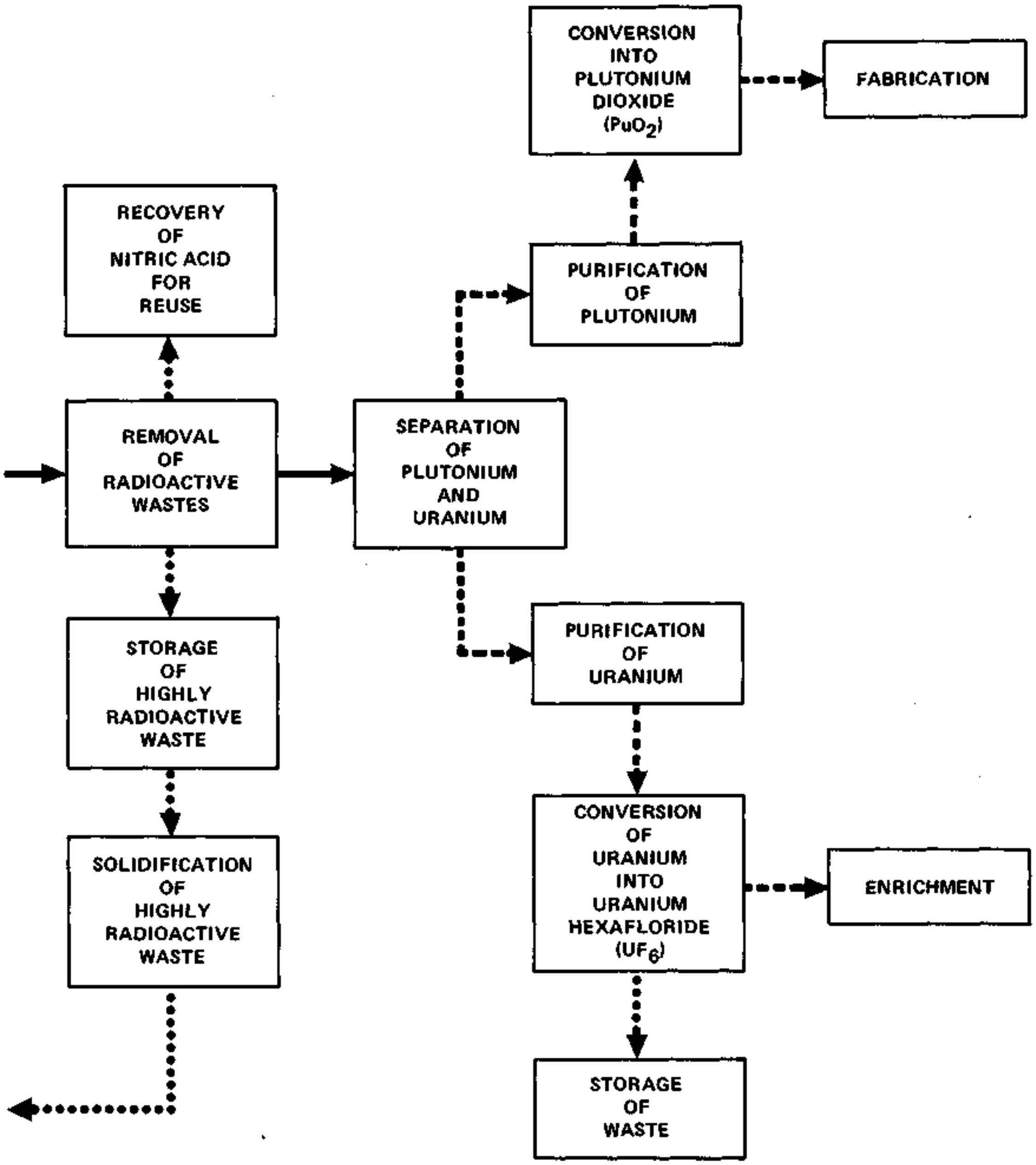
Uranium Price Schedule



SOURCE: Benefit Analysis of Reprocessing and Recycling
Light Water Reactor Fuel, ERDA, December 1976.

Purex Reprocessing of Spent Fuel





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