INSTITUTE FOR ENERGY AND
ENVIRONMENTAL RESEARCH

Washington, D.C. office:
6935 Laurel Avenue
Takoma Park, MD 20912

Phone: (301) 270-5500
FAX: (301) 270-3029
e-mail: ieer@igc.apc.org

Risky Relapse into Reprocessing

Environmental and Non-Proliferation Consequences of the Department of Energy's Spent Fuel Management Program

Noah Sachs

Institute for Energy and Environmental Research

with a Foreword by
Arjun Makhijani

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European office: Wilckensstr. 3, 69120 Heidelberg, Germany. Tel (011-49) 6221-47670, Fax (011-49) 6221-476719

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Foreword

For almost two decades, beginning with a far-sighted Ford administration decision, the United States has been alone among the major nuclear powers in recognizing that recovering plutonium from civilian power plant spent fuel does not make economic sense and, moreover, that it presents grave proliferation dangers (plutonium from civilian reactors can be used to make nuclear weapons). In 1982, the United States codified into law a prohibition against the use of plutonium of civilian reactor origin for military purposes. In 1988, the United States stopped producing plutonium in military nuclear reactors, and all plans for plutonium separation for military purposes were formally stopped in 1992. The military aspect of U.S. policy was driven by the official recognition that the United States was "awash in plutonium" (in the words of then Energy Secretary John S. Herrington) and by concerns about the safety of deteriorating production facilities.

These plutonium policies make the United States the only leading nuclear power that has actually renounced plutonium separation for either civilian or military purposes. As a result, the United States is in a unique position of leadership to address the dangers arising from continued reprocessing and accumulation of weapons-usable fissile material, whether they are of civilian or military provenance. Other declared nuclear weapons powers continue to separate plutonium for civilian or military purposes or both. Moreover, a number of countries that are not declared nuclear weapons states are accumulating separated civilian plutonium: Japan, Germany, Belgium, the Netherlands, Italy, Switzerland, and India are among them. Israel presumably continues to accumulate military plutonium. Several other countries are expressing interest in either acquiring civilian plutonium stocks by purchasing reprocessing services or in building reprocessing plants themselves.

A policy on such a crucial issue should not be put at risk without careful consideration for all the non-proliferation and other issues involved. Moreover, as many studies, including those done by the Institute for Energy and Environmental Research have stressed, most reprocessing technologies, including all operating plants, pose special environmental dangers arising from the production of low-level, transuranic, and especially liquid high-level radioactive wastes. Every increase in the already large and problematic inventory of high-level wastes, which is stored in tanks at DOE facilities, results in some increase in the risk of fires and explosions. This is, in many ways, already the most serious safety problem in the nuclear weapons complex.

Over the past few years, and especially during 1995, portions of the Department of Energy and some of its contractors have advocated various forms of reprocessing as the solution to the *environmental* problem of managing irradiated fuel and target rods in the nuclear weapons complex. Such pressures could result in a drift back to reprocessing in the United States that would not be classified as either military or civilian in purpose, but that would nonetheless pose similar proliferation and environmental dangers. Thus, instead of moving to the next logical step in its non-proliferation policy, that of permanently shutting down all reprocessing plants and decommissioning them, the United States appears to be moving in the opposite direction. This dangerous drift is occurring without adequate national debate about its proliferation, environmental, and economic consequences.

DOE and its contractors seem to be like the proverbial carpenter with only a hammer for a tool -- in this case the hammer is reprocessing. When DOE first proposed reprocessing as a technology for environmental management (in the late 1980s), IEER did a major study of the documents justifying the decision in collaboration with the Hanford Education Action League. In that case, Westinghouse and DOE proposed to reprocess spent fuel from the N-reactor at Hanford, which was then (and is still) stored underwater in pools called the K-basins. Our work showed that Westinghouse and DOE had rushed to the unwarranted conclusion that reprocessing was the most environmentally appropriate technology to address the problem of managing this spent fuel. We further concluded that dry storage of the spent fuel was more environmentally sound and probably less expensive. That was in 1990. Since that time DOE has agreed that dry storage is in fact the more appropriate choice for Hanford spent fuel. But now, proposals for reprocessing other spent fuel are mushrooming, as spending on weapons declines.

At the end of the Cold War, the problem of vast stocks of weapons-usable material and of potential black markets in them are among the most serious and urgent proliferation threats. These issues were highlighted (once again) in August in hearings held by the European Subcommittee of the Senate Committee on Foreign Relations, chaired by Senator Richard Lugar. The United States simply cannot afford to abandon its leadership role on reprocessing for the sake of a hasty approach to managing spent fuel, an approach that has the decided odor of pork-barrel spending for nuclear contractors. The next few years will be critical in determining the long-term future production and distribution of separated weapons-usable fissile materials, and decisions related to this issue need to be more carefully considered.

In order to assess the technical and policy soundness of recent claims that reprocessing ought be pursued as an environmental management technology, IEER undertook a review of all four DOE Environmental Impact Statements relevant to this subject. The review was carried out by Noah Sachs, the outreach coordinator of the plutonium project and the author of this report. The report grew out of a trip Noah and I made to Idaho in June 1995 to discuss DOE's proposal to ship spent fuel to the Idaho National Engineering Laboratory (INEL). Local groups were concerned that DOE's plan to regionalize spent fuel in a few locations in the United States may be a spur to reprocessing the spent fuel. It became clear that DOE may be drifting into a reversal of U.S. progress on reprocessing under pressure from its own sites.

IEER and the author are responsible for the contents of the report. I conducted a close review of the report and helped shape its recommendations in close collaboration with the author.

I would like to thank the following individuals for reviewing the report and providing many helpful suggestions:

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Arjun Makhijani
November 1995

Risky Relapse into Reprocessing

SUMMARY, FINDINGS, AND RECOMMENDATIONS

In the late 1980s and early 1990s, the Department of Energy halted reprocessing[1] at its three military reprocessing locations: Hanford, Washington; the Savannah River Site, South Carolina, and the Idaho National Engineering Laboratory. The end of the Cold War, a large plutonium stockpile, and safety issues related to the reprocessing plants all contributed to this decision. The cessation of reprocessing left many nuclear materials in limbo -- spent fuel originally slated for reprocessing remained in storage pools, and fissile material-containing solutions were left inside reprocessing plants at the Savannah River Site.

The solutions and some DOE spent fuel now pose environmental and safety problems because of accident risks and the possibility of increased radiation exposure to workers. Much of DOE's inventory of approximately 2,700 metric tons of spent fuel was not intended to be stored for long periods, and some spent fuel is corroding and releasing radioactive material into cooling pool water.

Over the past two years, the Department of Energy has issued four major Environmental Impact Statements (EIS's) and a number of other documents relating to spent fuel and nuclear material management. This report is a close evaluation of the following documents:

- *Final F-Canyon Plutonium Solutions EIS, December 1994*
  Outlines options for stabilizing plutonium-containing solutions stored in the F-Canyon reprocessing plant at the Savannah River Site.

- *Final Interim Management of Nuclear Materials EIS, October 1995*
  Discusses options for stabilizing seven types of nuclear materials at the Savannah River Site and for obtaining three types of "programmatic" materials deemed necessary for scientific research and DOE programs.

- *Draft Foreign Research Reactor Spent Fuel EIS, March 1995*
  Outlines alternatives for managing spent fuel from foreign research reactors. DOE is considering storage in the United States, reprocessing in the United States, reprocessing abroad, or some hybrid as the primary management alternatives.

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[1] Reprocessing is the separation of spent nuclear fuel into its constituent parts, mainly plutonium and/or uranium and lighter elements that are the product of nuclear fission in reactors.

- *Final Spent Nuclear Fuel/Idaho National Engineering Laboratory EIS, April 1995*
  DOE's overall spent fuel management plan, the SNF/INEL EIS focuses mainly on where spent fuel should be shipped to for interim storage. It also discusses possible stabilization techniques for DOE spent fuel, including reprocessing.

- *Proposal for the Demonstration of Electrometallurgical Processing*
  Several documents issued by DOE and Argonne National Laboratory in 1994 and 1995 describe this new kind of reprocessing technology whose testing is now delayed pending completion of an Environmental Assessment.

Although in 1992 DOE halted reprocessing and decided to permanently phase it out, these documents and others indicate that DOE is looking to reprocessing as a method of spent fuel and nuclear material management, possibly over the long-term. DOE believes that extracting fissile material from spent fuel and converting it to a solid form can reduce safety risks from interim storage. It also believes that the products of reprocessing may be easier and cheaper to dispose of in a geologic repository than some un-reprocessed spent fuel. DOE's current reprocessing proposals center around the Savannah River Site in South Carolina, but it is also investigating new reprocessing technologies, such as electrometallurgical processing, and it has considered constructing a new reprocessing plant in the United States. In addition, DOE is considering the use of one or more foreign reprocessing facilities to ease the waste management burden in the United States.

The reprocessing proposals at present apply to under 10% (by mass) of DOE's total spent fuel inventory, but DOE has not put any form of upper bound on the amount of spent fuel that may be reprocessed in the future.[2] Reprocessing could occur for as long as twelve years pursuant to the EIS's and even longer if additional spent fuel is found in the future to be corroding or if DOE implements several possible "future missions" for the reprocessing plants at the Savannah River Site. Over 4,000 kilograms of weapons-usable uranium and over 400 kilograms of weapons-usable plutonium could be extracted under current reprocessing proposals.

[2] Until recently, Hanford N-reactor spent nuclear fuel, which accounts for over 75% of the DOE spent fuel inventory, was being considered for electrometallurgical processing.

Principal Findings

1. There is no option for managing DOE spent fuel that is without risks, but reprocessing would be especially detrimental to U.S. non-proliferation interests and to sound environmental management of the nuclear weapons complex.

2. DOE has failed to adequately assess the non-proliferation and environmental issues surrounding reprocessing, and DOE appears to be drifting back toward reprocessing without a clear-sighted analysis of its drawbacks and risks.

3. DOE reprocessing policy is being made in piece-meal fashion in separate documents prepared by separate offices, and the overall impression is of policy incoherence.

4. Although DOE decided in 1992 to phase out reprocessing, reprocessing remains an open-ended project because DOE has not put any end-point on the amount of spent fuel that may be reprocessed or on the time-period in which reprocessing would take place. DOE has clearly stepped back from that 1992 decision.

5. Re-starting reprocessing, even if for environmental management purposes, would undermine current and future U.S. non-proliferation efforts, including efforts to convince Russia and other countries to halt reprocessing. It may also be the first step toward a return of civilian reprocessing in the United States.

6. There are positive signs in the DOE documents that some DOE officials are questioning the assumptions behind reprocessing and are working toward a spent fuel management program based on alternative technologies.

7. DOE has not adequately examined its experience with N-reactor spent fuel at Hanford for the environmental and cost lessons it holds for current spent fuel management policy.

8. Interim dry storage of spent fuel, possibly preceded by short-term improvements in wet storage, is the best alternative to reprocessing from the points of view of safety, environmental protection, and non-proliferation.

Discussion of Principal Findings

While the challenge of spent fuel management is formidable and complex, the Department of Energy appears to be drifting back toward reprocessing as a solution without an adequate analysis of its consequences or alternatives. Because reprocessing was what was done with most DOE spent fuel during the Cold War, parts of the DOE bureaucracy are resistant to considering other options, especially since many DOE and contractor personnel built their careers on the operation of reprocessing facilities. Maintaining a steady flow of money for some of the sites where reprocessing occurred in the past is an important political factor behind reprocessing, as is the strong belief in many quarters that plutonium is an energy asset rather than an economic liability, despite many independent studies to the contrary.

Reprocessing involves serious environmental and safety liabilities that have not been given due consideration by DOE. U.S. military reprocessing plants were never intended for environmental management, and in fact reprocessing was the leading cause of environmental contamination among all stages in the nuclear weapons production process. The reprocessing plants at the Savannah River Site that DOE is considering operating for up to twelve years or longer are already over forty years old.

One of the most significant flaws in DOE's analysis is that the EIS's do not discuss the increased risks of fires or explosions in high-level waste tanks that could result from generation of liquid high-level waste in reprocessing options. At the same time, DOE exaggerates the amount of high-level waste that would be generated in non-reprocessing options such as dry storage. DOE's haphazard approach to waste management issues is exemplified by the fact that some of its waste generation figures in the SNF/INEL EIS came from a report that stated that "...there is little documented basis or calculations to support the data presented."[3]

DOE data show that reprocessing solid spent fuel at the Savannah River Site pursuant to the Interim Management EIS will increase high-level waste at the Site by about three million gallons (about 9% of the high-level wastes currently stored at the SRS).[4] The plutonium extracted through reprocessing will become an additional waste burden for DOE, but again there is very little discussion of its disposition. Stored plutonium already poses serious environmental problems at many sites within the nuclear weapons complex. The last thing the United States should want to do as it struggles with the question of disposing of plutonium from dismantled nuclear warheads and other sources is to extract more plutonium through further reprocessing.

Further, while DOE's own data show significant negative health effects from reprocessing, DOE does not give sufficient weight to this factor in its decision-making. The estimated incremental radiation dose to the population within fifty miles of the Savannah River Site is four to five million times greater

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[3] Westinghouse 1994, p. 8

[4] DOE 1995b, pp. 2-55 to 2-58

from reprocessing than from interim storage, and DOE has estimated that one worker will die from cancer if it implements reprocessing at the Savannah River Site.[5]

DOE has also provided a misleading discussion of the possible advantages of reprocessing for final waste disposal. DOE believes that the vitrified high-level waste that will result from reprocessing will be easier and cheaper to dispose of in a geologic repository than some un-reprocessed DOE spent fuel. DOE's repository program has had a troubled history, however, and DOE spent fuel will not be put into a repository for two decades at the very earliest. DOE is investigating the suitability of Yucca Mountain in Nevada for a repository, but there is a chance that it will not be suitable, and the waste acceptance criteria, the rules that will govern what types of materials can go into a repository and in what form, have not been issued. A three-volume preliminary investigation by Sandia National Laboratories concluded that ***"...most decisions on*** [spent fuel] ***treatment or conditioning should wait until a repository type and site are known***."[6] [bold italics in original] It may very well turn out that reprocessing in the near-future for the purpose of long-term cost savings or to avoid technical uncertainties will be a waste of money and counter-productive on environmental grounds. DOE cost estimates for ten year periods, let alone the forty year period within which DOE believes repository emplacement could be completed, are highly speculative.

The best alternative to reprocessing is to store spent fuel for an interim period in dry storage facilities. DOE's own data show that interim storage poses far fewer safety, environmental, and health risks than reprocessing, and interim storage would allow DOE to conduct research on engineered barriers and non-separative processing options. In addition, interim storage would allow DOE to gain more information about a repository before making spent fuel stabilization decisions. Keeping corroding spent fuel in current storage facilities while new ones are built does carry risks, but reprocessing involves much greater risks. Further, current wet storage could be improved in some cases by putting the spent fuel in sealed containers, as was done at Hanford for some spent fuel well over a decade ago.

Perhaps the greatest flaw in DOE's current reprocessing policy is its open-ended nature, especially given the fact that DOE decided in 1992 to phase-out reprocessing operations. As long as DOE views reprocessing as a sound method for managing spent fuel, reprocessing will continue to be justified as the solution when additional types of spent fuel are found to be corroding or unstable in the future, and funds will not be devoted in a serious way to developing alternatives. In a November 15, 1995 letter, the Defense Nuclear Facilities Safety Board recommended that both reprocessing plants at the Savannah River Site be kept open indefinitely, stating that "the Department of Energy will always need to have available a capability for chemical processing of spent nuclear fuel..."[7] This is just one example of the commitment to reprocessing in some quarters.

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[5] DOE 1995a, Volume 1, Appendix C, pp. 5-41 to 5-43
[6] Sandia National Laboratories 1995, p. ES-37
[7] Conway 1995

A recent DOE study recommended against re-starting one of the reprocessing plants at the Savannah River Site and proposed consolidating operations in the other. While this is a positive development, DOE is also considering several possible "future missions" for reprocessing at the Savannah River Site that could involve reprocessing through 2012 in the single reprocessing plant. Because spent fuel management is such a long-term project, the current signs of a favorable attitude toward reprocessing provide a very real possibility that the United States will still be reprocessing in a decade or more from now. This is a remarkable retreat from DOE's 1992 position of phasing reprocessing out.

One positive development is DOE's decision not to reprocess N-reactor spent fuel at Hanford, which forms the bulk of the spent fuel inventory. There is no indication, however, that DOE has taken the lessons from Hanford and applied them to its larger reprocessing policy. Over five years ago, DOE proposed reprocessing the over 2000 metric tons of N-reactor spent fuel in Hanford's PUREX plant, using many of the same justifications it uses today. A 1990 study by IEER concluded that reprocessing was probably among the most expensive spent fuel management options and that it would increase the risk of a fire or explosion in the Hanford waste tanks. A U.S. General Accounting Office report also concluded that DOE had not shown that reprocessing was necessary. Despite DOE's sound eventual decision to store the fuel instead, DOE's current arguments for reprocessing other types of spent fuel exhibit many of the same analytical mistakes as the PUREX proposal and similarly underestimate the advantages of dry storage.

Some officials within DOE have been questioning the rationale for reprocessing and are beginning to raise non-proliferation concerns, and some of the inconsistencies among the EIS's may be related to the relative influence of those who support reprocessing compared to those who place a fundamental value on implementing U.S. non-proliferation policy. The Foreign Research Reactor EIS is the best of the recent documents in its more careful consideration of non-proliferation issues, and it discusses some of the environmental liabilities of reprocessing as well.

The non-proliferation drawbacks of reprocessing are numerous. The U.S. is the only declared nuclear weapon state not currently reprocessing for military or civilian purposes. As such it is in an extraordinary position to work to stem the proliferation dangers from reprocessing in other countries. Long-term reprocessing in the United States, even if for environmental management purposes, would undermine U.S. credibility in this area by creating the perception of a double-standard.

Shutting down all reprocessing in North Korea and curtailing military reprocessing in India and Russia have been key U.S. non-proliferation goals over the past several years. The connection between U.S. reprocessing and stopping reprocessing abroad was made by President Bush in 1992 when he officially halted U.S. military reprocessing. He said his decision was part of a "set of principles to guide our non-proliferation efforts in the years ahead," and the White House added that his decision was "intended to encourage countries in regions of tension such as the Middle East and South Asia to take similar actions."[8]

U.S. plans for several years of reprocessing in former military plants could have negative consequences for negotiations on the international treaty for a cut-off of military fissile material production and for negotiations on the 1994 U.S.-Russian agreement ending military fissile material production. Moreover, reprocessing would undermine U.S. credibility to halt civilian reprocessing in countries such as Britain, France, India, Russia, and Japan. President Clinton stated in 1993 that the U.S. abstention from reprocessing is important for not encouraging civilian plutonium programs abroad. Finally, reprocessing would undermine the U.S. position to halt nascent reprocessing programs in countries such as China, Ukraine, and Pakistan.

Most of the DOE documents evaluated in this report do not assess the impact of reprocessing on U.S. non-proliferation efforts. Moreover, DOE has not made a comprehensive commitment to blend-down any extracted highly enriched uranium (HEU) into non-weapons-usable low enriched uranium and to put any extracted plutonium under International Atomic Energy Agency safeguards. Despite a Clinton administration policy to "submit excess fissile material not needed for our deterrent to the IAEA," only one EIS mentions the policy and commits to doing so. The other EIS's are much more vague about the fate of extracted fissile material, and one document indicates that extracted HEU would be stored as HEU for an interim period rather than blended-down.

The negative non-proliferation consequences of reprocessing, combined with its environmental drawbacks, lend support to the argument for taking a more prudent, cautious approach to spent fuel management based on interim dry storage of spent fuel. Unfortunately, DOE has failed to properly consider the benefits and feasibility of this option.

Other Findings

1. *DOE terminology is obfuscating and obscures the sheer number of reprocessing proposals it is considering.* DOE terms such as "processing", "conditioning", and "treatment" may all refer to reprocessing, that is, the separation of plutonium and/or uranium from spent fuel, but the actual proposal being described is not immediately apparent from these terms. The option in the SNF/INEL EIS of constructing a new reprocessing plant at Hanford (a major development in U.S. non-proliferation policy) is referred to as Process Q, an opaque term to say the least. Misleading terminology is a poor foundation for coherent policy, and it may be a purposeful effort to hide reprocessing programs behind unfamiliar names.

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[8] *Statement by the President* and *Fact Sheet on Nonproliferation Initiative*. White House Office of the Press Secretary, July 13, 1992.

2. *The materials that can most justifiably be reprocessed are the fissile material-containing solutions in the reprocessing plants at the Savannah River Site.* These solutions do pose serious accident risks, and if the reprocessing plants are ever to be shut down and dismantled the solutions must be removed. For solid spent fuel at the Savannah River Site, DOE should reconsider the option of monitoring and improving current storage conditions while at the same time constructing a dry storage facility.

3. *Despite the National Academy of Sciences' conclusion that plutonium is an economic liability, some parts of DOE continue to view plutonium and possibly spent fuel as resources.* The SNF/INEL EIS refers to reprocessing as a method of "resource recovery," and the Record of Decision for the F-Canyon EIS states that "[i]t would not be appropriate...to characterize the stabilized plutonium as waste," with no further explanation.[9] DOE has not yet declared that its spent nuclear fuel is a waste product. It is apparent that the view of plutonium as a valuable asset still lingers within DOE and that DOE has not adjusted its plutonium policy to reflect post-Cold War circumstances.

4. *The National Academy of Sciences has also found problems with DOE's spent nuclear fuel management policy.* In a recent study on electrometallurgical processing, the NAS asserted that it had difficulty assessing the technology in comparison to other options, including direct disposal of spent fuel, because it "was unable to determine that DOE has developed a broad comprehensive strategy covering interim management and ultimate disposition" of DOE spent fuel and nuclear materials. The NAS also asserted that the absence of criteria for repository emplacement "precludes a full comparative analysis of the alternatives" of interim storage and reprocessing.[10]

5. *Electrometallurgical processing is not an appropriate waste management technology, and its continued development keeps the door open to a return of civilian reprocessing in the United States.* Argonne National Laboratory has touted the potential applications of the technology to commercial nuclear power plant spent fuel, and the technology has been tested with a small amount of commercial spent fuel. In addition, DOE plans to apply it to commercial spent fuel under future research and development efforts. Reprocessing commercial spent fuel would reverse long-standing U.S. practice and undermine U.S. authority to discourage commercial reprocessing in other countries.

6. *Reprocessing small amounts of spent fuel or nuclear material pursuant to one EIS with a short time-frame raises the incentives to use the reprocessing plants for larger amounts of spent fuel or nuclear material over the long-term.* It is a ripple effect that could result in eventually reprocessing all of the aluminum-clad spent fuel in the United States, once it is consolidated at the Savannah River Site under DOE's preferred alternative in the SNF/INEL EIS.

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[9] DOE 1994d, p. 14

[10] NAS 1995, pp. 27-28

7. *The potential implementation of reprocessing may be driven by political and pork-barrel considerations.* Senators Strom Thurmond and Frank Murkowski, key committee chairmen with oversight responsibility for DOE and energy policy, continue to look favorably on reprocessing for spent fuel management. Senator Thurmond has advocated reprocessing research reactor and commercial spent fuel at the Savannah River Site in his state, as well as "legislative mandates that reprocessing, once begun, not be interrupted."[11] An internal DOE memo proposed constructing a new reprocessing plant at the SRS in an effort to create "economic benefits" and convince South Carolina to drop a lawsuit against DOE. Given the politics of reprocessing and the pork-barrel nature of some of the projects, it may be very difficult to end reprocessing operations once they are initiated.

Recommendations

1. *The Department of Energy should undertake a comprehensive review of current reprocessing proposals and re-evaluate dry storage options for solid spent fuel based on more realistic data for cost and waste generation.* In proceeding to address the environmental legacy of fifty years of nuclear weapons production, the Department of Energy needs to clarify its intentions, goals, and methods regarding reprocessing and make these transparent to the public.

2. *Given the vast uncertainty regarding a repository, it would be prudent to store spent fuel for an interim period until there is more information about the form and type of fuel that can be put in a repository.* A period of interim storage would also allow DOE to develop canisters and engineered barriers that could safely contain diverse types of spent fuel, as well as new technologies that could prepare spent fuel for disposal without separating the fissile material. As long as DOE views reprocessing as a sound method of spent fuel management, there will be little incentive to fully fund these essential R&D activities.

3. *DOE should announce firm dates for decommissioning and dismantling its reprocessing plants.* This announcement would strengthen U.S. non-proliferation efforts and would eliminate the current open-ended nature of reprocessing operations. The date for decommissioning should allow enough time to remove fissile-material containing solutions from the reprocessing plants at the Savannah River Site but should not be more than one or two years away.

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[11] Letter to Senator Frank Murkowski, June 29, 1995

4. *A thorough non-proliferation analysis that recognizes international proliferation risks from U.S. reprocessing should be included in any future EIS's containing reprocessing proposals.* Such an analysis should also be integrated into DOE's internal discussions and decision-making regarding spent fuel management.

5. *Weapons-usable material extracted through reprocessing operations should be placed under IAEA safeguards*, and DOE should make a policy declaration to that effect. DOE should also consider inviting international monitors to observe the reprocessing procedures. The plutonium that will be extracted, along with plutonium in DOE's current stockpile deemed surplus to military requirements, should be declared a liability.

6. *DOE should abandon development of electrometallurgical processing and other new reprocessing technologies.* Instead, DOE should focus its spent fuel R&D efforts on developing new types of canisters and engineered barriers that might make diverse forms of spent fuel compatible with repository disposal. Such an investigation should not assume that Yucca Mountain will necessarily be the repository location. On the contrary, it should investigate compatibility with various rock types.

7. *DOE should use the term "reprocessing" for all technologies and proposals involving separation of uranium or plutonium from spent fuel.* This would eliminate ambiguities surrounding use of the term "processing" or other terms, allowing the public to better evaluate the proposals DOE is considering.

2)

Introduction

For over forty years, the Department of Energy and its predecessor agencies operated reprocessing plants[1] to extract fissile material for nuclear weapons and other military purposes. These plants extracted approximately 96 metric tons of plutonium from spent nuclear fuel and irradiated target rods and at the same time generated enormous amounts of highly radioactive waste.[2] Military reprocessing occurred at three sites: Hanford, Washington; the Savannah River Site, South Carolina; and the Idaho National Engineering Laboratory. The Department of Energy began to curtail military reprocessing in the late 1980s as the Cold War drew to a close, and some time before or during 1992 DOE ceased reprocessing spent fuel for nuclear weapons purposes.

The cessation of operation of DOE reprocessing plants in the late 1980s and early 1990s left spent fuel that had been slated for reprocessing, as well as other nuclear materials, in limbo. Over 2,100 metric tons[3] of spent fuel was left underwater in cooling pools, and some solutions containing fissile material were left inside the reprocessing plants at the Savannah River Site. Most DOE spent fuel and the fissile material-containing solutions were not intended to be left in storage for extended periods, and they now pose some environmental problems and safety risks. For example, some DOE spent fuel is corroding and releasing radioactive material into cooling pool water, and some of the facilities now storing spent fuel are not believed to be stable in the event of seismic activity. The main safety risks from the spent fuel and solutions is increased radiation doses to workers and the potential that an accident involving the solutions or corroding spent fuel would have larger consequences than if they were put into a more stable form.

The Department of Energy is engaged in developing plans to manage its inventory of approximately 2,700 metric tons of spent fuel for an interim period and to dispose of it in a geologic repository along with a much larger amount of spent fuel from commercial nuclear power reactors. DOE's Office of Spent Fuel Management, which is under the Office of Environmental Management (EM), is largely responsible for this program. EM is also developing plans to address environmental and safety issues stemming from the solutions in the reprocessing plants and various fissile-material containing scraps and residues. The problem of managing these materials is just one component of the overall environmental management task that DOE faces,

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[1] Reprocessing is the separation of spent nuclear fuel into its constituent parts, mainly plutonium and/or uranium and lighter elements that are the product of nuclear fission in reactors.

[2] Over 103 metric tons of plutonium was produced in reactors. However, 7.4 metric tons remains in irradiated spent fuel and has not been extracted.

[3] A metric ton is 1,000 kilograms. Throughout this report, the term "metric ton" of spent fuel is used as a short-hand for a more technical measurement called metric ton of heavy metal (MTHM), which is DOE's traditional measurement of spent fuel mass. MTHM refers only to the mass of plutonium, uranium, and thorium in the spent fuel. The actual mass of spent fuel is always larger than the mass of its heavy metals.

which also includes decontaminating weapon production facilities, disposing of wastes, improving storage of plutonium, converting high-level liquid waste into solid forms, and many other tasks.

DOE has categorized its spent fuel into 53 different types depending on uranium enrichment level,[4] cladding material,[5] and fuel type.[6] Some spent fuel, such as naval spent fuel, is considered "high integrity" and can be stored for decades. Other spent fuel is less stable and is chemically reactive and/or corroding. Early in her tenure, Secretary of Energy Hazel O'Leary made spent fuel management a high priority, and in November 1993 DOE released its *Spent Fuel Working Group Report* which identified spent fuel "vulnerabilities," or conditions that may lead to radiation exposure or environmental contamination, within the nuclear weapons complex. Subsequently, DOE released three *Plan of Action* reports on resolving spent fuel vulnerabilities.[7]

As Brian Costner of the Energy Research Foundation and Beatrice Brailsford of the Snake River Alliance pointed out at a 1995 conference, "DOE is moving toward being able to clearly and fairly describe what comprises its SNF program. This is a vital first step, and despite other criticisms of DOE's actions regarding SNF...the value of this effort should be recognized."[8]

Over 98 percent of DOE spent fuel is at three sites, and over 75 percent of it is from a single source, Hanford's N-reactor.

DOE Spent Fuel Inventory in Metric Tons, 1995

Location	Amount	Percent
Hanford	2133	80.6
INEL	261	9.8
Savannah River Site	206	7.8
Oak Ridge Reservation	1	.03
Other DOE facilities	27	1.0
Universities	2	.08
Other	16	.6
TOTAL	**2646**	**100**

SOURCE: SNF/INEL EIS, Summary, p. 8
NOTE: According to DOE, approximately 95 metric tons of spent fuel will be added to the inventory by 2035 from foreign research reactors, naval reactors, domestic research reactors, and other sources.

[4] Uranium enrichment refers to the percentage of the fissile uranium isotope U-235 in the fuel. Natural uranium contains roughly 0.7% U-235 and 99.3% U-238. The ratio of U-235 to U-238 can be increased in a uranium enrichment plant. Most commercial nuclear power reactors use uranium enriched to 3%-4% uranium-235. The fuel for most naval and some research reactors contains weapons-usable highly enriched uranium (HEU) enriched to 90% or more in U-235.
[5] Cladding material refers to the type of material out of which the tube that contains the fuel pellets is made. Cladding materials include aluminum, zirconium, stainless steel, and others.
[6] DOE 1994d, p. 31. Fuel type refers to the chemical form of the fuel pellets. Types include uranium oxide, uranium carbide, mixed uranium plutonium oxide (MOX), uranium zirconium hydride, and uranium metal.
[7] The reports were released in February, April, and October 1994.
[8] Costner and Brailsford 1995

Over the past year, the Department of Energy has released several documents and environmental impact statements (EIS's) that indicate that it is considering re-starting reprocessing -- this time not for military purposes, but for the purpose of addressing environmental and safety problems stemming from some DOE spent fuel. DOE's aim in reprocessing is to remove the fissile material from spent fuel and convert it to a solid form to reduce safety risks from continued storage of spent fuel. DOE also believes that the products of reprocessing may be easier and less costly to dispose of in a permanent geologic repository than some types of un-reprocessed spent fuel. In addition to re-starting existing reprocessing plants, DOE is investigating several new types of reprocessing technologies, and it has considered constructing a new reprocessing plant in the United States and utilizing reprocessing facilities in foreign countries.

Four recent EIS's relating to spent fuel and nuclear materials management contain proposals involving reprocessing:

- Final F-Canyon Plutonium Solutions EIS, December 1994
- Final Interim Management of Nuclear Materials EIS, October 1995
- Draft Foreign Research Reactor Spent Fuel EIS, March 1995
- Final Spent Nuclear Fuel/Idaho National Engineering Laboratory EIS, April 1995

Additionally, DOE and Argonne National Laboratory have issued several documents that outline a proposal to demonstrate electrometallurgical processing, a new kind of reprocessing technology.

The various reprocessing proposals at present apply to under 10% of the spent fuel in the DOE inventory, but much larger quantities of spent fuel, as well as other nuclear materials, could be reprocessed in the future. DOE has not put any kind of upper bound on the amount of spent fuel that may be reprocessed over the next few decades before repository emplacement. The reprocessing proposals center around the two reprocessing plants, F-Canyon and H-Canyon,[9] at DOE's Savannah River Site in South Carolina, though a recent DOE study concluded that DOE reprocessing missions could be accomplished using F-Canyon only.[10] Reprocessing of DOE spent fuel may also occur at the INEL in Idaho and at foreign reprocessing facilities. Reprocessing could occur for twelve years or longer pursuant to the various EIS's and documents, and over 4,000 kilograms of weapons-usable uranium[11] and over 400 kilograms of weapons-usable

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[9] Reprocessing plants are sometimes called canyons because they are long, narrow structures.
[10] DOE 1995f
[11] The Foreign Research Reactor EIS considers reprocessing 18.2 out of a total of 19.2 metric tons of foreign research reactor fuel and states that the total contains 4,600 kilograms of HEU. Mark-16 and -22 fuels, which are highly enriched, contain several hundred kilograms of uranium.

plutonium[12] could be extracted from spent fuel under the most likely reprocessing scenarios. DOE has pledged not to use fissile materials that may be extracted through reprocessing in nuclear weapons, but it has provided few details about the destination and possible uses of these materials.

While recognizing the complexity of DOE's spent fuel management task and the associated environmental and safety issues, this report argues that re-starting reprocessing would be detrimental both to sound environmental practice at DOE facilities and to U.S. non-proliferation interests. Although it is now being proposed as a tool for environmental management, reprocessing has been one of the leading causes of environmental contamination from nuclear weapons production in the United States and in other countries. The reprocessing plants that DOE may re-start at the Savannah River Site are aging structures that are over forty years old. Reprocessing will involve substantial waste generation, an increase in the risk of an accident in reprocessing waste tanks, and the extraction of materials whose ultimate disposition is a formidable task in itself. DOE data show that reprocessing creates more radioactive waste and more risks to workers and nearby communities than storing spent fuel for an interim period until its ultimate disposition can be decided. The spent fuel management program is a complex one involving dozens of variables, and there are large uncertainties regarding the proposed repository for spent fuel at Yucca Mountain, Nevada. Given these uncertainties, it makes sense to take an approach based on interim storage of spent fuel designed to allow development of options for final disposal.

This report draws a distinction between solid spent fuel and the fissile material-containing solutions that were left in the reprocessing plants when the plants were shut down. If the reprocessing plants are to be permanently decomissioned and closed, the solutions need to be taken out. Pumps, separations modules, and conversion lines may all have to be operated in order to pass the solutions through the system. This may involve separating fissile material from fission products and converting the fissile material to a metal or oxide form, but there are no other good options for the safe closure of the plants. Solid spent fuel stored in pools, on the other hand, does not pose the same magnitude of safety risks and can be monitored for a longer period until it can be moved to dry storage.

The present international arena is vastly different from the political circumstances under which reprocessing occurred in the past. The United States is the only declared nuclear weapon state that is not currently reprocessing for either military or civilian purposes.[13] As such it has the

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[12] 400 kilograms is a rough estimate. It is based on DOE figures that show 300 kilograms of plutonium in irradiated materials at the Savannah River Site (Grumbly 1994). Most of these materials are planned to be reprocessed. In addition, Argonne National Laboratory has said that 200 kilograms of plutonium are contained in the EBR-II spent fuel planned to be electrometallurgically processed (McFarlane and Lineberry, p. 3). About 4,000 kilograms of plutonium would be extracted if Hanford N-reactor fuel were reprocessed (Grumbly 1994).

[13] Civilian reprocessing refers to reprocessing spent fuel from commercial nuclear power reactors. The plutonium and uranium extracted through civilian reprocessing is normally fabricated into new fuel for nuclear reactors.

credibility to work to halt reprocessing in other countries and especially in Russia, where reprocessing and fissile material accumulation pose increasing proliferation risks. The Bush administration halted reprocessing in part to improve the international non-proliferation regime. The Clinton administration has stated that it does not want to encourage the commercial plutonium programs of other countries (which pose proliferation risks) and that the United States' abstention from reprocessing is important to achieve this goal. Reversing current practice, even if for environmental management purposes, would legitimize reprocessing and undermine U.S. non-proliferation efforts.

What is especially disturbing about DOE reprocessing policy is that it is a retreat from its own 1992 policy to phase out reprocessing at the Savannah River Site and INEL. While the 1992 policy envisioned some limited reprocessing in order to shut down reprocessing facilities in a safe manner and stabilize materials at the two sites, current plans appear to involve much longer-term reprocessing. DOE is considering several new "future missions" for one or both of the Savannah River Site reprocessing facilities, missions that may involve nuclear materials that are not currently at the SRS. DOE's interest in reprocessing means that funds will not be devoted in a serious way to investigating alternatives to reprocessing, since spent fuel projects tend to compete with each other for funds.

Given the drawbacks of reprocessing, why is DOE considering it so strongly as a waste management tool? DOE appears to be drifting back toward reprocessing without sufficient analysis of its consequences, alternatives to reprocessing, and the current non-proliferation climate. Because reprocessing was what was done with most DOE spent fuel throughout the Cold War, parts of the DOE bureaucracy seem resistant to seriously considering other options for spent fuel management. There are also obvious institutional interests in continuing to operate and/or keep operational reprocessing plants upon which thousands of jobs depend.

Various branches of DOE have issued dozens of documents relating to spent fuel management, and there has been poor coordination among them. This has not only lent to the prevailing confusion of DOE spent fuel management policy, but it has also served as a vehicle for advancing reprocessing proposals. Some DOE documents are better than others in terms of pointing out some of the liabilities of reprocessing, and the differences appear to result from internal DOE debates over the environmental and non-proliferation consequences of reprocessing.

This review of reprocessing and alternatives to it is divided into three main sections. The first section provides background information on the history of reprocessing in the United States, both military and civilian, and the Clinton administration's policy on reprocessing and fissile materials. The second section examines the non-proliferation and environmental consequences of reprocessing. It assesses the validity of DOE's main arguments in favor of reprocessing and discusses some alternatives. The third section is the bulk of the report and examines each of the EIS's and the electrometallurgical processing proposal in detail, pointing out areas of flawed analysis and the inconsistencies among the documents.

POLICY BACKGROUND

History of U.S. Military Reprocessing

The United States obtained plutonium for its nuclear arsenal from five reprocessing plants at Hanford, Washington and two reprocessing plants at the Savannah River Site in South Carolina. Hanford began operating in 1944 during the Manhattan Project, and the Savannah River Site in 1952. A variety of reprocessing techniques were used at Hanford, the most common and recent being the PUREX, or Plutonium URanium EXtraction process. PUREX involves dissolution of spent fuel in acid and separation of plutonium and uranium from other components by the addition of an organic chemical such as tributylphosphate. PUREX was the process adopted at the Savannah River Site. During the Cold War, most plutonium separated at these reprocessing plants was used to make the pits, or cores, of nuclear weapons, and most separated uranium was recycled into new fuel for plutonium production reactors. The Chemical Processing Plant at the Idaho National Engineering Laboratory (INEL) recovered enriched uranium from the spent fuel of naval and research reactors. This enriched uranium was recycled into fuel for the Savannah River Site plutonium production reactors.[14]

The United States operated at least one reprocessing plant in every year between 1944 and at least the late 1980s.[15] Plutonium extraction declined after the mid-sixties as plutonium was recycled from retired nuclear weapons, and it rose slightly in the early eighties due to an arms buildup under the Reagan administration.[16] DOE has stated that 90.6 metric tons of weapons-grade plutonium and 12.9 metric tons of fuel-grade plutonium, which can also be used in weapons, has been produced in U.S. military reactors.[17] The vast majority of this plutonium has been extracted from spent fuel in reprocessing plants. DOE has reprocessed more than 100,000 metric tons of spent fuel.[18]

All operating plutonium production reactors in the United States were shut down in 1988. Improved U.S.-Soviet relations, a large plutonium stockpile, the prospect of a START agreement with the Soviet Union, and aging facilities all contributed to this decision. Reprocessing was suspended at the Savannah River Site in March 1992 to address a safety concern regarding survival of the ventilation system in the F- and H-Canyons during a potential earthquake.

In April 1992, Secretary of Energy James Watkins authorized phasing out reprocessing operations at the Savannah River Site and INEL.[19] The phaseout plan included converting enriched uranium solutions in SRS's H-Canyon to a more stable form and "processing existing

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[14] Cochran et al 1987, pp. 37-38

[15] Though reprocessing was officially halted at the Savannah River Site and INEL in 1992, it is not known when reprocessing plants at these sites actually ceased extracting plutonium and/or uranium from spent fuel.

[16] Albright, Berkhout, and Walker 1993, pp. 31-33

[17] DOE 1994, p. 42

[18] DOE 1995e, p. 7

[19] Claytor 1992

inventories of aluminum-clad fuel at SRS as well as fuel receipts while stabilization is being conducted."[20] The phase-out decision was an important and symbolic one that demonstrated an intent to transition from INEL's and the Savannah River Site's historical reprocessing roles in the weapons production process. The policy provided inappropriate estimates for the scale of reprocessing needed for stabilization (projected to take five or six years), yet current DOE plans may involve reprocessing for an even longer time period. That is, *current policy is in many ways a retreat from the important groundwork that was laid in 1992.*

After the phaseout order was given, DOE decided (under pressure from environmental groups) to issue environmental impact statements on these reprocessing activities at the SRS, and the reprocessing canyons at the Savannah River Site did not operate from March 1992 until February 1995 pending completion of the EIS's.[21] Reprocessing at Hanford had ended in March 1990.[22]

On July 13, 1992, President Bush formally announced an end to U.S. fissile material production for military purposes. President Bush explained that his decision was part of a "set of principles to guide our non-proliferation efforts in the years ahead," and a White House "fact sheet on nonproliferation initiative" indicated that ending plutonium and HEU production was "intended to encourage countries in regions of tension such as the Middle East and South Asia to take similar actions."[23] The Bush administration recognized that officially halting military reprocessing and fissile material production in the United States would have a beneficial influence on the nuclear policies of other countries.

History of U.S. Civilian Plutonium Programs

Apart from extracting plutonium for its nuclear weapons, the United States also partially constructed an infrastructure for civilian plutonium use. In the 1940s and 1950s, uranium supplies were projected to be scarce, and recovering plutonium from the spent fuel of nuclear reactors through civilian reprocessing appeared to be a way to provide a large and continuous supply of fissile material for commercial nuclear reactors.

Three commercial reprocessing plants were built in the United States at West Valley, New York; Morris, Illinois; and Barnwell, South Carolina. The West Valley plant was the only one to operate. Between 1966 and 1972 West Valley separated 2058 kilograms of plutonium from 676 metric tons of spent fuel, mainly from the N-reactor at Hanford. The Morris plant suffered technical difficulties even before it was commercially commissioned and was declared inoperable

[20] Claytor 1992
[21] The HB-line at SRS began in January 1993 to process plutonium-238 for NASA missions.
[22] IPPNW and IEER 1992, p. 32
[23] *Statement by the President* and *Fact Sheet on Nonproliferation Initiative*. White House Office of the Press Secretary, July 13, 1992.

in 1974. The Barnwell plant was the subject of a licensing battle in the mid-seventies, and the project was put on hold when President Carter decided in 1977 to indefinitely defer all civilian reprocessing activities in the United States.[24]

President Reagan reversed his predecessor's policy and the Barnwell project lingered on through the early eighties, but the plant finally closed in December 1983.[25] The Reagan administration refused to subsidize the operation of the Barnwell plant indefinitely, and private industry could not or did not want to take up reprocessing on a commercial basis. A commercial facility for fabricating mixed plutonium-uranium oxide fuel was also built at Barnwell, but never operated.

Technical, regulatory, non-proliferation, and economic considerations all contributed to the failure of civilian reprocessing in the United States. Uranium turned out to be more abundant than projected, and the waste management, safety, and materials accounting standards that had to be met drove up the costs of the plants (large costs did not inhibit operation of the U.S. military reprocessing plants). Presidents Ford, Carter, and Reagan refused to provide federal money to support the reprocessing plants, and Presidents Ford and Carter were especially concerned about the potential of widespread reliance on a reprocessing and plutonium-based fuels to contribute to the proliferation of nuclear weapons.[26] President Ford announced in 1976 that "avoidance of proliferation must take precedence over economic interest" and that "reprocessing should be deferred until there is sound reason to conclude that the world community can effectively overcome the risks of proliferation."[27]

As will be discussed in more detail below, some of the current DOE reprocessing proposals may involve reprocessing commercial spent fuel, and plutonium extracted under DOE reprocessing proposals may be fabricated into fuel for commercial nuclear reactors. These proposals reverse long-standing practice in the United States and could be the first step down the civilian reprocessing path that the U.S. abandoned over a decade ago.

Other countries have pursued and implemented civilian reprocessing programs. Five countries (Britain, France, Russia, Japan, and India) are still operating civilian reprocessing plants despite the high costs of using plutonium as a fuel relative to uranium. The implications of these programs for nuclear proliferation are discussed below. The United States is the only declared nuclear weapon state not currently reprocessing for military or civilian purposes.

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[24] Albright, Berkhout, and Walker 1993, p. 105
[25] Carter 1987, p. 124
[26] Carter 1987, pp. 117-120
[27] As quoted in Cochran, Paine, and Werner 1992, p. 2

Continuing Affinity for Reprocessing and Plutonium

The long U.S. experience with military reprocessing created institutional interests in obtaining fissile material. Plutonium and highly enriched uranium (HEU) were produced on the military side at a rapid pace to meet the requirements of the expanding U.S. arsenal, and the risks to the environment and to the health and safety of workers and communities were allowed to remain high in pursuit of the product. A recent report on the costs of the U.S. nuclear arsenal calculated that the United States spent approximately $163 billion in 1995 dollars on obtaining bomb materials.[28] During the Cold War, the design and operation of enrichment, reprocessing, and other weapons production facilities conferred prestige and career advancement for those involved, while waste management (the "back-end" of the fuel cycle) was a personnel Siberia that did not carry prestige or great potential for promotion. As Carroll Wilson, the first general manager of the U.S. Atomic Energy Commission, acknowledged in 1979:

> Chemists and chemical engineers were not interested in dealing with waste. It was not glamorous; there were no careers; it was messy; nobody got brownie points for caring about nuclear waste...The central point is there was no real interest or profit in dealing with the back end of the fuel cycle.[29]

Despite the end of the Cold War, the end of plutonium production, and the poor economics of commercial reprocessing, the attachment to fissile materials and to a closed fuel cycle[30] remains strong among some nuclear scientists, DOE officials and contractors, and legislators today. Having been accustomed to viewing plutonium as a resource and having established careers in obtaining it, many DOE career personnel and contractors continue to hope for a more favorable U.S. attitude toward reprocessing and plutonium use. Personnel at the sites where reprocessing occurred in the past, as well as many members of nearby communities, are eager to see it continue in the future as a spent fuel management tool. Companies in the U.S. nuclear industry are urging DOE to convert plutonium from dismantled nuclear weapons into fuel for commercial nuclear reactors, and DOE is funding a "National Resource Center for Plutonium" in Amarillo, Texas to explore civilian uses of plutonium. Patrick Murphy, Washington representative of the American Nuclear Society, which represents over 16,000 nuclear scientists and engineers, said that he believes "99 out of 100 ANS members feel that nuclear fuel

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[28] Schwartz 1995, p. 8

[29] Wilson 1979, p. 15

[30] A closed fuel cycle refers to reprocessing spent fuel and extracting fissile material for fabrication into new fuel for nuclear reactors. While this kind of "recycling" sounds environmentally benign in theory, a closed fuel cycle is actually quite leaky because of substantial waste generation from reprocessing. In an open fuel cycle, sometimes called "once-through," spent fuel is not reprocessed but is instead destined for direct disposal.

reprocessing in the US should not be precluded by law or policy." He added that "[t]he issue of economics is separate and should be decided in the marketplace."[31]

There is some sentiment among powerful members of Congress in favor of reprocessing. Senator Frank Murkowski (R-AK), chairman of the Energy and Natural Resources Committee, announced after returning from a visit to French reprocessing facilities that he plans to introduce legislation to help U.S. utilities wishing to send commercial spent fuel overseas for reprocessing. "We, unlike the British and the French, have a policy of no reprocessing," he said, "that puts the utilities in a very, very difficult position who are about to run out of [waste storage space]." Further, Murkowski explained that "France has a policy that says 'We will not permanently put in the earth or sea anything that has plutonium in it.' To me that's a very responsible policy." Murkowski had previously opposed Japanese plans to ship plutonium by air from reprocessing plants in France to Japan because these shipments would have flown over Alaska.[32]

Senator Strom Thurmond (R-SC), Chairman of the Senate Armed Services Committee, which oversees DOE's operation of the nuclear weapons complex, has opposed shipments to and storage of spent fuel at the Savannah River Site in his state, but he continues to advocate reprocessing there. In a June 29, 1995 letter to Senator Murkowski, Senator Thurmond wrote: "I have for many years stated my opposition to Aiken, my hometown, becoming a nuclear dumping ground." In the very next paragraph, however, Senator Thurmond asserted that "a rational proposal for dealing with nuclear waste" should include, "at minimum:"

> Construction and funding of storage and reprocessing facilities at SRS specifically for *commercial*, research (foreign and domestic) and other DOE spent fuel, along with legislative mandates that reprocessing, once begun, not be interrupted.[33] [emphasis added]

High-level nuclear waste is an inevitable by-product of reprocessing. Without a serious repository program for high-level waste (a program the U.S. currently lacks), reprocessing at the Savannah River Site would add to the already huge quantities of high-level waste there. The Department of Energy and advocates of reprocessing tends to ignore or downplay the dangers from the wastes that would result from re-starting reprocessing.

Senator Thurmond attached an amendment to the Senate Defense Authorization Act (S. 1126) authorizing $30 million for development work at the SRS on "technological methods (including plutonium processing and reprocessing) of separating, reducing, isolating, and storing the spent nuclear fuel rods that are to be sent to the site from other DOE facilities and from foreign facilities." Such spending appears mainly directed at sending federal money to South Carolina.

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31 Letter from Patrick Murphy to Noah Sachs, July 18, 1995

32 Pamela Newman, "Murkowski Looks Overseas for Nuclear Waste Solution," *The Energy Daily*, April 28, 1995

33 Letter to Senator Frank Murkowski, June 29, 1995

Clinton Administration Policy on Reprocessing and Fissile Materials

President Clinton's policy on reprocessing was issued in September 1993 in Presidential Decision Directive No. 13. The document is classified, but it is believed to closely parallel a public document issued around the same time: the White House "Fact Sheet on Non-Proliferation and Export Control Policy" dated September 27, 1993.[34] The fact sheet stated that the Clinton administration policy toward reprocessing and fissile materials is to "seek to eliminate where possible the accumulation of stockpiles of highly enriched uranium or plutonium" and to "explore means to limit the stockpiling of plutonium from civil nuclear programs..." The fact sheet also stated that the "United States does not encourage the civil use of plutonium and, accordingly, does not itself engage in plutonium reprocessing for either nuclear power or nuclear explosive purposes." *This statement shows that the administration recognizes the link between its abstention from reprocessing and not encouraging the civil plutonium programs of other countries.* It is true that this statement does not explicitly bar reprocessing for environmental management purposes, but reprocessing for such purposes would contravene other goals laid out in the fact sheet, such as seeking to eliminate, where possible, accumulation of stockpiles of HEU and plutonium. Also, the use of plutonium extracted under the spent fuel management program as fuel for nuclear reactors may contravene this statement, because this is akin to reprocessing for nuclear power purposes.

In practice, the administration has been selective in opposing reprocessing and fissile material accumulation abroad. It has negotiated extensively with North Korea to shut down its reprocessing program and has worked to convince India and Pakistan to cap their military fissile material stockpiles. However, the U.S. has not made curtailing civil reprocessing a high priority, and it has not invoked consent rights over uranium supplied to Japan and Western European countries, a move that would bar countries from transporting spent U.S.-supplied reactor fuel to reprocessing plants in other countries. More positively, the administration has taken some steps to assist Russia in securing its fissile materials, although much more effort is needed in this area.

Despite this mixed record abroad, the administration's commitment to discouraging plutonium accumulation in the United States has so far been very strong in practice. Secretary of Energy Hazel O'Leary has called excess plutonium a "global security risk and an economic liability,"[35] and she strongly opposed the Integral Fast Reactor (IFR) at INEL on non-proliferation grounds even though her department would have received the funds for the project. The IFR was a reactor designed to burn plutonium, but it could be converted to breed more plutonium than it used. The IFR was coupled with "pyroprocessing" technology, a kind of reprocessing technology designed to separate fissile materials from IFR spent fuel for use in refueling the IFR, thus closing the IFR fuel cycle. Secretary O'Leary's opposition to the IFR project was a major factor in

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[34] The fact sheet may be found in the background documents in DOE 1995c, Appendix G.

[35] *New York Times*, August 19, 1994

turning congressional sentiment against it during 1994. In a 1994 letter to Senator John Kerry, O'Leary wrote: "Because it is based on plutonium reprocessing and recycle, continued development of the Integral Fast Reactor would undercut our efforts to discourage other countries from plutonium reprocessing and recycle."[36]

Congress eliminated FY95 funding for the IFR under DOE pressure, but it directed DOE to pursue the pyroprocessing technology on a stand-alone basis as part of an alternative mission program for Argonne National Laboratory. Non-proliferation and arms control groups praised DOE's opposition to the IFR; at the same time the continuation of the pyroprocessing program highlighted the political difficulty of completely eliminating plutonium fuel-cycle projects in the United States.

[36] O' Leary 1994

REPROCESSING -- CONSEQUENCES & ALTERNATIVES

Environmental Implications of Reprocessing

U.S. military reprocessing plants were never intended as environmental clean-up facilities, and in fact reprocessing has been the one of the leading causes of environmental contamination from nuclear weapons production in the United States as well as in other countries.[37] DOE's *Baseline Environmental Management Report* concluded that managing the wastes from reprocessing will account for over half of the total cost of addressing the environmental legacy of U.S. nuclear weapons production.[38] DOE environmental practice has improved since the peak years of nuclear weapons production, but re-starting reprocessing to address environmental and safety concerns relating to spent fuel will nonetheless pose environmental problems and safety risks and aggravate existing ones.

Radioactive Wastes from Reprocessing

Reprocessing generates substantial amounts of high-level, low-level, and transuranic wastes. About 100 million gallons of high-level waste have been generated over the past five decades, mainly due to plutonium extraction. In the United States, the acidic high-level wastes that resulted from reprocessing (the radioactivity was mainly from fission products) were neutralized and then stored in large waste tanks, and there is currently some potential that these tanks could explode due to a cooling system failure or the combustion of hydrogen or organic materials.[39] The worst nuclear accident in history occurred at the Chelyabinsk-65 site in Russia in 1957 due to a cooling system failure in a reprocessing waste tank. The explosion contaminated 1,000 square kilometers with a level of strontium-90 forty times as high as the background radiation level.[40]

Assessing the risk of such an explosion in the reprocessing waste tanks at Hanford and the Savannah River Site is difficult because the contents of the tanks and the distribution of materials inside the tanks are not well understood, especially at Hanford. DOE has acknowledged that hydrogen in certain Hanford tanks presented explosion risks, and hydrogen concentrations in tanks at the Savannah River Site have reportedly exceeded flammability limits on two occasions.[41]

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[37] A recent source on the environmental and health effects of nuclear weapons production is *Nuclear Wastelands: A Global Guide to Nuclear Weapons Production and Its Health and Environmental Effects.* Cambridge: MIT Press, 1995. *Nuclear Wastelands* is a joint project of the Institute for Energy and Environmental Research and the International Physicians for the Prevention of Nuclear War.

[38] *Baseline Environmental Management Report*, March 1995

[39] There is a small probability that an explosion could result from an accidental nuclear chain reaction in reprocessing waste tanks. Lack of knowledge of the type and distribution of tank contents prevents an accurate assessment of this risk.

[40] Saleska and Makhijani 1990, p. 45

[41] IEER and IPPNW 1992, p. 102 and p. 106

Despite the uncertainties in assessing the risk, it is reasonable to conclude that the addition of more high-level waste to the tanks from the current reprocessing proposals would increase the risk of a waste tank accident by some amount. While reprocessing does not create additional radioactivity, it turns solid fission products into high-level liquid wastes. Storing these wastes in the high-level waste tanks at the Savannah River Site may increase the health and environmental damage from an accidental tank fire or explosion. Such fires or explosions are a crucial concern despite the official stance that the likelihood of such events is very small because of the potentially severe consequences should they occur.

DOE estimates that reprocessing some of the spent fuel and targets currently at the Savannah River Site pursuant to the Interim Management EIS would generate about 11.6 million liters of high-level liquid waste over ten years.[42] This would be added to the waste tanks at the SRS, and it is a 9% increase over the amount of high-level waste that DOE said was at the SRS at the end of 1993. In absolute terms, these reprocessing activities will create enough waste to fill a cube that is nearly seventy-five feet on each side, and these waste figures do not include high-level waste generation from potential reprocessing foreign research reactor spent fuel or other materials. In assessing the relative merit of reprocessing as a waste management tool, DOE does not explore the implications for the safety of the waste tanks and thus overlooks an important disadvantage of reprocessing.

The contents of high-level waste tanks at Hanford and the Savannah River Site are planned to be vitrified, or mixed with molten glass to form glass logs in steel canisters. High-level waste from the current reprocessing proposals would also be vitrified after storage in the tanks for a number of years. Vitrification of SRS wastes would occur at the Defense Waste Processing Facility (DWPF) at the SRS, and those from Hanford will be treated at Hanford. As of early December 1995, the DWPF was not operational. It is six years behind schedule and $2 billion over budget.[43] The concerns about adding to the stores of liquid high-level wastes at the SRS are heightened by this history of delays and problems with the DWPF.

In addition to high-level radioactive waste, low-level waste and transuranic waste would also be produced by reprocessing. DOE estimates that 31,600 cubic meters of low-level waste and 720 cubic meters of transuranic waste would be generated from reprocessing 184.4 metric tons of aluminum-clad spent fuel at the Savannah River Site.[44] This is a 4.8% and 8.1% increase,

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[42] DOE 1995b, pp. 2-55 to 2-58. DOE estimates 2.1 million liters for reprocessing Mark-31 targets, 1.6 million liters for reprocessing EBR-II and Taiwan Research Reactor spent fuel, 7.3 million liters from Mark-16 and Mark-22 fuels, and 0.59 million liters from other aluminum-clad targets. There were 127 million liters of high-level waste at SRS at the end of 1993 (DOE 1994e, p. 47).

[43] GAO 1992, p. 3 and p. 14

[44] DOE 1995a, Appendix C, p. 5-49. 213.1 metric tons is the amount of aluminum-clad spent fuel that would be at the Savannah River Site after DOE regionalizes its fuel by fuel type pursuant to the SNF/INEL EIS. This figure includes 28.7 metric tons of research reactor spent fuel. The total amount reprocessed may actually be smaller depending on the decision regarding Mark-16 and Mark-22 targets and foreign research reactor spent fuel.

respectively, over the levels of these types of waste DOE has stated were at the SRS at the end of 1993.[45]

The discussion below on alternatives to reprocessing will show that interim storage of spent fuel would pose far fewer hazards and would generate substantially less waste than reprocessing.

Fissile Material Extracted by Reprocessing

Plutonium and uranium extracted under the current reprocessing proposals would become an additional waste burden for DOE, as DOE has pledged not to use these materials in nuclear weapons.[46] The plutonium would have to be stored for an interim period until ultimate disposition, and stored plutonium is already a major headache for DOE at several sites and especially at the Rocky Flats Plant near Denver. DOE's Office of Environmental Management is currently spending millions to resolve "vulnerabilities" within the weapons complex related to stored plutonium. Under the Interim Management EIS, DOE is planning to dissolve and reprocess some of the stored plutonium solids currently at the Savannah River Site because their continued storage in their current form poses safety risks.[47]

As for final disposition of plutonium, DOE is currently preparing an environmental impact statement on storage and disposition of plutonium from dismantled nuclear weapons and other sources, and any newly extracted plutonium would presumably be added to the stockpile of plutonium to be disposed of. The total amount of plutonium to be disposed of has not yet been decided, but a recent National Academy of Sciences study and most other studies on the subject take fifty metric tons as a notional amount for the purpose of making calculations and comparisons. Over 400 kilograms of plutonium could be extracted under current reprocessing proposals, and about 4,000 kilograms could be extracted if N-reactor spent fuel is reprocessed.

The two leading disposition options for plutonium are vitrification (either at the DWPF or a new vitrification plant) or conversion of plutonium into mixed-oxide (MOX) fuel for nuclear reactors and subsequent disposal of the spent MOX fuel. Whichever method is eventually chosen, the National Academy of Sciences has said that the task of disposing of plutonium is "pressing" and that "the solutions will be complex, expensive, and long-term."[48]

Disposition of plutonium as MOX fuel would entail use of a key component of a civilian plutonium infrastructure: a MOX fabrication plant. In a 1995 IEER book entitled *Fissile Material in a Glass, Darkly*, Arjun and Annie Makhijani argued for the vitrification option and

[45] DOE 1994e, p. 136 and p. 101. The source states that the Savannah River Site had 665,000 cubic meters of low-level waste and 8925.9 cubic meters of transuranic waste at end of 1993.
[46] See page 18 for more discussion of this pledge.
[47] According to the Interim Management EIS, the heat and radiation from decay of the plutonium is causing the plastic that surrounds the plutonium to degrade (DOE 1995b, pp. 1-20 and 1-21). This can lead to a buildup of hydrogen in the storage container, increasing the risk of an explosion or container failure.
[48] NAS 1994, p. 20

asserted that construction and use of a MOX fabrication plant would undermine the U.S. position to work toward curtailing civil plutonium programs in other countries. Disposing of plutonium extracted from spent fuel under the current proposals as MOX fuel would have even worse proliferation consequences than disposing of plutonium from dismantled warheads as MOX fuel. This is because reprocessing followed by MOX fabrication and use would be closely akin to a closed fuel-cycle and thus would seriously undercut efforts to halt reliance on a closed-fuel cycle in other countries. It would also circumvent the Clinton administration policy of not reprocessing for nuclear power purposes.

Disposing of the highly enriched uranium that may be extracted under the environmental management program (for instance, from foreign research reactor spent fuel) is technically more straightforward than disposing of plutonium. HEU can be "blended-down" into non-weapons-usable low enriched uranium (LEU) by mixing it with natural, slightly enriched, or depleted uranium. The LEU can be sold as reactor fuel, although some of it may have impurities which may prevent use in U.S. reactors without further processing.

In general, the recent EIS's propose blending-down HEU extracted by reprocessing, but they do so in an almost off-hand way with no discussion of schedule or technical and institutional issues. Over 4,000 kilograms of HEU may have to be blended-down, and measures to prevent theft, criticality,[49] and releases of radioactivity above regulatory limits are required. These measures are not discussed in the DOE documents and EIS's.

Because problems of storing and disposing of radioactive waste and fissile materials remain, reprocessing should not be seen as the end stage of addressing environmental and safety problems stemming from spent fuel. DOE makes this mistake throughout its recent EIS's, paying far too little attention to the problems that remain after reprocessing. Comments submitted by the Natural Resources Defense Council and the Energy Research Foundation on the Interim Management EIS summed up the situation succinctly: "Processing activities in the canyons result in two products: separated nuclear material and large amounts of radioactive waste. It is a substantial understatement to observe that the United States hardly needs more of either of these products."[50]

Specifically, the high-level wastes that would be produced present far greater risks of contributing to severe contamination in case of earthquakes and similar natural disasters, since they would be stored in liquid form, whereas almost all the fission products even in corroding spent fuel are in solid form either in the spent fuel or in the cooling pool filters. Only a tiny proportion is in the pool water at any time. The fact that DOE is converting the bulk of the

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[49] A criticality is a nuclear chain reaction that can occur if fissile material accumulates in such a configuration that neutrons emitted by radioactive decay split enough other atoms to cause a chain reaction. While it provides no where near the explosive energy of a nuclear weapon, a criticality can cause a small explosion and disperse radioactive material.

[50] Caputo and Costner 1995

radioactivity in the spent fuel into a more dangerous form so far as storage is concerned has not received recognition or analysis in the EIS's.

This is not the first time that the DOE has made this mistake. In 1989, the DOE/Westinghouse proposal to reprocess N-reactor spent fuel similarly neglected to analyze the impacts of increasing the quantities of liquid high-level wastes. After an IEER analysis pointed this out, DOE agreed to reconsider dry storage and eventually decided to pursue storage rather than reprocessing.

Safety Issues Involving the Reprocessing Plants

Reprocessing is a complicated industrial process, and the H-Canyon and F-Canyon at the Savannah River Site are over forty years old. Of all the steps involved in plutonium production, reprocessing involves the highest worker exposures and some of the greatest accident risks. This is because reprocessing converts solid spent fuel, which is extremely radioactive, into large volumes of liquid. Plant maintenance and addressing malfunctions and minor accidents in such a highly radioactive environment is dangerous even when the operations are done remotely, as they must be.

In addition to routine risks, reprocessing also poses risks of severe accidents, as was demonstrated by the explosion in the Russian reprocessing plant at Tomsk-7 in 1993. There have been three smaller, similar explosions in U.S. reprocessing history during the 1950s.[51]

In a November 15, 1995 letter to Hazel O'Leary, the Defense Nuclear Facilities Safety Board acknowledged the state of the aging reprocessing plants at the Savannah River Site: "Unfortunately, [the canyons] are old and while still operable are not in the best of shape." In a perfect example of twisted logic, however, the Board recommended that both canyons be kept operable because "if necessary each can back up the other in processing capability. Then in event of an unfortunate incident, such as an accident that incapacitated a Canyon (e.g., a fire, a massive contamination, a seismic event), there should still be the other to carry on."[52] This sentence sharply highlights the commitment to reprocessing in some quarters, without due regard to the potential consequences. For the DNFSB, maintaining a reprocessing capability is so important that it should continue even if a forty-year old reprocessing plant is decimated in a major accident.

Non-proliferation Implications of Reprocessing

In addition to environmental and safety drawbacks, re-starting reprocessing would have negative consequences for U.S. non-proliferation policy at a time when preventing nuclear proliferation should be one of the United States' highest priorities.

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[51] IPPNW and IEER 1992, pp. 57-58

[52] DNFSB letter to Secretary Hazel O'Leary, November 15, 1995

The Department of Energy has stated that the fissile materials that may be separated under its environmental management program would not be used in nuclear weapons, committing to "prohibit the use of plutonium-239 and highly enriched uranium separated and stabilized during the phaseout, shutdown, and cleanout of weapons complex facilities for nuclear explosive purposes."[53] DOE already possesses tons of plutonium and HEU from dismantled nuclear warheads.[54]

In the international arena, however, perceptions of intentions are often at least as important as actual intentions, and reprocessing could undermine U.S. non-proliferation goals in several areas. First, many countries, especially non-aligned countries, could view DOE reprocessing as antithetical to the disarmament commitments the United States made when it signed the Non-Proliferation Treaty in 1968 and re-affirmed when the Treaty was indefinitely extended in May 1995. Article VI of the Treaty commits signatories to "pursue negotiations in good faith on effective measures relating to the cessation of the arms race at an early date and to nuclear disarmament..." If the U.S. reprocesses for environmental management purposes, other countries may perceive only that the United States is continuing to add to its stockpile of weapons-usable fissile material despite the end of the Cold War. They may not put much faith in the DOE commitment to prohibit use of the material in weapons because this commitment has no verification measures and because it could easily be reversed in the future.[55]

Since the NPT was signed, a cessation of fissile material production has been widely viewed along with a comprehensive test ban as the key measures by which the nuclear weapon states should demonstrate implementation of Article VI. Non-nuclear weapon states have sharply criticized the nuclear weapon states at NPT review conferences for their failure to achieve these measures, and reprocessing for up to a decade or more, regardless of DOE intent, could exacerbate tensions between the United States and some non-nuclear weapon states. Furthermore, if the United States and other countries are perceived to be violating Article VI, it could lead to defections from the NPT, a possibility stressed repeatedly in 1995 by Sri Lankan ambassador Jayantha Dhanapala, chair of the NPT review and extension conference.

In the near-term, U.S. reprocessing could undermine negotiations taking place in Geneva on a fissile material cut-off. The "Declaration of Principles for Nuclear Non-Proliferation and Disarmament" adopted by the United States and most other NPT signatories in May 1995 calls for "[t]he immediate commencement and early conclusion of negotiations on a...Convention banning the production of fissile material for nuclear weapons or other nuclear explosive

[53] Reis and Grumbly 1994

[54] The United States government has not declared how much of the plutonium and HEU from dismantled warheads is surplus to military requirements, and the U.S. could keep most of it as a reserve or even build new nuclear warheads with it should it deem that step to be necessary.

[55] It is doubtful that the United States would place much value in this kind of commitment, which has no verification measures, from another country.

devices..." For the U.S. to operate the reprocessing facilities it used during the Cold War could be perceived as contrary to the spirit of the Geneva negotiations, just as recent Chinese and French nuclear tests, while legal under international law, are widely perceived as contrary to the spirit of the Geneva negotiations on a Comprehensive Test Ban Treaty.[56]

Over the longer-term, U.S. reprocessing could complicate inspection and verification components of an international fissile material cut-off treaty. DOE's preferred options under the Interim Management EIS call for reprocessing at the Savannah River Site through 2002, and the Foreign Research Reactor EIS discusses reprocessing for twelve years between 1996 and 2008.[57] Such long-term operation of formerly military plants under an international treaty regime designed to halt military reprocessing could be perceived as inequitable or possibly as a treaty violation.

The potential concerns of other countries about the intent behind reprocessing could be somewhat assuaged by a DOE commitment to put any plutonium extracted under the environmental management program under IAEA safeguards and to blend down any extracted highly enriched uranium into non-weapons-usable low enriched uranium. DOE has yet to make such commitments, however. The Clinton administration, in its September 27, 1993 fact sheet on non-proliferation discussed above, stated that it "will submit U.S. fissile material no longer needed for our deterrent to inspection by the International Atomic Energy Agency."[58] Despite this presidential policy, only one of the EIS's discussed in this report, the F-Canyon EIS, expresses an intention to place extracted fissile material under IAEA safeguards, and even this EIS does not outline the technical and institutional steps necessary to do so. One document discussed below states that HEU extracted by reprocessing could be stored as HEU rather than blended-down. These are serious flaws in DOE policy that will exacerbate the negative non-proliferation consequences of reprocessing.

Apart from raising questions about U.S. intentions, reprocessing would undermine the U.S. position to work toward halting reprocessing in other countries. Stopping all reprocessing in North Korea and military reprocessing in India and Russia have been major U.S. non-proliferation goals over the past several years. The perception of a U.S. double-standard on reprocessing could hinder further efforts with these countries, as well as with other countries of U.S. proliferation concern with nascent reprocessing programs, such as Pakistan. China is developing a civilian reprocessing infrastructure to provide fissile material for its ambitious nuclear power program.

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[56] The "cut-off" treaty may bar reprocessing of only that spent fuel generated by military reactors after the treaty enters into force. The spent fuel that DOE may reprocess has already been generated, except for foreign research reactor spent fuel, which is not military in nature. Still, these distinctions do not obviate the fact that prolonged U.S. extraction of weapons-usable fissile material could undermine the negotiations and the implementation of the treaty.

[57] DOE 1995c, p. F-285

[58] DOE 1995c, Appendix G

Ukraine has recently submitted a proposal to the G-7 industrialized countries to build a civilian reprocessing plant at the Chernobyl site.[59]

A historic 1994 agreement between the United States and Russia to halt fissile material production is still very much in flux and could be undermined by U.S. reprocessing. A verification component of the agreement has not yet been finalized,[60] and the agreement has not entered into force because of disputes over exchange of classified information and over financing replacement power sources for the plutonium production reactors at Tomsk and Krasnoyarsk. Russia may still be reprocessing spent fuel from these reactors and extracting weapon-grade plutonium.[61] DOE is of the opinion that reprocessing already-created spent fuel will not jeopardize further negotiations on the U.S.-Russian agreement. However, given the continual flux in Russian politics, this cannot be taken for granted. As negotiations continue, U.S. plans for long-term reprocessing activities in formerly military plants could raise Russian concerns about equity and verification. U.S. reprocessing may also make it more difficult for the United States to dissuade Russia from replacing its military plutonium production reactors with civilian plutonium breeder reactors as power sources. Finalizing the agreement and assuring its entry into force should be high U.S. foreign policy priorities.

Reprocessing in the United States would also hinder efforts to halt civilian reprocessing in other countries. Civilian reprocessing has not received as much high-level attention from the U.S. government as military reprocessing, but it is a long-term proliferation danger. Britain, France, Russia, Japan, and India continue to operate reprocessing plants to obtain plutonium for commercial energy purposes despite the poor economics of commercial plutonium. Several countries in Western Europe, such as Belgium, Germany, and Switzerland, own plutonium separated in Britain and/or France.

By the year 2000, the total amount of separated plutonium in the civilian sector is expected to surpass the total amount of plutonium in the world's nuclear arsenals. It is expected to continue to grow thereafter (see the table below). This trend is disturbing because although civilian plutonium has a different isotopic composition from the plutonium that has been produced for weapons, it can be used to make a nuclear explosive. This was demonstrated in a successful 1962 test by the United States Atomic Energy Commission.[62] The rapid accumulation of plutonium in the civilian sector increases the chance that some of it could be diverted to weapons use.

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[59] Europe Information Service, October 17, 1995

[60] The agreement bars extraction of plutonium produced in military nuclear reactors after the agreement enters into force. As the current DOE reprocessing proposals involve already-created plutonium, they are not explicitly barred by the agreement, and Russian inspectors most likely would not observe the reprocessing procedures.

[61] Russia has claimed that as of October 1, 1994 it ceased using plutonium extracted through reprocessing the spent fuel of the reactors in nuclear warheads (*Arms Control Today*, March 1995, p. 15).

[62] DOE 1994, p. 186

Estimated Global Accumulation of Separated Plutonium in Metric Tons

Type	1970	1980	1990	1994, end	2010
Military	130	210	265	270	<275
Commercial	5	40	120	180	370-546

SOURCE: 1970, 1980, 1990, 1994 figures: IEER calculations from diverse sources.
2010 figures based on Albright, Berkhout, Walker 1993, pp. 203-206.[63]

The security dangers from reprocessing (both military and civilian) are especially prominent in Russia, where political and economic instability have raised serious questions about continued governmental control over the nuclear weapons complex. Reprocessing increases the amount of separated weapons-usable material and provides opportunities for employees to have access to it. There have already been seizures of smuggled weapons-usable fissile materials within Russia, and German police seized smuggled plutonium on three separate occasions in 1994. Despite the security risks from fissile materials in Russia, President Yeltsin gave approval in 1995 to complete construction of the RT-2 reprocessing plant at Krasnoyarsk-26, which when completed will separate several thousand kilograms of commercial plutonium per year.

The dangers posed by fissile materials in Russia are widely acknowledged as one of the greatest proliferation risks the world faces. Declining wages, high-levels of organized crime, and shifting political currents heighten the chance of a diversion of fissile material by a plant employee or other insider. A state or terrorist group obtaining Russian plutonium or highly enriched uranium -- greatly shortening the path to a nuclear capability -- remains a proliferation nightmare. Russia should not aggravate these dangers by continuing to extract weapons-usable fissile material from spent fuel.

As a country that has stopped both civilian and military reprocessing, the United States is in a strong position to work with Russia and the other states that operate reprocessing plants to halt plutonium extraction and use. *Any move to re-start reprocessing, even if for an environmental management program, would undermine the United States' authority and credibility on this issue at a time when its leadership is most needed.* This would be especially true if U.S. reprocessing plants are re-started without a firm and legal commitment to shut down all reprocessing plants in the U.S. by a specific date in the near future.[64] Permanently

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[63] Albright, Berkhout, and Walker do not provide a military estimate for 2010 but predict a very small increase in military plutonium stocks over 1990 levels. The lower commercial figure for 2010 is if reprocessing contracts in existence in 1990 were stretched out over 20 years. The higher figure is the maximum potential separation capacity of reprocessing plants that will operate until 2010.

[64] Plants used only to separate medical and research isotope, such as molybdenum-99, are not included in this discussion. The EIS's discussed in this report do not involve such facilities.

decommissioning and dismantling U.S. reprocessing plants, which are aging structures anyway, would enhance the U.S. position to achieve non-proliferation objectives. The DOE study recommending consolidating reprocessing operations in the F-Canyon at the Savannah River Site and putting H-Canyon into a "de-inventoried standby condition"[65] is a positive step. Still, a decision to use one reprocessing plant instead of two does not carry the benefits of a decision not to reprocess at all. Moreover, the study does not call for a permanent, irreversible shut down of H-Canyon; by definition, a plant on stand-by can be reactivated.

Interim Storage: An Alternative to Reprocessing

It would be overly simplistic to oppose reprocessing without suggesting an alternative. DOE's spent fuel vulnerability reports are catalogues of spent fuel stored in inadequate facilities under unsuitable conditions. Corroding or reactive spent fuel does pose some safety risks to workers in terms of increasing radiation doses, and allowing the corrosion to continue for prolonged periods would make it more difficult to move, repackage, or stabilize the spent fuel. Because each type of DOE spent fuel is different in chemical and nuclear properties and because the final disposal of DOE spent fuel is likely to be two decades or more away, the uncertainties and complexities of spent fuel management are enormous. This causes some to argue that DOE should utilize a spent fuel management approach with which it has a fair amount of experience, that is, reprocessing. *Yet for the vast majority of DOE spent fuel, DOE is planning to resolve spent fuel "vulnerabilities" through non-reprocessing methods, at least in the near-term.* For example, DOE plans to move corroding spent fuel in the ICPP-603 basin at INEL to a more modern storage facility, and it is planning to remove corroding N-reactor spent fuel at Hanford from storage pools into a new storage facility.

Improving the safety conditions in storage pools and eventually moving spent fuel into interim storage is the most attractive alternative to reprocessing in terms of near-term spent fuel management. DOE's own data show that interim storage poses far fewer risks to workers, offsite populations, and the environment than reprocessing. Issues of longer-term repository disposal of spent fuel will be discussed later in the report.

Two interim storage options are available. Wet storage involves storage under water in a cooling pool and is the storage method in use at most nuclear reactors around the world. For spent fuel that is corroding, mitigation measures can be taken in the wet storage environment. For example, DOE encapsulated corroding spent fuel in Hanford's K-West basin in order to prevent radioactive material releases into the basin water. Such mitigation measures can help to reduce the urgency to reprocess spent fuel. However, storage of spent fuel under water for

[65] DOE 1995f, p. 1

prolonged periods leads to generation of substantial quantities of low-level radioactive waste and may complicate packaging of the spent fuel for repository disposal.

Dry storage has been used in the nuclear industry for over forty years, and several U.S. nuclear power plants have licensed, built, and operated dry storage facilities over the past seven years.[66] Dry storage involves encapsulating spent fuel in steel cylinders that may be placed in steel casks or in a concrete or steel vault. The spent nuclear fuel is stored in racks within the cylinder in air or an inert atmosphere, and spent fuel with deteriorating or suspect cladding can be placed into sealed cans before being placed in the cylinder. Dry storage has the advantage of avoiding the potential that radioactive materials would leak into the cooling ponds and subsequently into soil. DOE has stated that "[a]ssessments of dry storage indicate that in most applications it results in fewer environmental, safety, and health vulnerabilities than current wet storage methods."[67] Criticality concerns with dry storage can be minimized by adding neutron absorbers and controlling the spacing between spent fuel elements. Dry storage in an inert gas also minimizes risks of fires and halts further corrosion of spent fuel.

DOE's own data in several EIS's show that interim storage options for spent fuel pose fewer environmental and safety problems than reprocessing. For example, DOE documents indicate that wet or dry storage options generate less radioactive waste than reprocessing for a given amount of spent fuel. DOE estimates that 2.1 million liters of high-level liquid waste would be generated by reprocessing Mark-31 targets at the Savannah River Site, while less than half that, 0.87 million liters, would be generated from improving storage.[68] The amount of high-level waste generated from the storage option is exaggerated because of the way high-level waste is defined (see the section on the Interim Management EIS for further discussion).

In general, storage options also pose far fewer safety risks than reprocessing in terms of radiation doses to workers and the offsite population and in terms of estimated fatal cancers in workers and the offsite population. DOE data show that the incremental radiation dose to the offsite population near the Savannah River Site may be as much as *four to five million* times greater from reprocessing than from spent fuel storage.

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[66] This information on dry storage is based on DOE 1995c, pp. 2-41 to 2-42

[67] DOE 1994d, p. 5

[68] DOE 1995b, p. 4-11

Radiation Dose Incremental to No Action Alternative at the Savannah River Site

Management Technique	Onsite workers		Population within 50 mile radius (person-rem/year)	
	mrem/year[69]	person-rem/year	Air Pathways	Water Pathways
Dry Storage	84	0.2	3×10^{-6}	5×10^{-7}
Wet Storage	105	0.2	4×10^{-6}	6×10^{-7}
Reprocessing*	147	71	15	2.2

SOURCE: Spent Nuclear Fuel/INEL EIS, Volume 1, Appendix C, p. 5-41.
NOTE: Data are for the preferred Regionalization by Fuel Type alternative in the SNF/INEL EIS in which Savannah River Site would manage 213.1 metric tons of spent fuel. Corresponding data for No Action are 100, 0.2, 4×10^{-6}, and 6×10^{-7}.

* The table in the EIS says "processing," but the EIS states that this refers to the use of "existing F- and H-area facilities" that is, existing reprocessing plants (Volume 1, Appendix C, p. 3-13).

DOE data also show that while the increased cancer risk to the offsite population is relatively small from reprocessing, the risk of an onsite worker dying from cancer due to reprocessing is over 330 times greater than the risk from spent fuel storage.

Fatal Cancer Incidence Incremental to No Action Alternative over Forty Years at the Savannah River Site

Management Technique	Workers	Population within 50 mile radius	
		Air Pathways	Water Pathways
Dry Storage	.003	6×10^{-8}	9×10^{-9}
Wet Storage	.003	8×10^{-8}	1×10^{-8}
Reprocessing*	1	0.3	0.05

SOURCE: SNF/INEL EIS, Volume 1, Appendix C, pp. 5-42 and 5-43
NOTE: Data are for the preferred Regionalization by Fuel Type alternative in SNF/INEL EIS in which SRS would manage 213.1 metric tons of spent fuel. Corresponding data for No Action alternative are 3×10^{-3}, 7×10^{-8}, and 1×10^{-8}.

* The table in the EIS says "processing."

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69 The DOE administrative dose limit for workers is 2,000 mrem/year. However, radiation protection guidelines require that doses below the maximum allowable limit be kept as low as reasonably achievable (ALARA).

The environmental, safety, and health differences between reprocessing and interim storage are quite dramatic. It should be noted that DOE is estimating that one worker will die from cancer as a result of its potential choice of reprocessing as the spent fuel management technique at the Savannah River Site. The Interim Management EIS also shows a wide difference between some of the consequences of reprocessing and storage. Under a maximum consequence accident scenario, for example, DOE estimates that reprocessing EBR-II and Taiwan Research Reactor spent fuel would cause 6.5 latent cancer deaths in the offsite population near the Savannah River Site. Improving storage of these materials, in contrast, would cause less than 0.01 latent cancer deaths in the offsite population even with a maximum consequence accident.[70] *In general, according to DOE's own data, reprocessing causes more waste generation and much greater risks to workers and offsite populations than storage alternatives.*

Further, all of these claims regarding doses do not take into account differential risks from accidents or natural catastrophes. As noted earlier, the risks from an accidental fire or explosion in a tank or from a tank rupture during an earthquake are likely to be far more severe from liquid high-level wastes than from storage of solid spent fuel and storage of the filters that are used to clean the pool water.

DOE Arguments in Favor of Reprocessing

Given the environmental and safety advantages of interim storage of spent fuel versus reprocessing, how can DOE justify its consideration and in some cases its preference for reprocessing spent fuel? DOE and its contractors have advanced several arguments:

1. *Reprocessing may be necessary to get spent fuel into a form suitable for disposal in a geologic repository.*

The Department of Energy has spent $4 billion on its repository program, most of it on the Yucca Mountain site in Nevada. The repository is planned to be used for vitrified military high-level reprocessing waste as well as for spent fuel from commercial nuclear reactors, but it has had a troubled history of delays and cost overruns and its future is uncertain. DOE has not yet concluded whether the Yucca Mountain site is suitable, yet no other sites are being investigated because Congress has prevented DOE from doing so. DOE expects to open Yucca Mountain some time after 2010, but there is a chance that it may never open. Most significantly, the Waste Acceptance Criteria, the regulations that will govern the type and form of nuclear material that will be allowed into the repository, have not been issued yet because DOE is still

[70] DOE 1995b, p. 2-58

studying the geologic properties of the site and possible chemical and nuclear reactions that could occur inside a repository.[71]

As stated above, the high-level waste from past and potential reprocessing activities is expected to be vitrified, with the glass logs planned for disposal in a geologic repository. While the formal Waste Acceptance Criteria have not been issued, DOE operates on the assumption that borosilicate glass, the glass that will be used to contain the reprocessing waste, is qualified for repository disposal. DOE has stated that some un-reprocessed DOE spent fuel, on the other hand, may not be suitable for a repository because of chemical reactivity, the potential that materials in the spent fuel could ignite (pyrophoricity), and because corroding spent fuel or highly enriched spent fuel could lead to a criticality in a repository. It is for these reasons that even for spent fuel that DOE plans to store in the near-term DOE does not rule out the possibility that reprocessing may be needed some time in the future before repository emplacement.

There is some question, however, about whether borosilicate glass is suitable for the proposed repository at Yucca Mountain. Borosilicate glass may degrade due to a process called hydration aging if the repository ever became moist. Subsequent flooding of the repository could carry radioactive materials upward to the biosphere.[72] IEER and others have been pointing out the potential mismatch between the repository and the waste form for as long as a decade. If further investigations at Yucca Mountain conclude that borosilicate glass is not suitable, then the current reprocessing proposals, designed for environmental management, will have created a waste form that will need to be processed again.

In any case, looking only at the disposition of high-level liquid reprocessing waste in a repository is misleading, because the plutonium extracted during reprocessing would also have to be eventually disposed of in a repository. For plutonium, neither of the proposed disposition waste forms (spent MOX fuel or plutonium in glass) is qualified for repository disposal, and both forms pose their own criticality risks in a repository, risks that could be greater than those from direct disposal of spent fuel.[73] The ultimate disposition of plutonium and uranium extracted from reprocessing is a subject largely ignored in the DOE documents. The reservations that DOE expresses regarding qualifying waste forms for repository disposal appear systematically only in the context of spent fuel but are generally absent when new reprocessing techniques such as electrometallurgical processing are being discussed.

Given the uncertainties regarding waste forms and the proposed repository, moving spent fuel into dry storage has the advantage of providing flexibility as to whether and how spent fuel

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[71] A DOE conclusion about the suitability of Yucca Mountain is expected in 1998, and a final EIS on a repository is expected in 2000.

[72] See IEER's 1991 report *Glass in the Rocks -- Some Issues Concerning the Disposal of Radioactive Borosilicate Glass in a Yucca Mountain Repository*, pp. 12-17, for more information on hydration aging.

[73] This is not to say that the forms are inadequate for already-separated plutonium from dismantled warheads, since that material already exists in separated form and must be disposed of somehow.

should be stabilized before emplacement in a repository. It makes little sense to expend resources reprocessing in the next few years, especially given its environmental and non-proliferation consequences, if it is not yet known what form spent fuel will need to be in for repository emplacement twenty, thirty, or forty years down the road. The SNF/INEL EIS, which discusses possible spent fuel stabilization and conditioning techniques but does not express an explicit preference among them, shows a more appropriate degree of uncertainty about the utility of reprocessing than other DOE documents. It states that "[b]ecause repository acceptance criteria are not defined, it is not currently possible to determine whether fissile material will have to be separated from some fuels to meet disposal criteria."[74] With such uncertainty, an approach to spent fuel management based on interim storage is the most prudent course.

It is true that highly enriched or corroding spent fuel may not be suitable in a repository without stabilization in some manner. However, this stabilization does not have to involve fissile material separation. For example, engineered barriers could be designed specifically for particular types of corroding spent fuel to keep it separate from other materials in a repository for hundreds of years. Such engineered barriers could also enable far better containment of radioactive materials provided that such a goal is built into the research program. It may also be possible to design engineered barriers for disposal of spent fuel containing highly enriched uranium to minimize criticality risks. These questions have not been carefully researched in the context of a repository program.

The Swedish repository program for civilian spent fuel provides an illustration of an approach to engineered barriers that would be desirable not only for DOE spent fuel, but also for the huge quantities of civilian spent fuel at U.S. nuclear power reactors. The Swedish program places an equal emphasis on engineered barriers and geologic conditions in and around the repository to contain radioactive wastes. The geologic repository thus acts as a back-up to engineered barriers, should they not perform as designed. This builds in a redundancy that is needed in the uniquely difficult enterprise of high-level radioactive waste disposal, which requires estimates of performance for hundreds of thousands of years. The U.S. program relies mainly on the natural geologic system to contain the wastes, while placing essentially no long-term (more than 10,000 years) requirements on engineered barrier containment.

Arguments for near-term reprocessing based on long-term criticality risks in a repository have been undermined by a 1995 report by Sandia National Laboratories. The three-volume report studied criticality risks in an unsaturated tuff environment similar to Yucca Mountain, including those risks from highly enriched spent fuel, and came to the preliminary conclusion that "it would be difficult to create conditions that would provide enough water to (1) corrode the containers..., (2) remove neutron absorbers or uranium, and (3) moderate a nuclear chain reaction within the repository. In addition, a criticality may not be technically disruptive to repository

[74] DOE 1995a, Volume 3, Part A, p. 3-30

performance."[75] The report also contradicted those who predict insurmountable regulatory hurdles to disposing of diverse types of DOE spent fuel in a repository, stating that "no characteristic of the spent fuel owned by DOE would contribute to a repository...being less likely to comply with existing regulations than if it contained other spent fuel types..."[76] Most significantly, the report addressed "the question regarding what decisions about [spent fuel] treatment can be made by DOE before a repository type and site have been identified," and concluded that "the findings suggest that ***most decisions on treatment or conditioning should wait until a repository type and site are known***."[77] [bold italics in original] While Sandia's technical conclusions about criticality are a matter of continuing investigation, they indicate that it is inappropriate to use a possible criticality in a repository to argue for reprocessing in the near-term.

An interim storage period would allow DOE to gain more information about a repository and to develop engineered barriers and/or other new technologies for spent fuel stabilization that do not involve fissile material separation. In just the few years since DOE began to focus on its spent fuel management problem, several new processing technologies have been identified that could potentially serve as alternatives to PUREX reprocessing. Technologies that DOE is researching include:

- Chopping spent fuel and adding depleted uranium or a neutron poison to prevent a criticality, followed by vitrification
- Melting spent fuel with depleted uranium or a neutron poison followed by vitrification
- Dissolving spent fuel in acid and adding depleted uranium or a neutron poison followed by vitrification
- The glass material oxidation and dissolution system (GMODS), in which spent fuel could be vitrified directly.[78]

DOE investigations of new techniques for stabilizing spent fuel without any separation of fission products from actinides should be continued and intensified. But DOE is also researching techniques such as electrometallurgical processing and the chloride volatility process that separate fissile materials from spent fuel and thus approximate PUREX reprocessing. These should be abandoned.

A technique to prepare unique types of DOE spent fuel for repository emplacement may be as simple as melting metal around it along with a neutron absorber, or it may be more complex,

[75] Sandia National Laboratories 1995, p. ES-37
[76] Sandia National Laboratories 1995, p. ES-38
[77] Sandia National Laboratories 1995, p. ES-37
[78] All of these technologies are described in DOE 1995c, pp. 2-22 to 2-23, and some of them are described in DOE 1994a.

but as long as DOE views reprocessing as a good method for spent fuel management, it is unlikely that funds would be devoted to looking at alternative stabilization techniques in any serious way. DOE's *Technology Integration Plan* alludes to this fact: "Lack of tasks and funding for disposal-related technology development reflects the uncertainty of policy issues relative to near-term SNF...decisions."[79]

DOE's likely objection to this line of argument may be based on cost considerations. DOE may assert that reprocessing in the near future is more efficient than building new interim storage facilities, investigating new technologies to prepare spent fuel for disposal, and building a new plant to ready spent fuel for a repository without fissile material separation. "Obviously," DOE has said, "selection of existing technologies to condition the SNF offer savings of time and money, and provide timely assurance to stakeholders that solutions exist and are being implemented."[80] The cost savings from reprocessing are not so obvious, however, especially since DOE does not appear to include the cost of disposing of fissile material in its calculations. Over the near-term periods covered in the Interim Management and Foreign Research Reactor EIS's, costs of reprocessing and storage are roughly comparable.[81] DOE predicts higher costs for non-reprocessing options over the long-term, but any estimate of costs over a thirty or forty year period is highly speculative.

One example of DOE's long-term estimation of costs may be found in the Foreign Research Reactor EIS. DOE states that if foreign research reactor spent fuel is not reprocessed but is instead stored for an interim period, then there would be large cost uncertainties related to repository disposal. These uncertainties stem mainly from potential criticality risks of putting HEU spent fuel into a repository. The EIS states that reducing the enrichment of the spent fuel to 1% without fissile material separation would increase costs by at least $1 billion in undiscounted 1996 dollars. This is because a much larger mass of material would have to be emplaced in the repository. In addition, costs on the order of several hundred million dollars would be required to design, develop, and conduct the nonseparative dilution activities.[82]

Again, these are cost projections for three decades into the future, and DOE has set up a straw man by assuming that the alternative to reprocessing is to reduce the enrichment of uranium in foreign research reactor spent fuel to 1%. Even spent fuel from commercial power plants has almost twice this amount of fissile material in it (including uranium-235 and all fissile isotopes of plutonium). There is no basis for DOE to assume that any blending down of this spent fuel is necessary or that appropriate engineered barriers and a sound choice of repository would not be able to address the issues surrounding management of this spent fuel at least as well as reprocessing. As stated above, DOE has found the storage option to be the most attractive for

[79] DOE 1994a, p. 2-2
[80] DOE 1994a, p. 3-9
[81] Cost issues are discussed in more detail in the sections of this report relating to these two EIS's.
[82] DOE 1995c, p. F-268

the N-reactor spent fuel at Hanford, which comprises over 75% of DOE's spent fuel inventory. This alone would justify a more careful scrutiny of the dry storage option than DOE has given.

DOE should focus its spent fuel management program on improving current storage of spent fuel, constructing new storage facilities, and developing spent fuel stabilization techniques that do not separate fissile material. Finally, it should decommission and dismantle its existing reprocessing plants.

2. *Reprocessing is necessary to remediate short-term safety and environmental problems stemming from some corroding spent fuel.*

This argument is currently being made in reference to corroding spent fuel and targets at the Savannah River Site, materials that are covered in the Interim Management EIS. It should be noted that the same argument was used by DOE and Westinghouse five years ago in reference to the corroding N-reactor fuel at Hanford. DOE eventually chose not to reprocess the spent fuel, however, and it has followed and will follow a storage option for that fuel.

The policy and technical issues surrounding the corroding materials at the Savannah River Site are discussed in more detail in the Interim Management EIS section of this report. That section finds some problems with DOE's decisionmaking process for many of the materials proposed for reprocessing at the SRS.

The major problem with this argument for reprocessing is not short-term issues of which type of materials can justifiably be reprocessed, though there are some weaknesses in DOE's analysis in this area. Rather, the problem is that as DOE's inventory of spent fuel ages, there will undoubtedly be additional materials that will begin to corrode or degrade. If reprocessing is viewed as a sound management method for such corroding spent fuel, then DOE may continue to justify keeping reprocessing plants operational indefinitely. DOE will have little incentive to investigate in the near-term non-reprocessing options that could address the problem of corroding spent fuel over the long-term.

Leaving spent fuel in wet storage for a few years as a dry storage facility is constructed carries some safety risks as radiation levels in the pools may increase and as further corrosion may complicate movement of the fuel to a dry storage facility. But all spent fuel management options carry risks, and the risks from reprocessing appear to be much greater than those from continued storage.

Conclusions of the National Academy of Sciences

The fact that the Department of Energy has no comprehensive decision-making process for assessing various spent fuel management technologies and options is recognized by one of the United States' leading scientific institutions. A committee of the National Academy of Sciences, in a 1995 report on electrometallurgical processing, asserted that it had difficulty assessing the technology in comparison to other options, including direct disposal of spent fuel, because it was "unable to determine that DOE has developed a broad comprehensive strategy covering interim management and ultimate disposition of DOE SNF from operation of DOE, U.S. commercial, and U.S. and foreign research reactors." The committee acknowledged DOE's preparation of several reports and EIS's on various aspects of this task, but stated that "integration of these and other yet-to-be-developed strategic planning elements into a broad comprehensive DOE strategy remains to be accomplished." Also needed, said the NAS, "is sufficient dialogue with affected public, commercial, and governmental interests to develop a consensus that will provide the basis for the necessary long-term implementation of the strategy."[83]

The NAS committee, which was composed of experts from academia, industry, and national laboratories, found it "essential that DOE determine how...treatment technologies fit into its overall strategy for disposal of SNF..." and asserted that the absence of criteria for nuclear materials disposition "precludes a full comparative analysis of the alternatives of (1) an SNF management policy based on improved long-term interim SNF storage and (2) a strategy based on near-term SNF processing to produce materials acceptable for final disposition. The schedule and cost implications of such trade-offs, which would result only from comprehensive studies of the options, would appear indispensable to DOE's establishing a SNF management policy."[84]

In its measured language, the NAS in effect chastised DOE for an inadequate spent fuel management policy.

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[83] NAS 1995, pp. 27-28

[84] NAS 1995, pp. 27-28

CURRENT DOE REPROCESSING PROPOSALS

The DOE environmental impact statements containing the reprocessing proposals were prepared pursuant to the National Environmental Policy Act (NEPA) of 1969. This act requires that an EIS be prepared for "legislation and other major federal actions significantly affecting the quality of the human environment" and that agencies "study, develop, and describe appropriate alternatives to recommended courses of action..."[85] The EIS's discussed in this paper do list and describe several alternatives to address each type of problem relating to spent fuel or other materials, and DOE may argue that its description of a reprocessing proposal in an EIS provides no indications about its intentions to implement it. Indeed, it is true that in most cases DOE is legally required to discuss reprocessing in the EIS's as an alternative for spent fuel management.

This line of argument cannot be applied to the Interim Management EIS, however, because it lists DOE's preferred alternatives, most of which involve reprocessing. In the Foreign Research Reactor EIS and the Spent Nuclear Fuel/INEL EIS, DOE does not state an explicit preference for reprocessing, but there are some passages that indicate that reprocessing is a possibility. Finally, DOE's purportedly neutral outlining of alternatives is biased in some cases because some of the EIS's exaggerate the drawbacks of storage options and underestimate the drawbacks of reprocessing. DOE's implementation of NEPA, a law designed to clarify the advantages and disadvantages of courses of action in full public view, actually obscures some of the hazards and consequences of reprocessing from the public and from DOE decisionmakers.

DOE terminology also obscures DOE's intentions from the public, as well as the sheer number of reprocessing proposals it is considering. "Processing" is the term used most often by DOE to refer to what is commonly known as "reprocessing". DOE defines "processing" as "applying a chemical or physical process designed to alter the characteristics of the spent nuclear fuel matrix."[86] This definition encompasses PUREX reprocessing. When DOE refers to "processing" in the F- and/or H- canyons at the SRS, or "processing" at the Dounreay plant in Scotland, it means chemical separation of fissile materials, using the PUREX method, but the actual technology being discussed is not immediately apparent from the terminology. Other DOE terms that may refer to separation of plutonium and/or uranium from spent fuel are *conditioning, stabilization, treatment, chemical separation, aqueous processing, chemical processing, and electrorefining.*

For five decades, the term "reprocessing" has had a meaning that is both technically informative and politically important: it is the separation of actinides from the fission products in spent fuel. This means the actinides can potentially be used, usually after further processing, as nuclear reactor fuel or as material for nuclear weapons. Reprocessing options should be clearly

[85] 42 U.S.C. 4321 *et seq*

[86] DOE 1995a, Volume 1, p. H-13

spelled out as such and distinguished from non-separative options, if only because of reprocessing's clear and crucial non-proliferation implications. Another phrase that is in the technical literature that would convey a clear message about the kinds of operations involved is "partitioning". It denotes separation of elements from one another and, in this context, generally of the separation of fission products from actinides.

"Reprocessing" as defined by DOE means recovering fissile and fertile material from spent fuel with an intent to "recycle such materials primarily for defense programs."[87] This definition, which emphasizes the intent behind the process, does not correspond to common usage of the term, described above. DOE also does not even use its own definition of the term "reprocessing" consistently, referring to the commercial separation activities of France and Britain as "reprocessing" even though these have a declared non-military purpose.[88] Page two of DOE's *Spent Fuel Working Group Report* describes Reactor Irradiated Nuclear Materials (RINM) as materials whose "constituent elements...have not been separated by processing." Page four of the same report describes RINM as materials whose "constituent elements...have not been separated by reprocessing."[89] DOE's confusing terminology and seeming unwillingness to consistently call the technology by its common, widely-accepted, and widely-understood name contributes to suspicions that it is not being forthright about its intentions. Misleading terminology is a poor foundation for coherent policy. Such distortion and inconsistent use of terms also lends credence to the notion that it may be a purposeful effort to hide reprocessing programs behind unfamiliar names.

This report uses the term "reprocessing" to mean any separation of uranium and/or plutonium from fission products.

Demonstration of Electrometallurgical Processing

The pyroprocessing technology that was spared by Congress in 1994 when the associated Integral Fast Reactor (IFR) was eliminated is planned to be tested by DOE at Argonne National Laboratory-West in Idaho, the test area for Argonne National Laboratory, which is located in Illinois. Whereas in 1994 pyroprocessing was proposed as the reprocessing technology to close the fuel cycle for the IFR, in 1995 electrometallurgical processing (as the technology is now called) is being proposed as a waste management tool. But the technology remains essentially the same. Argonne scientists Harold F. McFarlane and Michael J. Lineberry were candid about this in a recent paper: "Given the drastic changes in the US advanced reactor development program [the

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[87] DOE 1995a, Volume 1, p. H-14
[88] see for example, Foreign Research Reactor EIS, summary p. 24
[89] DOE 1993, Volume I, p. 2 and p. 4

cancellation of the IFR], the demonstration program described in this paper is a remarkably similar, but truncated version of the program plan of a year ago."[90]

Some opponents of the technology claim that the development of electrometallurgical processing was allowed to continue despite the cancellation of the IFR because of a deal struck between DOE and Congress. The Illinois and Idaho congressional delegations were especially concerned about the job losses due to the IFR cancellation and fought for funding for electrometallurgical processing. The trade journal *Nucleonics Week* has quoted a DOE source as saying the electrometallurgical processing project is "just about the only thing they've got left to do" at Argonne-West. "It's a jobs issue."[91] Congress has appropriated $25 million for electrometallurgical processing in FY96. In addition, Congress has appropriated $25 million for treatment of Experimental Breeder Reactor-II (EBR-II) spent fuel, as part of funding for termination of the EBR-II reactor.

An electrometallurgical processing plant was expected to be tested at Argonne-West beginning in 1995 for a duration of three years with driver assemblies[92] from the EBR-II. However, DOE has postponed the start-up of the facility pending completion of an Environmental Assessment. The decision to delay testing was made after several public interest groups wrote a lengthy letter to Secretary O'Leary in August 1995 detailing why an Environmental Impact Statement, the most rigorous analysis under NEPA, was required before the facility could be started.[93] The substantive policy and technical issues surrounding electrometallurgical processing are likely to remain despite preparation of the Environmental Assessment.

Argonne National Laboratory is interested in testing the process on EBR-II driver and blanket assemblies because it states that the sodium metal in these assemblies is chemically reactive and prevents long-term storage and repository disposition of the spent fuel. Some of this spent fuel, however, has already been in storage for close to thirty years, and Ray Hunter of DOE's Office of Nuclear Energy, Science, and Technology acknowledged that "the near-term storage of EBR-II spent fuel presents no compelling environmental, safety, or health concern."[94] He justified processing the EBR-II spent fuel from the standpoint of long-term cost savings. This is one of several examples of DOE proceeding with reprocessing when it is not absolutely necessary on environmental grounds. Moreover, the magnitude of the long-term cost savings, if any, cannot be established given that the technology is untested and given that there are large uncertainties surrounding disposition of the waste products from the process.

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[90] McFarlane and Lineberry 1995, p. 1

[91] *Nucleonics Week*, June 8, 1995

[92] Driver assemblies are made from plutonium or highly enriched uranium and are fissioned to provide neutrons for capture by target assemblies. This neutron capture produces plutonium in the targets.

[93] Horner et al 1995

[94] Letter from Ray Hunter to Dan Horner, Nuclear Control Institute, June 28, 1995

Description of the Technology

Metallic spent fuel can be introduced into the electrometallurgical process once it is are chopped up. Oxide fuels, such as commercial reactor fuel, would have to be first converted to metal by reduction with metallic lithium.[95] In the electrorefining step, the chopped spent fuel is mixed with electrolytic salts at 500°C, and an electric current is run through the mix. Uranium is collected at a solid steel cathode and a mixture of uranium and plutonium, americium, neptunium, and other transuranic elements is collected at a liquid cadmium cathode. The two cathodes are taken out of solution and heated at 1000°C to 1200°C to remove excess salts and/or cadmium, and the metals on the cathodes are fashioned into uranium ingots and plutonium alloy ingots which will be stored "pending a national decision on DOE-owned highly enriched uranium and plutonium."[96] That HEU extracted from the process may be stored as HEU is inconsistent with DOE's general plan to blend down HEU extracted from potential reprocessing activities. A failure to blend down in this case would exacerbate the negative non-proliferation consequences of the technology because the U.S. would unnecessarily accumulate stocks of weapons-usable uranium.

The fission products from the process would be contained in two high-level waste forms: a metal form containing noble metal fission elements and structural pieces from the fuel assembly and a molten salt form containing active fission products.[97] These wastes will be stored pending repository disposal, but none of them have been qualified or certified for repository disposal. The 1995 National Academy of Sciences report on electrometallurgical processing concluded that the "major limitation of the electrometallurgical process...is its present inability to produce waste forms with behavior that is well understood."[98] On this score alone, electrometallurgical processing may be worse than storage of spent fuel because of the uncertainties it introduces.

Utility for Spent Fuel Management

Argonne documents explain that the benefit of electrorefining is that it could process dozens of types of spent fuels into standard products -- the high-level waste stream and the two types of ingots. This could reduce the time and expense of qualifying diverse DOE spent fuel types that differ from standard commercial spent fuel for repository disposal. A DOE report stated that the process "provides a standard means for processing DOE SNF for ultimate disposal. By electrochemical treatment, all SNF stored at the INEL, Hanford, and SRS, can be treated by

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[95] Argonne National Laboratory 1995, p. 1-2

[96] McFarlane and Lineberry 1995, p. 6

[97] DOE 1995a, Volume 2, p. C-4.1.8-3. To address proliferation concerns, Argonne has proposed a variation on the process in which the plutonium and other transuranic elements would be left in the one of the waste streams and not cast into ingots. This defeats Argonne's goal of separating actinides from materials that will be disposed of in a repository, however.

[98] NAS 1995, p. S-6

one common method, producing three common HLW waste forms."[99] Argonne documents state that by removing long-lived fissile materials and actinides, the chance of an accidental nuclear chain reaction in a repository would be reduced and the volume of waste that would need to be disposed of in a repository would be reduced.[100] The actinides will eventually be disposed of in a repository, however, and storage of the fissile material and actinides that will be removed through the process is a formidable task in itself. The NAS said that "[t]he unspecified nature of 'interim storage' for the actinides (including plutonium) appears to be a major unresolved factor."[101]

The waste management benefits of the technology are a matter of some controversy even within the government. A May 1994 report by the Congressional Office of Technology Assessment analyzing the technology pointed out that many of the fission products that would be left for repository disposal after electrometallurgical processing, such as iodine-129 and technetium-99, actually have longer half-lives than some of the actinides that would be extracted.[102] The report also cited a Lawrence Livermore study that concluded that as a waste management tool it solves the wrong problem, because the main environmental danger from a repository is not the actinides but the highly radioactive fission products that could leach out to the environment.[103] The National Academy of Sciences was more positive about the technology. It concluded that it "appears sufficiently promising for treating a variety of DOE spent fuels that continued R&D would be warranted in federal FY96."[104] The NAS had a number of reservations, however, and refrained from suggesting whether the technology should ultimately be adopted by DOE for spent fuel other than EBR-II spent fuel.

Extraction of Weapons-Usable Material

The Department of Energy considers the technology to be a processing method but not a reprocessing method, perhaps because the resulting fissile materials would not be used for defense purposes. This is a semantic and specious distinction. Like the traditional PUREX process, electrometallurgical processing would separate out uranium and plutonium from fission products. The main difference between electrometallurgical processing and PUREX in terms of non-proliferation implications is that plutonium extracted from the electrometallurgical process would be impure as it would be mixed with some uranium, actinide elements, and other materials. These other elements would make the plutonium ingots highly radioactive and thus more difficult to

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[99] DOE 1994a, p. B-4
[100] Argonne National Laboratory 1995, p. 1-3
[101] NAS 1995, p. 30
[102] OTA 1994, p. 30. The OTA report, *Technical Options for the Advanced Liquid Metal Reactor*, examines the pros and cons of the ALMR/IFR system coupled with pyroprocessing technology. Most of its conclusions and recommendations also apply to pyroprocessing technology alone.
[103] OTA 1994, p. 31
[104] NAS 1995, p. S-1

handle and divert to weapons use.[105] It was for these reasons that McFarlane and Lineberry stated that electrometallurgical processing is a "proliferation-resistant" technology that "has no potential application for MOX recycle to LWR's or for military purposes."[106]

While not ideal for nuclear weapons, the plutonium alloy resulting from the process could be used in nuclear weapons. Even the IFR's developers acknowledged the "uncontested fact that it would be technically possible to make nuclear explosives from material extracted in some (unspecified) fashion from an IFR process stream."[107] [parentheses in original] McFarlane and Lineberry indicated that each plutonium-containing cathode removed from the electrorefiner could hold up to 75% plutonium and could contain up to four kilograms of plutonium.[108] The NAS reported that the cathode would contain approximately 30% uranium.[109] That is, almost all of the cathode is composed of plutonium and uranium. Reprocessing EBR-II driver assemblies will extract about seven kilograms of plutonium, and reprocessing the EBR-II blankets will extract 200 kilograms of plutonium.[110] The NAS report pointed out that the plutonium alloy, as well as the uranium metal, are not expected to be suitable for a geologic repository without further treatment.[111]

One Argonne document indicated that "pure uranium is separated from the transuranic elements" in the process,[112] while another document indicated that "relatively pure uranium" may be "electrotransported" under "carefully controlled conditions."[113] Depending on which document is correct, the process would extract pure or relatively pure HEU if the fuel introduced into the process were highly enriched.[114] HEU is a weapons-usable material. The EBR-II driver assemblies that were planned to be processed are 60% to 75% enriched.[115] Argonne has stated that it will blend down any HEU produced from reprocessing the driver assemblies to about 20% enrichment either in the cathode processor or in an even higher-temperature furnace.[116] As discussed above, HEU extracted from processing other types of fuel is expected to be stored in ingot form pending a decision on fissile material disposition. Neither the technical Argonne documents nor the DOE documents outlining the process raise the possibility of submitting the

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105 OTA 1994, p. 21
106 McFarlane and Lineberry, p. 6
107 Comments from William H. Hannum, Research Program Manager, Engineering Research, Argonne National Laboratory, February 8, 1994, quoted in OTA 1994, p. 36. Again, this conclusion would apply to pyroprocessing alone because it was designed to recycle the materials for the IFR.
108 McFarlane and Lineberry, p. 4
109 NAS 1995, p. 24
110 McFarlane and Lineberry, p. 3
111 NAS 1995, pp. 23-24
112 Argonne National Laboratory 1995, p. 1-3
113 McFarlane and Lineberry, p. 6
114 The uranium cathode will have the same enrichment level as the spent fuel that is introduced into the process.
115 McFarlane and Lineberry, p. 3
116 McFarlane and Lineberry, p. 4. It is unclear why Argonne would not blend down the HEU to an even lower enrichment. Commercial power reactors generally use uranium fuel enriched in the range of 3% to 4%.

HEU ingots or the plutonium alloy ingots to IAEA safeguards or having the process itself subject to IAEA safeguards.

Application to Commercial Spent Fuel

Argonne backers of the project expect that the electrometallurgical technology could be applied widely to many types of DOE spent fuel and even to commercial spent fuel in the United States. In the same paragraph where they stated that the process is not applicable to commercial fuel reprocessing (MOX recycle), McFarlane and Lineberry wrote:

> If successful, Argonne's pyroprocessing demonstration for spent fuel management could mark one of the major breakthroughs in nuclear fuel cycle technology in the past three decades. Processing EBR-II spent fuel with second generation equipment will allow evaluation of extrapolation of this technology to other fuel types, including over 80% of the spent DOE fuel and *even to commercial light water reactor (LWR) fuel...*If the actual demonstrated throughput potential is anywhere in the ballpark, the economic ramifications of broader application of this technology will ensure its consideration as a viable fuel cycle option.[117] [emphasis added]

This is one example among many in this report where reprocessing is proposed without an environmental justification for why such large amounts of spent fuel may *need* to be processed. Indeed, processing commercial spent fuel would take an oxide form widely believed to be acceptable in a repository and turn it into a metal form whose suitability for repository disposal is highly questionable.

The electrometallurgical process has already been tested on a laboratory scale with one kilogram of irradiated oxide fuel from a commercial pressurized water reactor,[118] and there is one isolated passage in the Spent Nuclear Fuel/INEL EIS that states that future research and development activities at INEL will involve "electrometallurgical processing using limited quantities of commercial SNF."[119] All this evidence taken together demonstrates that electrometallurgical processing may be the first step down the road toward commercial reprocessing in the United States, contrary to long-standing U.S. practice and the Clinton administration statement that the U.S. does not reprocess for nuclear power purposes.

Another example of an unnecessary reprocessing proposal is the SNF/INEL EIS's claim that "naval spent fuel could also be electrometallurgically processed to recover uranium and separate out the fission products and transuranic elements..."[120] This is technically true, but why would DOE want to reprocess naval spent fuel? DOE considers it among the most stable types of spent fuel in its inventory. It has a thick cladding to withstand combat conditions, and the same

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[117] McFarlane and Lineberry, p. 6
[118] DOE 1994a, p. B-4
[119] DOE 1995a, Volume 1, p. 3-9
[120] DOE 1995a, Volume 2, Part B, p. C-4.1.8-3

EIS reports in a different section that naval spent fuel is "well-suited for direct storage...without additional stabilization."[121] Perhaps it is because naval spent fuel will be stored at INEL and thus would provide a ready feedstock for the process for years to come.

Non-proliferation Implications

While the United States would be highly unlikely to use fissile material extracted through electrometallurgical processing in nuclear weapons (because it already has a large plutonium stockpile of higher quality from dismantled warheads), operating the process would send a negative signal to other countries about the seriousness of U.S. intentions to dispose of plutonium. It would also contravene the presidential goal of "eliminat[ing] where possible the accumulation of stockpiles of...plutonium."

Another proliferation problem is that once tested in the United States, the technology may be exported to other countries as a "proliferation-resistant" method of spent fuel management. Widespread use of the technology, however, could actually lead to the proliferation of nuclear weapons as countries around the world gain access to a compact technology that separates fissile material from spent fuel. A report prepared by Martin Marietta for DOE concluded that while a country under IAEA safeguards would have difficulty diverting material from the process, a country renouncing safeguards would have a considerable advantage toward building a nuclear weapon if it had the pyroprocessing technology.[122] A small laboratory hot-cell facility could be used to purify the extracted plutonium into weapons-usable material using an aqueous ion exchange process. Martin Marietta also appears to have a rather sanguine view of IAEA detection capabilities that is not universally shared even for PUREX technology.

The OTA report concluded that "[c]ompared with older technologies that have been used to reprocess spent reactor fuel and to separate plutonium, the ALMR [IFR] system may offer more proliferation advantages....However, these possible advantages must be weighed against the risks of widely deploying systems that could be later modified if the owners had the proper technical capability and weapons-building motives."[123] It should be noted that the United States agreed in Article IV of the Non-Proliferation Treaty to participate "in the fullest possible exchange of equipment, materials, and scientific and technological information for the peaceful uses of nuclear energy." When the U.S. has opposed such an exchange of peaceful nuclear technology, as with the Russian sale of nuclear reactors to Iran, it has caused conflicts with the countries involved. The IAEA believes Iran to be in compliance with its safeguards agreement. Developing a new radioactive waste management technology may create political demands from other countries for access to it. For the U.S. to deny sale or transfer of this technology to countries it considers to be proliferation risks could provoke further conflicts.

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[121] DOE 1995a, Volume 1, p. J-4
[122] OTA 1994, pp. 35-36
[123] OTA 1994, p. 5

A final proliferation drawback is that continued funding of electrometallurgical processing and imminent operation of the technology leaves the door open to a return of the Integral Fast Reactor since electrorefining is the key advanced technology of the IFR and since the technology will produce materials originally intended to be fashioned into fuel for the IFR. If the ingots turn out to be unsuitable for a repository without changing their form or composition, the IFR may be proposed as a solution. The IFR still has strong support in Congress and the nuclear industry.

DOE's decision not to reprocess Hanford N-reactor spent fuel eliminates the major inventory of spent fuel for which electrometallurgical processing's proponents have cited a utility. DOE continues to fund the development of electrometallurgical processing despite the lack of a clear rationale and despite its proliferation liabilities. The pork barrel aspects of such funding could, over time, turn into pressures to fund the use of the plant or other plants for a wide variety of spent fuel. This is clearly one hope of the proponents of this technology.

Because of the non-proliferation drawbacks of electrometallurgical processing and its questionable utility as a waste management tool, the further development of the technology should be halted.

Other Spent Fuel Partitioning Technologies

Electrometallurgical processing is not the only new form of fissile material or actinide separation from spent fuel being investigated by DOE. The Idaho National Engineering Laboratory is conducting research on the "chloride volatility process" in which spent fuel will be turned into a gas at temperatures exceeding 1200°C and the constituent parts separated by fractional condensation. The TRUEX (transuranic extraction) process being developed at Argonne National Laboratory is a chemical process which dissolves spent fuel in an organic solvent and separates transuranic elements from it. The TRUMP-S (Transuranic Management by Pyroprocessing -- Separation) is being developed by Rockwell International at DOE Santa Susana laboratory in California and at the University of Missouri. Los Alamos and Hanford are also developing spent fuel partitioning technologies. It is beyond the scope of this paper to describe and assess these various technologies in detail, but their proliferation consequences may be similar to those of electrometallurgical processing.[124]

Several public interest groups, most based in California, have filed suit to block DOE and other defendants, mainly DOE contractors, from "funding, assisting, conducting, or permitting to continue" R&D on the various spent fuel partitioning technologies. The plaintiffs' amended complaint charged that DOE's refusal to view the technologies as reprocessing technologies means that the technologies will be subject to less stringent export control regulations. The amended complaint seeks to prevent DOE and the other defendants from "transferring to the Japanese," who partially funded some of the projects, "any information acquired in any of the

[124] For more information on these technologies, see DOE 1994a.

various research and development projects...related to partitioning transuranics (or uranium) from spent nuclear fuel in any form."[125] The case is in the discovery process and the plaintiffs do not expect a decision until 1996 at the earliest.

Final F-Canyon Plutonium Solutions EIS

Since February 1995, DOE has been operating sections of the F-canyon reprocessing plant at the Savannah River Site in order to stabilize plutonium-containing solutions stored inside the plant. Pursuant to a Record of Decision for the November 1994 F-Canyon Plutonium Solutions EIS, the plutonium in the solutions is being processed to a metal form.

Eighty thousand gallons of plutonium-nitrate solutions were left in the F-Canyon when reprocessing was halted in 1992. The solutions resulted from dissolving spent fuel from plutonium production reactors in nitric acid, and they were left in several locations in the PUREX process when reprocessing was halted.[126] Plutonium in solution is especially susceptible to a criticality since plutonium particles can precipitate out of the solution to form a critical mass. Such a criticality could lead to a breach of the solution container and to radiation exposures. DOE detected some precipitation of plutonium in the solutions in 1993 and added boron, a neutron absorber, to prevent a chain reaction of fissioning plutonium atoms.[127] The solutions had been in the canyon for over two years when the EIS was completed, but they were never intended to be stored for more than 180 days.[128]

DOE was concerned about the potential for other accidents involving the solutions such as leaks, cooling system failures, fires, and earthquakes. An accident involving the solutions would likely spread more radioactivity and would be more difficult to clean-up than if there were a similar accident involving the plutonium after conversion to a solid form. The Defense Nuclear Facilities Safety Board assessed the problem and recommended that "preparations be expedited to process the dissolved plutonium and trans-plutonium isotopes[129]... into forms safer for interim storage." The Board considered the problem to be "especially urgent."[130]

The alternatives laid out in the EIS for stabilizing the F-Canyon solutions are:

- separate plutonium from solution and convert the plutonium to metal
- separate plutonium from solution and convert the plutonium to an oxide
- vitrify the solutions in the Defense Waste Processing Facility

[125] Energy and Resource Advocates et. al. 1995, p. 27
[126] See DOE 1994b, p. 2-4, for a diagram showing the locations of the solutions inside the plant.
[127] DOE 1994b, p. 1-7
[128] DOE 1994b, p. B-17
[129] Trans-plutonium isotopes refers to americium-curium solutions that DOE has on a slower track for stabilization.
[130] DOE 1994b, p. S-2

- vitrify the solutions in a new F-Canyon vitrification facility

DOE's preference for processing to metal stemmed mainly from its desire to stabilize the solutions quickly to reduce the chance of accidents or criticality events and to use proven technology. According to the EIS, the processing operation could begin quickly and could be completed in under two years. However, the FB-line processing to metal operations did not begin until November 1995, nine months after the Record of Decision. According to DOE, the two vitrification options could not begin for at least five years due to the need to modify facilities to handle large amounts of plutonium. Conversion to oxide would require modifications to the FB-line that would take three years.[131]

The processing to metal alternative was the process used for four decades to fabricate plutonium metal "buttons" at the Savannah River Site that were then shipped to the Rocky Flats Plant near Denver for fabrication into warhead cores. The EIS says that DOE would not "attempt to meet previous specifications or chemical purities that were applicable for weapons production,"[132] but admits that the material would be weapons-usable nonetheless.[133] The buttons will be put into secure storage at the SRS pending DOE decisions on disposition of its plutonium stockpile. The EIS does not say exactly how much plutonium is in the solutions, but it states that it is "much less than 10 percent of the plutonium inventory at the SRS,"[134] or much less than 0.2 metric tons.[135]

While the conversion of plutonium nitrate solutions to metal will result in conversion of plutonium to a weapons-usable form, it is the completion of a reprocessing operation begun years ago. The F-Canyon solution proposal appears to be a defensible use of the F-Canyon to resolve safety concerns for which no ideal solution exists. Further, if F-Canyon is ever to be permanently decomissioned and dismantled, it is necessary to remove the solutions from the plant somehow. All of the options involve operating some separations modules in the plant to remove impurities and to move the solutions through the stages of the plant. Even the two vitrification options involve some separation of plutonium from fission products in order to purify the solutions prior to vitrification.

As will be discussed in more detail below, DOE's inventory of solid spent fuel does not present the same kind of environmental problems or the same level of urgency as the solutions.

The waste that may be generated by the four stabilization alternatives for the solutions is roughly similar, and the EIS concludes that "[w]ith the exception of vitrification, the impact on SRS waste management capacities from implementing any of the alternatives would be

[131] DOE 1994b, pp. 2-5 to 2-11
[132] DOE 1994b, p. 2-5
[133] DOE 1994b, p. C-47
[134] DOE 1994b, p. C-21
[135] About 2 metric tons of plutonium are at SRS in both separated and unseparated forms.

minimal."[136] According to DOE, as of September 30, 1993 there were approximately 126,000 cubic meters of high-level waste and 9,900 cubic meters of transuranic waste on site.[137]

Waste Generation Over Ten Years Under Alternatives for Stabilizing F-Canyon Plutonium Solutions (Cubic Meters)

Type of Waste	Process to metal	Process to oxide	Vitrification (DWPF)	Vitrification (F-Canyon)
Saltstone[138]	5,689	6,461	4,813	5,592
Transuranic	60	175	4	147
Low-level	11,907	14,371	10,174	13,820

SOURCE: F-Canyon Plutonium Solutions EIS, p. 4-28

Fate of Extracted Plutonium and Non-proliferation Implications

The F-Canyon Plutonium Solutions EIS is the only one of the recent documents containing reprocessing proposals to refer to the Clinton administration policy of submitting excess fissile material to inspection by the International Atomic Energy Agency. It indicates that DOE "intends to offer [plutonium from the F-Canyon solutions] along with other material at SRS for IAEA inspection when the material is in a form and consolidated in a storage facility suitable for safe and effective monitoring by the IAEA."[139] Submitting fissile material extracted from solutions to the IAEA is a sound policy because it would allay concerns about the destination of the fissile materials. However, the absence of a timetable in the EIS itself and DOE's lack of a plan for IAEA inspections even as it has begun processing to metal raises questions about when and whether IAEA safeguards will be implemented. Other DOE documents relating to reprocessing do not mention the Clinton policy or an intention to turn extracted plutonium over to the IAEA. This inconsistency raises further questions about DOE's commitment to this policy.

Inviting Russian inspectors and/or IAEA inspectors to monitor the reprocessing procedures should also have been considered as a way to mitigate the negative non-proliferation consequences. It is only by observing reprocessing procedures that the international community could be shown that material submitted to the IAEA is the material separated. Brian Costner of the Energy Research Foundation, a DOE watchdog group near the Savannah River Site, urged

[136] DOE 1994b, p. 4-27
[137] DOE 1994b, p. 4-26
[138] Saltstone is the low-radioactivity fraction of high-level waste. It comes from precipitation within the high-level waste tanks and is mixed with cement, flyash, and slag to form concrete blocks.
[139] DOE 1994b, p. C-44

DOE for over a year to invite outside inspectors to observe the reprocessing. He received no response from DOE.

A section of the F-Canyon EIS relating to security and non-proliferation states that the different alternatives would result in plutonium of varying degrees of utility for production of nuclear weapons, with processing to metal resulting in a form most closely resembling that used in weapons and vitrification resulting in a form, glass logs, that would be most difficult to convert to weapons use. The section repeats the DOE commitment not to use the material in weapons and states that the Savannah River Site is a secure facility protected by armed guards.[140] The EIS does not discuss the broader international implications of processing plutonium to metal, such as the potential for undermining U.S. credibility to work to halt reprocessing in Russia and other countries. This discussion should have been included in the EIS.

A further problem with DOE's intentions for storage and disposition of the plutonium is its refusal to characterize the plutonium as a liability. The Institute for Energy and Environmental Research, along with forty-five other groups and individuals, sent a letter to President Clinton in October 1994 urging him to declare plutonium excess to military requirements a liability. The letter stated that this would formalize current U.S. practice and strengthen U.S. leadership to work to halt plutonium programs in other countries and especially in Russia. The National Academy of Sciences has characterized excess plutonium as a liability; Secretary of Energy Hazel O'Leary has called it a "global security risk and an economic liability."[141]

It would seem that the plutonium extracted from the F-Canyon solutions, which DOE states will not be used in weapons and which is presumably destined for interim storage and repository disposal, either in vitrified form or as spent MOX fuel, could be considered a waste product and a liability. The Record of Decision for the EIS, however, states: "It would not be appropriate under any of the alternatives that would result in stabilized plutonium to characterize the stabilized plutonium as waste," with no further explanation.[142] This is a puzzling sentence (not found in the EIS itself) that in a charitable interpretation presumably refers to potential use of the plutonium in MOX fuel. However, the National Academy of Sciences has concluded that disposing of plutonium as MOX fuel, despite the offsetting monetary benefits of electricity generation, will entail a net expenditure of funds, and that the net costs for the MOX option and vitrification are roughly equal. Thus, even plutonium destined for disposition as MOX fuel should be considered a waste and a liability.

DOE should be forthright about whether it views the plutonium metal to be made at the SRS as a resource. A less charitable interpretation of the sentence in the Record of Decision is that it is conflict with DOE's commitment not to use extracted plutonium in weapons because weapons use is the only possible "resource" use of the plutonium. The plutonium from the F-

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[140] DOE 1994b, pp. 2-16 to 2-17
[141] *New York Times*, August 19, 1994
[142] DOE 1995d, p. 14

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Canyon solutions should be formally declared a waste along with all plutonium that the U.S. deems excess to military requirements.

The overly favorable attitude toward the plutonium in the ROD is echoed in DOE's *Spent Nuclear Fuel Strategic Plan*, which states that "[t]he Department has not determined whether DOE-generated spent fuel is a waste or a resource."[143] If the NAS has concluded that already-separated plutonium is a liability, than surely DOE can admit that its spent fuel is a waste. What possible resource use can there be for DOE's spent fuel? The two sentences together point to how deeply entrenched within DOE is the view of plutonium as a valuable material and to how resistant this view is to economic reality.

Final Interim Management of Nuclear Materials EIS

The F-Canyon plutonium solutions were "spun-off" from the Interim Management of Nuclear Materials EIS, which has a larger scope, in order to complete the NEPA process earlier for those solutions. The F-Canyon EIS states that a "decision to proceed with the proposed action" would not prejudice DOE decisions on how to stabilize other nuclear materials and spent fuel at the Savannah River Site because "such decisions would involve different facilities and entail commitments of additional resources."[144]

Despite DOE assurances, it seems plausible that operating F-Canyon and FB-line and having operating procedures and authorizations in place for these facilities would add to the attractiveness of using them for stabilization of other nuclear materials.[145]

The Interim Management EIS, issued in draft form in March 1995 and final form in October 1995, strongly suggests that stabilizing the F-Canyon plutonium solutions is likely to be just the start of reprocessing operations at the Savannah River Site. The purpose of the EIS is to lay out the alternatives for managing spent fuel and other nuclear materials at SRS over the next ten years. In addition, it outlines alternatives for obtaining certain "programmatic materials" such as americium, curium, and neptunium, which DOE says are needed for research and scientific applications, and for obtaining plutonium-242, which DOE states is needed for a classified defense programs mission. DOE was originally going to re-start the separations canyons at the Savannah River Site to stabilize the materials without issuing an environmental impact statement, arguing that reprocessing was a continuation of earlier practice and thus not subject to National Environmental Policy Act requirements. A law suit threatened by the Natural Resources Defense

[143] DOE 1994d, p. 1

[144] DOE 1994b, p. C-47

[145] The operation of F-Canyon for the plutonium solutions is one of the reasons that DOE is considering consolidating reprocessing operations there and not starting H-Canyon.

Council, the Energy Research Foundation, and Citizens for Environmental Justice helped to convince DOE to prepare the Interim Management EIS.[146]

The safety hazards from SRS nuclear materials have been analyzed in four documents:

- The 1993 DOE Spent Fuel Working Group report
- The 1994 complex-wide plutonium vulnerability study
- May 1994 recommendations of the Defense Nuclear Facilities Safety Board
- A Savannah River Site-specific report by DOE's Office of Environment, Safety, and Health

According to DOE, some nuclear materials at the SRS, such as most research reactor spent fuel and unirradiated nuclear fuel, are stable and can continue to be stored with minimal maintenance. Other nuclear materials requires some kind of stabilization because of accident risks and environmental vulnerabilities. Mark-31 targets in the L-reactor basin, for example, are corroding and releasing fissile material and fission products into water, which could lead to increased radiation exposure for workers and possibly to an accidental nuclear criticality. Like the F-Canyon plutonium solutions, solutions containing plutonium and highly enriched uranium that are stored in the H-Canyon are susceptible to a criticality and pose similar accident risks. Heat generated by packaged plutonium metal in storage in FB-line and Building 235-F is degrading the plastic that surrounds the plutonium, which could potentially lead to an explosion or breach of container.[147] DOE divided the nuclear materials at the SRS into three categories: stable materials, programmatic materials, and candidates for stabilization. The stable materials comprise over 98% by mass of all the nuclear materials at the SRS.[148]

Programmatic Materials and Candidates for Stabilization at the Savannah River Site

Material	Amount	Location
Plutonium-242 solutions	3500 gallons	H-Canyon
Americium and curium solutions and targets	3800 gallons, 174 slugs, 65 assemblies	F-Canyon, P-reactor basin, RBOF
Neptunium solution and targets	1600 gallons, 9 targets	H-Canyon, Bldg. 321-M
Plutonium-239 solutions	9000 gallons	H-Canyon
HEU solutions	60,000 gallons	H-Canyon, H-area
Plutonium vault materials	2800 packages	FB-line, HB-line, Bldg. 772-F, Bldg. 235-F, SRTC
Irradiated Mark-31 targets	16,000 slugs	K-, L-reactor basins,

[146] Caputo and Chandler 1993

[147] See DOE 1995b, pp. 1-14 to 1-21 for DOE's descriptions of safety and environmental hazards from nuclear materials at the SRS.

[148] DOE 1995b, p. 1-25. The bulk of the stable material is depleted uranium stored in drums and unirradiated fuel, targets, and reactor components.

		F-Canyon, RBOF
Mark-16 and Mark-22 fuels	1900 assemblies	K-, L-, and P-reactor basins, H-Canyon
Other aluminum-clad targets	1800 slugs and assemblies	K-, L-, and P-reactor basins
Failed Taiwan Research Reactor and EBR-II slugs	82 canisters	Receiving Basin for Offsite Fuel

SOURCE: Final Interim Management EIS, p. 1-24

DOE's preferred options for stabilizing nuclear materials and for obtaining programmatic materials are heavily weighted toward reprocessing. As may be seen from the table below, DOE's preferred alternative for nine out of ten types of material involves reprocessing. Some portion of the plutonium and uranium in vaults is also likely to be reprocessed.

DOE's Preferred Alternatives in the Interim Management EIS

Material	Preferred Alternative	Reprocessing Plant
Plutonium-242 solutions	Process to oxide	H-Canyon/HB-line
Americium and curium solutions and targets	Vitrification	unspecified
Neptunium sols. and targets	Process to oxide	H-Canyon/HB-line
H-Canyon Pu-239 solutions	Process to oxide	H-Canyon/HB-line
H-Canyon uranium solutions	Blend down to LEU	H-Canyon/FA-line
Plutonium & uranium in vaults	Depends on purity[149]	F-Canyon/FB-line H-Canyon/HB-line
Mark-31 targets	Process to metal	F-Canyon/FB-line
Mark-16 and -22 fuels	Process and blend down to LEU[150]	H-Canyon/F-Canyon
Other aluminum-clad targets	Process and Vitrify in DWPF[151]	H-Canyon/F-Canyon
TRR and EBR-II slugs	Process to metal	F-Canyon/FB-line

SOURCE: Interim Management EIS, pp. 2-5 to 2-46
NOTE: Under preferred scenarios, the americium and curium solutions and targets and the H-Canyon uranium solutions would be reprocessed prior to vitrification or blending-down to LEU, respectively.

[149] There are four preferred alternatives for the vault material, depending on the purity of the material. Relatively pure material could simply be heated and repackaged. Less pure material would be reprocessed, then converted to an oxide or metal or vitrified in an F-Canyon vitrification facility (p. 2-96).
[150] This was the preferred option in the Draft EIS. In the Final EIS, DOE switched it to No Action pending further reviews, but recently decided to go ahead with the original plan.
[151] This was the preferred option in the Draft EIS. In the Final EIS, DOE switched it to No Action pending further reviews, but recently decided to go ahead with the original plan.

The EIS provides very little information on the mass of materials and their fissile material content, explaining that "the exact quantities of special nuclear materials or isotopes stored in single containers or locations are classified because of sensitivities associated with theft, diversion, or sabotage."[152] It does report that there are approximately 200 metric tons of spent fuel at the SRS[153] and that 147 metric tons of this is Mark-31 targets.[154] Further, it states that there are 1.8 metric tons of separated plutonium and 0.3 metric tons of unseparated plutonium on site.[155] DOE has stated that it is "pursuing declassification of information related to the amount of plutonium resulting from stabilization actions at the SRS."[156]

There are no good options for stabilizing the wide variety of nuclear materials at the Savannah River Site. Even if the phase-out of reprocessing at the site had been more orderly, it is likely that some of the solid materials would not have been reprocessed and would still pose environmental and safety hazards today. Taking no action is not a viable alternative. Not only would it be environmentally irresponsible, but DOE estimates that simply providing minimal custodial care for the nuclear materials would cost $2.8 billion over the next ten years.[157] Some stabilization is necessary to reduce safety risks in the spent fuel storage facilities and especially to remove nuclear materials from the reprocessing plants so that the plants can be permanently decommissioned and dismantled.

While it is commendable that DOE is beginning to address safety issues from nuclear materials at the SRS, it has jumped too quickly toward stabilization options involving reprocessing without adequate consideration of its risks and of alternatives such as dry storage. Reprocessing is most appropriate for the fissile material-containing solutions in the H-Canyon. Like the F-Canyon plutonium solutions, the H-Canyon plutonium and uranium solutions should be reprocessed and converted to a solid form because of accident risks and because their removal from the reprocessing plant is likely to necessitate some operation of the separation modules. Solid spent fuel such as the Mark-31 targets, Mark-16 and -22 fuels, and Taiwan Research Reactor spent fuel is a different story, however. For these materials, dry storage remains a viable option whose benefits are underestimated in the EIS.

The Draft Interim Management EIS estimated that construction of a dry storage facility for degraded or corroding spent fuel at the Savannah River Site would take ten years. This figure was sharply criticized by observers inside and outside of DOE as being unduly pessimistic. The ten-year figure rendered storage alternatives to reprocessing very unattractive. In the Final EIS, DOE acknowledges that a dry storage facility could be constructed in five years "if certain actions

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152 DOE 1995b, p. F-53
153 DOE 1995b, p. A-15
154 DOE 1995b, p. A-12
155 DOE 1995b, p. A-15
156 DOE 1995f, p. 10
157 DOE 1995b, p. 2-84

occurred to accelerate the schedule (e.g., a request for emergency funding from Congress and establishment of a line-item project in the 1998 fiscal budget for DOE)."[158] The new dry storage facility could be of the dry vault or the dry cask design. The existence of an "accelerated construction schedule" for dry storage, however, has not made a difference in DOE's preferences because it believes that reprocessing could still be accomplished faster. Because of safety risks, DOE is critical of the option of stabilizing spent fuel in a wet storage environment through repacking, canning, and maintaining water purity until a dry storage facility becomes available. This report does not deny that there are such risks, *but the crucial point, not properly considered by DOE, is that risks from reprocessing are even greater*.

The attractiveness of dry storage as a stabilization method is unfairly undermined in the EIS by DOE's attribution of high-level waste generation to dry storage. As mandated in the Nuclear Waste Policy Act of 1982, "high-level" radioactive waste is defined as irradiated spent fuel or first cycle wastes from reprocessing operations. It is impossible that continuing wet storage of solid spent fuel and eventually moving it to a dry storage facility could generate high-level waste as defined by U.S. law, though these actions would certainly generate other types of waste. Yet the EIS lists substantial high-level waste generation for these actions (870,000 liters for the Mark-31 targets and 370,000 liters for Mark-16 and -22 fuels).[159]

DOE's attribution of high-level waste generation to dry storage is based on an *ad hoc* categorization of the waste that is created. The filters that trap fission products in cooling pool water at the SRS are regenerated, and the liquid chemical wastes containing the fission products are discharged into the high-level waste tanks. The Interim EIS has called these "high-level liquid" wastes. This *ad hoc* labeling, which is not sanctioned by U.S. regulations, is misleading. It creates the impression that filtering pool water under storage options necessarily leads to high-level waste generation. In fact, filters in *commercial* spent fuel cooling pools are solid and are classified as Class B low-level waste. It is not necessary to regenerate the filters and create liquid wastes. Indeed, given that that the high-level waste tanks are the riskiest facilities at the SRS, in terms of the potential consequences of an accident, it may be wiser to store the solid filters above ground and simply replace them instead of regenerating them.

It is instructive to examine more closely some of the solid spent fuel at the SRS that DOE is considering reprocessing.

Taiwan Research Reactor and Experimental Breeder Reactor-II Spent Fuel

DOE only recently concluded that the TRR and EBR-II spent fuel in the Receiving Basin for Offsite Fuels need to be stabilized. DOE considered them to be stable material in the Draft Interim Management EIS. On August 3, 1995, the Chairman of the Defense Nuclear Facilities

[158] DOE 1995b, p. 2-35
[159] DOE 1995b, p. 2-55 and p. 2-56

Safety Board transmitted a report to DOE which stated that "corroding spent fuel in the Receiving Basin for Offsite Fuel (RBOF) is releasing more than twice the amount of fission products into the basin water than the corroding Mark-31 targets are releasing into the L-basin. The significant corrosion is contaminating the facility, generating significant waste, and contributing to personnel exposure."[160] DOE has found that one of approximately 60 canisters in RBOF containing EBR-II spent fuel is leaking inert gas, and the EIS states that "it is reasonable to conclude that this canister is releasing radioactivity to the basin water."[161] DOE is proposing to reprocess only that one canister of EBR-II spent fuel. In contrast, DOE has found that 16 of the 81 canisters containing TRR spent fuel have failed and are leaking inert gas, yet DOE is proposing to reprocess all 81 canisters, which contain 20 metric tons of spent fuel.[162] DOE does not provide an explanation for why it is proposing to reprocess all the TRR canisters. While it is true that reprocessing could begin earlier than dry storage for the TRR and EBR-II spent fuel, DOE data also show that the liquid high-level waste generation from reprocessing is over five times greater than that from dry storage.[163] Further, DOE has not spelled out the differences in terms of environmental and health dangers between the fuel that it proposes to reprocess at SRS and Hanford N-reactor fuel, much of which is also corroding, which DOE is planning to put into dry storage.

Mark-16 and Mark-22 Fuels and Other Aluminum-Clad Targets

In the Draft EIS, DOE called for reprocessing these materials and blending down the resulting highly enriched uranium from the Mark fuels. DOE also wanted to vitrify in DWPF solutions resulting from dissolving the other aluminum-clad targets.[164] In the final EIS, DOE changed its preferred alternatives for these materials to "No Action" pending further study of the cost, schedule, and technical issues surrounding dry storage. Then, in December DOE issued a Record of Decision for the Interim Management EIS and reverted to its original reprocessing plans for these materials.

DOE cited cost considerations as well as the safety risks from keeping the materials in wet storage for five years until a dry storage facility could be built as the main reasons for its preference for reprocessing. DOE also argued that the technical uncertainty of putting highly enriched and aluminum-clad fuels in a repository supported the reprocessing option.[165] DOE's brief study on dry storage concluded that the total cost of reprocessing the materials would be

[160] DOE 1995b, p. 1-11. The concerns raised by the DNFSB in August were not based on new information. DOE has known of the problems with the materials for years.
[161] DOE 1995b, p. 1-18
[162] DOE 1994b, p. A-12
[163] DOE 1995b, p. S-25
[164] Refers to approximately 1,800 targets stored in the K-, L-, and P-areas. The targets contain mainly thorium, cobalt, and thulium, and only small amounts of fissile material (p. 2-40).
[165] DOE 1995g, p. 3 and p. 7

$101 million, including high-level waste storage and repository emplacement of the vitrified high-level waste. The total cost of dry storage, according to DOE, ranged from $139 million to $1.24 billion depending on the amount of fissile material placed in each repository canister.[166] The ten-year cost for reprocessing and storage not including repository emplacement was about equal,[167] however, and the Foreign Research Reactor EIS states that if repository emplacement of HEU spent fuel is found to be feasible, then the life-cycle costs for reprocessing and dry storage are about equal.[168] The Mark-16's contain approximately 440 kilograms of HEU, and the Mark-22's contain approximately 240 kilograms of HEU.[169]

In these cost figures, DOE considered the Mark-16 and -22 fuels and other aluminum-clad targets as a package, but the targets should be viewed as a separate case. The argument for dry storage of the targets is strong because, according to DOE, "the estimated number of canisters going to the proposed geologic repository would increase only slightly" above the number of canisters from generated from reprocessing "because the amount of material would be small and the fissile material content of the material would be low."[170] Thus, the cost for repository disposal for the other aluminum-clad targets is likely to be much lower on a per unit basis than for the Mark-16 and -22 fuels.

Mark-31 Targets

The Mark-31 targets that DOE is proposing to reprocess represent approximately 80% of the mass of all aluminum-clad spent fuel currently at the SRS and 71% of the mass of all spent fuel at the SRS. The targets, the bulk of which are in the L-reactor basin, are clad in a thin layer of aluminum only 0.076 centimeters thick. The targets were designed with thin cladding to facilitate chemical dissolution and plutonium extraction, and now the targets are releasing uranium, plutonium, and fission products into the basin water.[171] The EIS states that reprocessing could be completed within 3 years,[172] and that "[n]o actions would occur to achieve a specific purity for [the extracted plutonium] other than those necessary to operate the process."[173] The EIS does outline an accelerated dry storage option for the targets, but DOE prefers reprocessing because it could begin and end sooner and allegedly would cost less.

There are significant differences between the consequences of reprocessing and dry storage for the Mark-31 targets. Table 2-9 shows that 6.5 latent cancer deaths in the population within 50 miles of SRS would result from a "maximum consequence" accident in reprocessing

[166] DOE 1995g, pp. 4-5
[167] DOE 1995g, p. 7
[168] DOE 1995c, p. 2-16
[169] Westinghouse 1995, p. 13
[170] DOE 1995b, p. 2-102
[171] DOE 1995b, p. 1-16
[172] DOE 1995b, p. 2-97
[173] DOE 1995b, p. 2-32

Mark-31 targets and converting the plutonium to metal. In contrast, less than one one-hundredth of a latent cancer death would result in the same population from a "maximum consequence" accident under the improving storage alternative.[174] Similarly, the table shows that there would be over twice as much high-level liquid radioactive waste generated over ten years by the processing to metal alternative than the improving storage alternative (2.1 million liters compared to .87 million liters).[175] Again, there are problems with attributing that amount of high-level liquid waste generation to the storage option. The EIS also appears to be internally inconsistent regarding high-level waste generation. Table D-41 provides a breakdown of liquid high-level waste generation for improving storage by the steps necessary to accomplish the task, but the total for all the steps is only .373 million liters, not .87 million liters.[176]

DOE has taken mitigation measures for the Mark-31 targets in the wet storage environment, including placing the targets into metal canisters and cleansing the cooling pool water. These measures have already reduced the safety risks associated with the targets. By continuing to monitor and improve the wet storage environment while constructing a dry storage facility, it is possible that DOE could address the essential safety concerns in a manner that harmonizes environmental, timing, and non-proliferation goals.

In response to a public comment on the Draft EIS,[177] DOE evaluated the consequences of a "minimum processing scenario" that essentially parallels the recommendations of this report. That is, the scenario entails reprocessing existing solutions only, and not solid spent fuel.[178] The solid spent fuel would be maintained in basins and eventually moved to a new dry storage facility. According to the EIS, the cost of the minimum processing scenario would be $3.1 billion over ten years, close to the estimated cost of the implementing DOE's preferred alternatives, which is $3.0 billion.[179] The minimum processing scenario would generate 31 million liters of high-level waste, compared to 43 million liters for preferred alternatives, a difference of over 38%.[180]

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[174] DOE 1995b, p. 2-55

[175] DOE 1995b, p. 2-55

[176] DOE 1995b, p. D-48

[177] The Draft EIS evaluated only three scenarios: No Action, Preferred Alternatives, and a Comparative Alternatives Scenario, which was the collection of alternatives for each type of material that had the highest environmental impact. Comments on the Draft EIS by Brian Costner of the Energy Research Foundation and Drew Caputo of the Natural Resources Defense Council charged that the Comparative Alternatives Scenario was "a straw man of the highest order -- because it collects the worst of the worst in terms of environmental impact, the Department would never select it. The Department also would never select the no-action alternative..." (p. F-43 of the Final EIS). The commentors then suggested that DOE evaluate a minimal processing scenario.

[178] Nine neptunium reactor targets would be dissolved in H-Canyon for "programmatic reasons" (p. 2-76).

[179] DOE 1995b, p. 2-85 and p. 2-87

[180] DOE 1995b, p. 5-3

Indefinite Nature of Purportedly Short-Term Reprocessing

DOE's reprocessing proposals for solid spent fuel would have more credibility if DOE would describe and commit to some end point at which reprocessing operations would cease and the separations canyons would be dismantled. This kind of commitment would demonstrate that reprocessing is currently being proposed for a limited environmental purpose for a limited time period. At present, however, reprocessing is essentially an open-ended project, and years or even decades from now there is a high likelihood that DOE will find other nuclear materials that are degrading or corroding. There will thus always be some way to justify keeping the reprocessing plants operational, especially if DOE fails to act now on developing alternative stabilization technologies.

Even with just the materials that are candidates for stabilization under the Interim Management EIS, reprocessing operations under the preferred alternatives will occur for about six years between 1996 and 2002.[181] These six years of reprocessing could be extended even further depending on DOE's decision on foreign research reactor spent fuel and DOE's conclusions about whether additional material will be reprocessed.

While the recent DOE study recommending putting the H-canyon on stand-by is a positive development, the gain is modest because permanent decommissioning of this facility does not appear to be in the cards at present. Indeed, the recommendation to shift operations from H-Canyon was mainly based on cost and personnel considerations, and it would "provide the flexibility in the near term to allow the Department to revert back to the two-canyon approach if decisions expected to be made over the next year require additional separation facility capacity at the Savannah River Site."[182] The recommendation would leave the F-Canyon open as the only active reprocessing plant at the SRS without a clear path to shut it down in the foreseeable future. This is a retreat from the goal of permanently halting reprocessing at the Savannah River Site, as envisioned in DOE's 1992 policy on phasing out reprocessing.

Apart from the Interim Management EIS materials and the possible chemical separation of foreign research reactor spent fuel, DOE is considering several other "future missions" for SRS reprocessing facilities, most involving off-site materials. For example, DOE expects that the SRS canyons are the optimal facilities for stabilizing scrub alloy (plutonium-bearing residues) from the Rocky Flats plant near Denver. About 700 kilograms of scrub alloy containing 140 kilograms of plutonium are stored in the Rocky Flats Environmental Technology Site.[183] DOE is also considering using an SRS canyon to dissolve, reprocess, and blend-down metals or oxides of HEU as part of the program to dispose of HEU from dismantled nuclear weapons and other sources. Using reprocessing canyons as part of the HEU disposition process undermines the non-proliferation benefits of disposing of HEU.

[181] DOE 1995b, p. 2-72
[182] DOE 1995f, p. 1
[183] Westinghouse 1995, p. A-7

A recent Westinghouse study evaluated several scenarios for reprocessing at the SRS. In the case where no H-Area facilities would be started, which is likely, and the F-Canyon is used for both the scrub alloy and the HEU disposition, reprocessing could occur through the year 2005. Westinghouse also evaluated the case where F-Canyon would be used for scrub alloy, HEU disposition, and "all aluminum-clad SNF until the inventory at SRS is depleted," in which reprocessing would occur through 2012.[184] These are very long time periods in which to operate an aging F-Canyon facility, and they represent a stark departure from the original 1992 policy of stabilizing Savannah River Site materials and phasing out reprocessing.

It is the indefinite nature of the DOE reprocessing proposals, with attendant non-proliferation and environmental consequences, that is the major drawback of DOE's current attitude toward reprocessing. Without DOE putting an end point on reprocessing, the separations canyons at the SRS may enter their sixth or even seventh decade of operations.

The reprocessing option for *all* DOE aluminum clad spent fuel and the potential for long-term maintenance of a reprocessing capability at SRS became a far more likely course on November 15, 1995, when the Defense Nuclear Facilities Safety Board issued a letter supporting keeping open both the F- and H-Canyons for the indefinite future and deriding those in DOE who would want to close the canyons permanently:

> The only remaining facilities in the United States which can be used in large scale processing of aluminum-clad spent fuel elements are the F-Canyon and the H-Canyon at the Savannah River Site. The Board is informed that there is a degree of advocacy in some quarters within the Department of Energy for permanently shutting down one or both of these facilities, and that such measures are under discussion in the Department. ...[T]he Board strongly believes that it would be most short-sighted to take such actions, from which recovery would not be possible....
>
> ...*In the Board's view, the Department of Energy will always need to have available a capability for chemical processing of spent nuclear fuel,* since this is the only proven safe way by which the highly radioactive material can be converted into a form suitable for ultimate geologic disposal. This means that the capability now existing at Savannah River continues to be essential.[185] [emphasis added]

The DNFSB letter does not mention non-proliferation issues, the need for canyon upgrades to allow "safe" operation, or the problem of increasing the risk of fires or explosions in the SRS high-level waste tanks. Yet, in effect, it reverses a long-standing decision of the U.S. government, taken in 1992, to phase-out reprocessing at the SRS.

[184] Westinghouse 1995, p. 22
[185] Conway 1995.

Non-Proliferation Issues

The EIS does briefly evaluate the non-proliferation implications of reprocessing at the SRS. This section in the Final EIS is an improvement over the section in the Draft EIS, which, like the similar section in the F-Canyon EIS, discussed only the possibility that fissile material could be diverted from the Savannah River Site. The Final EIS mentions "potential international sensitivities of processing and consolidating plutonium from the SRS inventory,"[186] but it does not elaborate on the nature of these "sensitivities". While the section appropriately points out that no new plutonium would be created under the preferred options and that some of the existing stock of highly enriched uranium would be blended down into LEU, there is no discussion of the affect of long-term operation of the separations canyons on other countries' plutonium programs.

Unlike the F-Canyon EIS, the Interim Management EIS does not commit to turning extracted fissile material over to the IAEA. This is a major flaw as it is official Clinton administration policy to "submit U.S. fissile material no longer needed for our deterrent to inspection by the International Atomic Energy Agency."[187] IAEA safeguards would also demonstrate good faith that the material would not be used in weapons. A later DOE report did mention that "the Department is continuing a dialog with IAEA representatives concerning the potential for international safeguards and inspections..."[188]

While the bulk of the non-proliferation analysis in the EIS is inadequate, one section of the EIS describes DOE's study of optimal strategies for facility utilization at the SRS and indicates that a key factor in the study is "[f]urtherance of nonproliferation policy goals through early shutdown of reprocessing capability (such as the F-Canyon PUREX process)."[189] This sentence, not found in the Draft EIS, is one of the few in the recent DOE documents that indicates that DOE understands that there is some connection between halting reprocessing and supporting U.S. non-proliferation efforts. However, the later study that recommended against re-starting H-Canyon took a narrow view of the non-proliferation benefits of doing so, mainly that F-Canyon blends down HEU before separation from fission products, so pure HEU would not be extracted.[190]

Shutting down H-Canyon is a good policy, if it indeed remains shut down, but it does not carry the non-proliferation benefits of halting all reprocessing in the United States. Shutting down both canyons after the fissile material-containing solutions are removed would be a historic decision that should be implemented for the sake of sound environmental management and non-proliferation.

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[186] DOE 1995b, p. 2-66
[187] DOE 1995c, Appendix G
[188] DOE 1995f, p. 10
[189] DOE 1995b, p. 2-107
[190] DOE 1995f, p. 10

There is another proposal in the EIS that would have especially negative consequences for U.S. non-proliferation efforts, however: DOE's desire to obtain plutonium-242 by operating H-Canyon and HB-line to process it to an oxide. The plutonium-242 is apparently to be used in the U.S. "stockpile stewardship" program for the hydrodynamic testing of nuclear weapons. This involves detonating high-explosives in a sphere around the plutonium-242 and examining the dynamics of the resulting compression of the material. The compression is similar to what happens when an actual nuclear weapon detonates, but the compression of plutonium-242 would not lead to a nuclear explosion. The stated purpose of hydrodynamic testing is to maintain the safety and reliability of warheads in the U.S. arsenal. However, hydrodynamic testing can also provide information useful to the design of new nuclear warheads and has been criticized as having the potential to undermine the Comprehensive Test Ban Treaty being negotiated in Geneva. Plutonium-242 has been used in hydrodynamic testing in the past and could be used in the Dual-Axis Radiographic Hydrotest (DARHT) facility currently under construction at Los Alamos National Laboratory in New Mexico. DARHT is a facility that would X-ray from two axes the compression of a simulated warhead pit. The utility of DARHT for maintaining the safety and reliability of nuclear weapons is a matter of some dispute even among nuclear weapons scientists.[191]

The DOE proposal to obtain plutonium-242 could be a double blow to U.S. non-proliferation interests. First, a reprocessing facility would be operated to obtain the material. Second, the material would be used to support a program that is viewed by some countries as antithetical to the CTBT and to U.S. disarmament commitments under the NPT made in 1968 and reaffirmed in 1995.

Draft Foreign Research Reactor EIS

The implementation of reprocessing under DOE's *Draft Environmental Impact Statement on a Proposed Nuclear Weapons Non-proliferation Policy Concerning Foreign Research Reactor Spent Nuclear Fuel* is less definite than the proposals in the Interim Management EIS. The discussion of reprocessing and its environmental and non-proliferation implications in this EIS is somewhat more detailed, however. Prepared largely within DOE headquarters with input from the State Department, the Foreign Research Reactor EIS is the best of the recent EIS's in terms of pointing out some of the liabilities of reprocessing.

[191] Makhijani 1995

Overview of Foreign Research Reactor Policy

The purpose of the Foreign Research Reactor EIS is to outline the alternatives for managing spent fuel from research reactors in foreign countries. Research reactors are used for medical, industrial, and agricultural applications. They have been useful in cancer research, semiconductor and solar panel design, environmental sciences, and many other areas. DOE's "Basic Implementation" proposal is to manage 19.2 metric tons of foreign research reactor spent fuel in the form of 22,700 fuel elements.[192] At present, there are approximately 104 research reactors in 41 foreign countries.[193]

Until the 1980s, almost all research reactors in the world were fueled with highly enriched uranium, which is weapons-usable. The United States has been the major global supplier of HEU, and starting in 1958 the United States began accepting and reprocessing spent U.S.-supplied fuel from these foreign research reactors in order to maintain control over the HEU cycle and minimize proliferation risks. The practice of foreign spent fuel acceptance is known as the off-site fuels policy. In 1978, the Department of Energy initiated the Reduced Enrichment for Research and Test Reactors (RERTR) program, which aimed to further reduce proliferation risks by convincing countries to convert their research reactors from highly enriched to low-enriched uranium fuel that could not be used in weapons. In return, foreign research reactor operators demanded that the U.S. continue to take back the spent nuclear fuel.[194] About 38 reactors above one megawatt in 26 countries have converted to LEU fuel under the program.[195] Reactors under one megawatt generally have life-time cores. The off-site fuels policy and the RERTR program have been successful if little-heralded planks in U.S. non-proliferation policy.

The off-site fuels policy expired in 1988 for HEU fuels and 1992 for LEU fuels,[196] and the Foreign Research Reactor EIS is being prepared to assess the impacts of continuing to accept spent fuel from foreign research reactors. The EIS warns that a failure to continue to take back spent fuel would raise proliferation risks because a weapons-usable material will remain in reactor cores and spent fuel, countries may reprocess the spent fuel if the U.S. does not take it, and some research reactors may have to cease operation if their storage pools become full.[197] The EIS states that this could result in countries accusing the United States of violating Article IV of the Non-Proliferation Treaty, in which the United States pledged to extend the benefits of peaceful nuclear technology to other signatories. Also, if the research reactors do not continue to convert to LEU fuels, the U.S. will not supply them with HEU fuel and they may have to turn to other suppliers, most likely China and/or Russia.

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[192] DOE 1995c, p. 2-9
[193] DOE 1995c, p. 1-7
[194] DOE 1995c, p. 1-2
[195] *Nucleonics Week*, September 22, 1994
[196] DOE 1995c, p. 1-3
[197] DOE 1995c, p. 1-7

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Urgent-Relief Shipments

In late 1993, DOE proposed to ship 409 spent fuel elements to the Savannah River Site from eight research reactors in Europe that claimed they would have had to shut-down or reprocess their spent fuel if the U.S. did not accept it.[198] The state of South Carolina filed suit to block this "urgent-relief" shipment, fearing that the SRS would become a *de facto* permanent disposal site for the spent foreign research reactor fuel given DOE's troubles with a permanent repository. Julie Horton, spokesperson for the South Carolina attorney general, explained that the state did not want to be "the dumping ground for the world."[199] South Carolina District Court Judge Matthew Perry twice ruled for the state, issuing first a preliminary injunction and then a permanent injunction, but he was overturned twice on appeal. The first shipment of 153 assemblies arrived by train at the SRS on September 30, 1994, and by fall 1995 all the spent fuel elements had arrived at the SRS.

The South Carolina lawsuit provoked discussions within DOE of how to get South Carolina's acceptance of long-term shipments of foreign research reactor fuel. In late 1994 a memo was drafted within the Office of Environmental Management for Assistant Secretary Grumbly's signature that authorized a "shift in strategy" as the draft Foreign Research Reactor EIS was nearing completion from one that relied solely on domestic storage to one that relied on a "combination of processing and storage." The presumption behind the memo was that South Carolina would be less opposed to accepting the spent fuel if it is reprocessed because South Carolina believes that reprocessing would maintain employment at the SRS and provide economic benefits for the state. Assistant Secretary Grumbly never signed the memo, and he may have never even seen it before it was leaked to the press and public interest groups. Nevertheless, the fact that lower-level officials within EM even considered the proposals in the memo provides some indication of the strength of support for reprocessing within EM, as well as of the political motivations that may be driving current reprocessing proposals.

The (unknown) author of the memo wrote:

> Processing could be proposed at existing facilities at the Savannah River Site and possibly in a reprocessing plant in the United Kingdom, augmented by construction of interim dry storage, if necessary. Domestic processing would be proposed in conjunction with a commitment to conduct an aggressive research and development effort investigating the benefits of constructing and operating a new spent fuel processing facility. Such a facility would be designed and operated to treat the spent fuel to meet waste management criteria, not to produce weapons-usable material. The term "processing" is deliberately used to describe the proposal because any chemical separation of spent fuel, whether domestic or abroad, would be conducted in conjunction with a proposal to blend-down highly enriched uranium to low enrichment consistent with United States non-proliferation goals.

[198] DOE released an Environmental Assessment for this urgent relief shipment in April 1994.

[199] *NuclearFuel*, October 10, 1994

> Proposing to process spent fuel, instead of merely storing it, would significantly erode key arguments raised by the State of South Carolina and the South Carolina Congressional delegation against our proposed long-term acceptance of foreign research reactor spent fuel. Further, the economic incentives associated with re-starting operations at existing facilities and possibly constructing and operating a new processing facility should generate support for the proposal from those who favor processing. Such a shift in strategy may also provide an opportunity to negotiate a settlement to the litigation associated with the acceptance of foreign fuel under the Urgent-Relief Environmental Assessment.[200]

Later, the memo explicitly proposed a deal to convince South Carolina to drop its lawsuit and allow the spent fuel shipments:

> In exchange for South Carolina dismissing the suit, the Department would agree to seriously consider in the environmental impact analysis the processing of spent fuel at the Savannah River Site. Further, the Department could offer South Carolina an enhanced role in the National Environmental Policy Act review process, to ensure full and fair consideration of the processing option.[201]

The memo was obtained by public interest groups and members of the press and caused a storm of protest. Several representatives of public interest groups strongly voiced their objections to reprocessing and especially to constructing a new reprocessing plant for the purpose of gaining concessions from South Carolina. Once the memo became public, foreign research reactor operators also opposed the "shift in strategy" on the grounds that it would be harder for DOE to defend against lawsuits challenging reprocessing than against lawsuits challenging storage.[202]

The "shift in strategy" memo was a clear demonstration of a politicized DOE reprocessing policy. Reprocessing at the Savannah River Site was not justified on a perceived need to stabilize research reactor spent fuel, or even on economic grounds, but instead on the grounds of political expediency. There was no discussion in the memo of the environmental or non-proliferation implications of constructing a new separations canyon at the Savannah River Site. As already noted, the "processing"/"reprocessing" distinction is specious, especially since a new spent fuel "processing" plant could be used to separate plutonium from spent fuel as well.

Overview of the EIS

The public opposition to the memo may have strengthened the hand of those within DOE who are opposed to reprocessing. The Draft Foreign Research Reactor EIS issued in March 1995 does not reflect the extent of support for reprocessing that is evident in the memo. Indeed, several passages emphasize the environmental and non-proliferation liabilities of reprocessing.

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[200] DOE 1994f, pp. 2-3
[201] DOE 1994f, p. 3
[202] *NuclearFuel*, February 13, 1995

Nevertheless, the EIS does list chemical separation of fissile materials in the United States and chemical separation of fissile materials at a foreign facility as reasonable spent fuel management alternatives along with storage options. While listing a range of reasonable alternatives is required by law, advocates of reprocessing actively lobbied to have reprocessing options explored favorably in the EIS.

There are several decisions that will be made based on the EIS. First, DOE must decide whether the spent fuel should be brought to the U.S. or managed abroad. Second, DOE must decide on a management technique for the spent fuel. For management in the U.S., DOE is considering wet or dry storage, chemical separation, or "developmental" processing. For management abroad, DOE is considering providing assistance in creating storage space in other countries or providing "financial and/or logistical" assistance to reprocess the spent fuel in Britain and/or France. Hybrid alternatives are also possible, such as reprocessing some fuel in the United States and some abroad, or storing one portion of the spent fuel and reprocessing another. DOE must also decide issues such as financing, transportation routes, and program duration.[203]

Under the Basic Implementation plan, LEU or HEU spent nuclear fuel generated at foreign research reactors during the next ten years would be accepted. Actual shipments would occur during a thirteen-year period because an additional three years may be needed for spent fuel to cool before shipment and for logistical issues to be worked out.[204] The U.S. would not accept spent fuel generated after the ten-year period and hopes that foreign countries would have enough time to pursue alternative management methods, such as building storage facilities.[205]

DOE has not yet selected preferred alternatives, but the EIS states that the preferred alternatives will be chosen based on U.S. government non-proliferation policies, DOE agency missions, potential environmental impacts, cost, public concerns about fairness and equity to the states and communities involved, and uncertainties in funding, technology, and repository acceptance criteria.[206]

Chemical Separation (Reprocessing) in the United States

If reprocessing in the United States were chosen as the management technique, it could potentially occur at the Savannah River Site and/or INEL. DOE has decided to regionalize all of its spent fuel by fuel-type pursuant to the SNF/INEL EIS discussed below, so it is likely that under this alternative aluminum-clad foreign research reactor spent fuel would be managed at the

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[203] DOE 1995c, pp. 2-1 to 2-25
[204] DOE 1995c, p. 2-6
[205] This hope may be overly optimistic. The EIS in great detail describes how the research reactor's conversion to LEU is contingent upon U.S. spent fuel acceptance because conversion is expensive and the LEU fuel is less efficient. When the incentive of spent fuel acceptance stops at the end of the ten year or thirteen year period, research reactors may switch back to HEU fuels, with the attendant commerce in a bomb-grade material.
[206] DOE 1995c, pp. 2-1 to 2-14

Savannah River Site and that spent TRIGA[207] fuel from foreign research reactors would be managed at INEL. DOE proposes to accept approximately 18.2 metric tons of aluminum-clad spent fuel and approximately 1 metric ton of TRIGA spent fuel under the Basic Implementation alternative.[208]

In theory, the TRIGA spent fuel could be chemically separated at INEL, but according to the EIS this would require the construction of a new tank farm for radioactive waste, new bins for calcined waste, and a vitrification plant, so this subalternative is "not preferred" by DOE.[209] The EIS says that chemically separating the 18.2 metric tons of aluminum clad-spent fuel at the Savannah River Site would take approximately twelve years, whether it were done alone or as part of "larger-scale" separation activities. The pace of receiving the fuels from foreign countries would largely determine the pace of chemical separation.[210] In all the recent DOE documents relating to reprocessing, this twelve-year figure is one of the longest time periods in which reprocessing may occur, though, as noted above, DOE has not put any kind of upper bound on timing or on the amount of material that may eventually be reprocessed.

Either of the reprocessing canyons at the Savannah River Site could be used for the spent fuel.[211] High-level waste from chemical separation would be transferred to the F/H-Area Tank Farm and then to the DWPF for vitrification. According to DOE, the high-level glassified waste from separating the 18.2 metric tons of aluminum-clad spent fuel would fill about 60 DWPF canisters, 1.2% of the number of canisters that will be filled from glassifying high-level waste already on site.[212] The canisters would be stored at the Savannah River Site for up to forty years, depending on a repository schedule.[213] The EIS indicates that "[c]hemical separation would also generate five types of waste that would not result from storage of intact spent nuclear fuel: high-level radioactive waste, hazardous waste, mixed hazardous and radioactive waste, and low-level 'saltstone' waste."[214]

Direct Storage

DOE argues that the potential locations for storage of foreign research reactor fuel in the United States would have to be consistent with DOE's overall spent fuel management policy in which aluminum-clad spent fuel will be managed at the SRS and all other types at INEL. According to DOE, during the first few years of acceptance, the foreign research reactor spent fuel would be stored in existing wet or dry storage facilities. For the period beyond those first

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207 TRIGA stands for Training, Research, Isotope, General Atomics reactors
208 DOE 1995c, p. 2-9
209 DOE 1995c, p. 2-19
210 DOE 1995c, p. F-285
211 DOE 1995c, p. F-285
212 DOE 1995c, p. 4-93
213 DOE 1995c, p. 4-86
214 DOE 1995c, p. 2-17

few years, DOE anticipates using new dry or wet storage facilities (unless it chooses reprocessing).[215] Most significantly, the EIS acknowledges that "there are no identified technical constraints that would prevent dry storage of foreign research reactor spent nuclear fuel."[216] DOE estimates that dry storage casks sized for foreign research reactor spent fuel and coupled with existing spent fuel handling facilities could be available for loading within 18 to 36 months. A larger dry storage facility may be ready for loading in five to seven years.[217]

The main obstacle to implementing storage alternatives is political: the State of South Carolina remains opposed to the option.[218] South Carolina seems to be willing to accept the risks from spent fuel transportation if reprocessing is implemented at the SRS because it views reprocessing as the long term future of the site. It is not willing to accept the even lower risks from storage. As discussed above, Senator Strom Thurmond of South Carolina is opposed to storage but welcomes reprocessing at the site. Of course, reprocessing does not eliminate the need for storage of highly radioactive wastes, it merely changes the chemical form that the radioactivity is in. Employment at the SRS appears to be one of the principal reasons for South Carolina's support of reprocessing.

Developmental Processing Techniques

In a December 28, 1994 memo entitled "Analysis of a Potential New Processing Facility in the Foreign Research Reactor Spent Nuclear Fuel Environmental Impact Statement," Assistant Secretary Grumbly directed his staff to take "immediate action" to include an alternative in the Foreign Research Reactor EIS which would "initiate development work leading to a decision on whether to construct and operate a new SNF processing facility." The processing facility would "be capable of changing the FRR SNF into a form suitable for geologic disposal, without necessarily separating the fissile materials. A number of alternative processes would ultimately be considered for use in such a facility. Examples of these potential processes should be briefly discussed in the EIS." Further, Grumbly proposed that the discussion in the EIS "should describe the range of quantities of spent fuel that such a facility might be designed to handle (hypothetically, from as little as just the foreign research reactor spent fuel...to a maximum of all of DOE's spent fuel)."[219]

The EIS lists several of the technologies outlined above which could potentially serve as alternatives to PUREX reprocessing (chop and dilute, melt and dilute etc.).[220] While it is a positive development that DOE is at least considering such alternative technologies in the context

215 DOE 1995c, p. 2-11
216 DOE 1995c, p. F-3
217 DOE 1995c, p. F-5
218 The State of Idaho recently dropped its lawsuit against DOE barring all spent fuel shipments to INEL.
219 DOE 1995c, Appendix G
220 DOE 1995c, pp. 2-22 to 2-23

of a formal EIS, DOE should abandon further research on those technologies, such as electrometallurgical processing and the chloride volatility process, that separate fissile material from spent fuel. Constructing a major new "processing" facility that separates fissile material and using it for large amounts of DOE spent fuel is no better than large-scale PUREX reprocessing in terms of proliferation consequences and possibly environmental consequences.

Most significantly, the EIS reports that "[i]t is possible that the foreign research reactor spent fuel could be accepted intact in a geologic repository." If after further research it is found that this is not so, then some new form of processing, perhaps based on one of the technologies listed above, may be necessary prior to disposal. The EIS states that "DOE and the Department of State expect...that the new process would produce less severe impacts than the historical chemical separation activities."[221]

DOE Attitude Toward Chemical Separation in the United States

While the "shift in strategy" memo clearly supported reprocessing spent fuel at the Savannah River Site, the EIS itself is more tentative about the desirability of chemical separation in the United States. According to the EIS, the advantages of chemical separation are:

> -- The high-level radioactive waste from the spent nuclear fuel would be transformed into forms that are more suitable...for storage than intact aluminum-based spent fuel.
>
> -- The high-level waste would be converted to a form that is expected to be acceptable for disposal in a geologic repository.
>
> -- Construction of some or all of the new spent nuclear fuel storage space would be avoided.
>
> -- The conventional chemical separation facilities exist, as well as the waste treatment facilities required to put the high-level radioactive and other waste steams in forms suitable for disposal. In contrast, there are the large technical, cost, and regulatory uncertainties associated with direct disposal of intact foreign research reactor spent nuclear fuel (much of it containing HEU).
>
> -- If disposal of intact spent nuclear fuel is shown to be technically infeasible, or if the waste acceptance criteria for a geologic repository require significant dilution of the HEU due to criticality concerns, DOE estimates that the life-cycle costs of chemical separation may be substantially lower than the cost of storage and geologic disposal of intact spent nuclear fuel. (Alternatively, if direct disposal of intact foreign research reactor spent nuclear fuel, including that containing HEU, is shown to be technically feasible, DOE

[221] DOE 1995c, pp. 4-52 to 5-53

estimates that the costs of chemical separation and the storage/direct disposal option would be nearly the same.)[222]

This is a dubious list of advantages that focuses mainly on repository disposal issues, and it deserves close scrutiny. *In contrast to the Interim Management EIS, the Foreign Research Reactor EIS does not provide a justification for reprocessing based on an urgent need to stabilize the foreign research reactor spent fuel.* This is another example of DOE proposing reprocessing when it is not absolutely necessary on environmental grounds. There is no immediate environmental or safety need to reprocess the foreign research reactor spent fuel, yet reprocessing (if chosen as the management alternative) is expected to begin as early as 1996.

DOE's claim that high-level waste from reprocessing would be more suitable for storage than foreign research reactor spent fuel conveniently ignores the increased risk of an accident in a reprocessing waste tank. DOE assumes that the waste, once mixed into borosilicate glass, would be acceptable for disposal in the Yucca Mountain repository. However, as discussed above, hydration aging of the glass could potentially lead to release of radioactive materials to the biosphere. The potential mismatch between the repository and the waste form could increase the life-cycle costs of chemical separation because highly radioactive waste might have to be taken out of borosilicate glass and put into some other form before disposal.

DOE's admission in the last point that it does not yet know whether spent foreign research reactor fuel can be directly disposed of in a geologic repository provides all the more reason not to begin reprocessing procedures until DOE has more fully studied a repository and waste acceptance criteria. Much of the foreign research reactor spent fuel would be low-enriched anyway, and LEU poses far lower criticality risks in a repository than HEU. Storing the spent fuel for an interim period would provide the flexibility needed to make these important decisions about ultimate disposition.

Comments on the EIS by Brian Costner of the Energy Research Foundation pointed out that the reprocessing facilities "do indeed exist, but they are forty years old, and subject to substantial technical, cost, and regulatory uncertainties never discussed in the EIS." He added that "in the last few years, several significant and never before reviewed safety questions have come to light."[223] His comments also explained that the tanks where high-level reprocessing waste would be stored are also decades old and that it is not true that facilities exist for preparing other types of reprocessing waste for disposal.

According to DOE, the disadvantages of chemical separation are:

-- Chemical separation would increase the total volume of waste...

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[222] DOE 1995c, pp. 2-15 and 2-16

[223] Costner 1995

-- The separated uranium, which DOE would prefer to blend down to LEU, would have to be stored until it can be sold or otherwise disposed of.

-- The forms of the wastes generated by chemical separation are complex, involving corrosive, flammable, and toxic liquids.

-- The use of chemical separation by the United States as a spent nuclear fuel management technology could increase the accumulation of stockpiles of HEU. The United States does not engage in reprocessing (chemical separation) for either nuclear power or nuclear explosive purposes, and seeks to eliminate, where possible, the accumulation of stockpiles of HEU or plutonium.[224]

Several disadvantages are not mentioned here, such as the impact of reprocessing on the safety of the SRS waste tanks and the technical difficulties of the blending down process. Also, DOE does not list as a disadvantage the impact on U.S. non-proliferation efforts of running one or more reprocessing plants in the United States for as long as twelve years, even if the extracted HEU is blended down.

Nevertheless, the explicit outline in the EIS of the disadvantages of reprocessing represents a step in the right direction for DOE. It shows that at least some officials within DOE are beginning to question the assumptions that have driven reprocessing policy. The other EIS's simply assume that reprocessing is a sound technique for spent fuel management, and the lack of a similar cost and benefit discussion is a remarkable omission from the other EIS's.

The EIS concludes its assessment of chemical separation in the United States with the following paragraph:

Taking these advantages and disadvantages into account, chemical separation of spent nuclear fuel in existing facilities is not preferred by DOE as a technology for management of spent nuclear fuel in the United States because of the necessity of handling additional waste streams and because it could increase the accumulation of stockpiles of HEU. Nonetheless, chemical separation remains a reasonable alternative, especially in light of DOE's substantial technical expertise in these operations and the availability of existing facilities.[225]

The wording of this paragraph may have been carefully crafted to satisfy pro- and anti-reprocessing groups within DOE and to state a preference against reprocessing while leaving a door open to implement it, possibly in order to obtain South Carolina's acquiescence in accepting spent fuel shipments. A surprising thing about this paragraph is that it goes so far as to express a preference for a policy against reprocessing all types of spent nuclear fuel, that is, not just the foreign research reactor spent fuel that is the subject of the EIS. But as shown above,

[224] DOE 1995c, p. 2-16
[225] DOE 1995c, p. 2-16

reprocessing was DOE's preferred stabilization alternative under the Interim Management EIS for some types of spent fuel, targets, and other nuclear materials already at the Savannah River Site. This is a clear inconsistency between the two EIS's.

The inconsistency is likely a reflection of the internal debate within DOE over the utility of reprocessing as a waste management tool. The Interim Management EIS was prepared largely by the Halliburton NUS Corporation, a South Carolina-based DOE contractor, and the Aiken, South Carolina DOE field office, while the Foreign Research Reactor EIS was prepared by DOE's Washington headquarters with State Department input. Aiken is a city that was built on plutonium and reprocessing in the same way that Pittsburgh was built on steel,[226]and in general the DOE sites where reprocessing occurred in the past tend to be stronger advocates of reprocessing than the upper management in the Office of Environmental Management. Changing the pro-reprocessing culture of DOE will require strong leadership from Secretary O'Leary, Assistant Secretary Grumbly and other high-level officials within DOE headquarters.

Despite the preference in the EIS not to reprocess, the EIS outlines some cases where reprocessing may be justified, proposing "to limit near term chemical separation as a method for managing spent nuclear fuel in the United States to only those cases where it would be needed to accomplish one or more of the following:"[227]

> 1. Protection of the health and safety of workers or the public;
>
> 2. Conversion of the spent nuclear fuel into a more stable physical form to enable it to be safely stored prior to ultimate disposition;
>
> 3. Conversion of the spent nuclear fuel into a physical form that is acceptable for disposal in a geologic repository; or
>
> 4. To address programmatic conditions, such as the unavailability of suitable storage facilities or the likelihood of substantial life-cycle cost savings from chemical separation (followed by treatment, storage, and disposal of the resulting wastes) versus storage and disposition of intact nuclear fuel.[228]

These conditions on reprocessing are very broad. Indeed, the circumstances under which DOE would allow chemical separation to occur are similar to the reasons DOE proposes to implement chemical separation. For example, as discussed above, DOE believes reprocessing is advantageous to address points #2 and #3. Limitation #4 would allow reprocessing of large portions of DOE spent fuel, since much of it is not stored in suitable forms or facilities today.

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[226] See the *San Francisco Chronicle*, April 11, 1995, for a lengthy article on the changes in Aiken due Savannah River Site layoffs and the uncertain future mission of the site.

[227] DOE 1995c, p. 2-16

[228] DOE 1995c, pp. 2-16 to 2-17

Indeed, the limitations allow reprocessing of whatever spent fuel DOE might choose to reprocess.

Though the proposed limitations on reprocessing are weak, this section again points to the evolving nature of DOE policy on reprocessing. This section challenges the long-standing presumption in favor of reprocessing and puts the burden on advocates of reprocessing to justify their support for it based on (admittedly weak) written criteria. In sum, while the draft EIS states that the reprocessing alternative is, on balance, not the preferred one, there appears to be an enormous amount of room for a change in policy either in the final EIS or perhaps even thereafter.

Non-proliferation Consequences of Reprocessing in the United States

To meet U.S. non-proliferation policy, DOE prefers to blend down HEU separated from spent research reactor fuel in the United States into low-enriched uranium, but in a familiar pattern, neither institutional and technical procedures nor a schedule for blending down is outlined.[229] The EIS indicates that LEU resulting from blending-down could be returned to the commercial sector for re-use as reactor fuel,[230] and the small amount of plutonium in spent fuel would not be separated.[231] The EIS states that if DOE decides not to blend down HEU recovered under the Interim Management EIS (for example, from the HEU-solutions in the H-Canyon), then HEU recovered from the foreign research reactor spent fuel would also not be blended down, and would instead be placed under IAEA safeguards. DOE does not prefer this alternative, however, because it recognizes that the policy of taking back spent fuel from foreign research reactors, which was designed to limit the accumulation of HEU abroad, should not result in HEU stockpiling in the United States.[232] Blending-down is the preferred option in the Interim Management EIS as well.

The Foreign Research Reactor EIS acknowledges that despite U.S. government intentions to blend down HEU into non-weapons-usable form, "other states may perceive only that the U.S. has re-started reprocessing."[233] According to the EIS, this could have negative non-proliferation consequences:

> For example, the potential exists that other states (e.g., Iran), might use the restart of reprocessing in the United States as an excuse to continue current programs or begin new ones -- activities that would run counter to U.S. nuclear weapons nonproliferation interests. The implications in North Korea, where the United States has been actively

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[229] DOE 1995c, p. 2-21
[230] DOE 1995c, p. 2-20
[231] DOE 1995c, p. 4-84
[232] DOE 1995c, pp. 2-20 to 2-21
[233] DOE 1995c, p. 4-84

working to create a nonreprocessing zone, as well as in other states, could complicate current U.S. nonproliferation activities.[234]

This is the most explicit passage about the international non-proliferation implications of U.S. reprocessing in all of the EIS's and documents discussed in this report. Going beyond the standardized language of the F-Canyon EIS, this passage grants that U.S. reprocessing could be detrimental to U.S. non-proliferation interests abroad. The only other place that comes close to granting this point is the Interim Management EIS's statement that shutting down one of the canyons at the SRS would support U.S. non-proliferation efforts. The more forceful language and wider scope of non-proliferation implications outlined in the Foreign Research Reactor EIS compared to other documents could be yet another reflection of State Department and DOE headquarters involvement in formulating research reactor spent fuel policy.

It should be mentioned that not only may North Korea or Iran take U.S. reprocessing as a license for their activities, but Russia and other states currently operating reprocessing plants may view it as a kind of legitimization of reprocessing. It remains to be seen whether the negative non-proliferation implications of starting reprocessing for management of foreign research reactor fuel, as acknowledged by DOE, would be enough to offset the assumed cost savings and assumed ease of using existing facilities.

The passage also points to a little-acknowledged fact. If reprocessing plants are operated in the U.S. for the foreign research reactor spent fuel, and if extracted HEU is blended-down (thus avoiding weapons-usable fissile material accumulation in the United States), the negative non-proliferation consequences of reprocessing may nevertheless remain. Other countries may see only that U.S. is operating its Cold War reprocessing plants for as long as twelve years, and they would not be able to verify the purpose or the product of the reprocessing. In addition, other countries would not appreciate the fact that the U.S. is reprocessing the very spent fuel that it is trying to prevent them from reprocessing.

Cost of Reprocessing Foreign Spent Fuel vs. Storage in the United States

There are large uncertainties in estimating costs for various management options because the spent fuel has not been characterized and because of the long time-frame for spent fuel acceptance. DOE cost estimates appear to underestimate the true cost of reprocessing and overestimate the cost of storage options.

The EIS states that reprocessing spent foreign research reactor fuel alone is not economically viable because of the expense of operating a separations canyon for a small amount of material. The undiscounted cost of separating 18.2 metric tons of aluminum-clad spent fuel alone at the Savannah River Site would be $2.15 billion in 1996 dollars,[235] while chemically

[234] DOE 1995c, p. 4-84

[235] DOE 1995c, p. 4-129. Includes cost of storage of 1 metric ton of TRIGA fuel at INEL.

separating the same amount of foreign research reactor fuel concurrently with the other materials at the Savannah River Site would cost $1.5 billion.[236] A decision to reprocess foreign research reactor spent fuel is thus "predicated upon a decision by DOE to re-start the chemical separation facilities at the Savannah River Site under the Interim Management of Nuclear Materials EIS."[237]

It has already been shown that one or more reprocessing canyons are likely to be re-started pursuant to that EIS. In addition, according to the DOE, operating parts of the F-Canyon to stabilize the plutonium solutions will "serve to maintain the operability of facilities that could potentially be used for chemical separation of foreign research reactor spent fuel at the Savannah River Site."[238] *In a kind of ripple effect, operating separations canyons and conversion lines for other purposes increases the incentive to use them for the foreign research reactor spent fuel.*

The EIS explains that "[c]oncurrent processing is not currently evaluated as an option after 2003, but this may change as a result of NEPA reviews on other programs."[239] That is, DOE anticipates that after the Interim Management materials are reprocessed (completion is expected before 2003), there may be other materials that could be reprocessed concurrently with the foreign research reactor spent fuel. The EIS does not elaborate on the nature of these materials or reasons for reprocessing any other spent fuel. This lends further credence to this report's argument that a failure to place a definite near-term endpoint on reprocessing could lead to a situation where the plants are kept operational indefinitely to manage spent fuel that is found in the future to be corroding.

DOE may be underestimating the cost for chemically separating foreign research reactor fuel during the period of operation of canyons pursuant to the Interim Management EIS by not attributing costs correctly to the research reactor fuel. For example, DOE provides a very low estimate that the incremental cost of separating foreign research reactor fuel in the H-Canyon between 1997-1999, when it is expected to operate to stabilize HEU solutions, will be only $1 million.[240] But the EIS also states that the total annual cost of operating H-Canyon is $84 million.[241] It thus attributes only 0.6% of the annual cost to the foreign research reactor spent fuel, and the real annual operating cost of H-Canyon is about twice the $84 million figure. Comments on the EIS by Brian Costner of the Energy Research Foundation charged that "the EIS should better ensure that the foreign research reactor spent fuel program is charged a full and fair percentage of operating costs and overhead."[242]

Similarly, the EIS does not attribute the estimated $210 million cost of upgrading reprocessing facilities at the Savannah River Site to the foreign research reactor spent fuel. It

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[236] DOE 1995c, p. 4-129. Includes cost of storage of 1 metric ton of TRIGA fuel at INEL.
[237] DOE 1995c, p. 2-19
[238] DOE 1995c, p. 1-13
[239] DOE 1995c, p. F-267
[240] DOE 1995c, pp. F-285 and F-286
[241] DOE 1995c, p. F-285
[242] Costner 1995

argues that these "would, presumably, be borne by other programs requiring use of the facilities, e.g. programs to stabilize the existing Savannah River Site materials under a separate EIS."[243] A large portion of this cost, which again is probably on the low end, should be attributed to the foreign research reactor spent fuel because the need to manage this material was cited as a primary justification for the upgrades.

DOE's comparison of the costs of reprocessing versus storage is also suspect. The EIS concludes that the costs are about the same ($1.4 billion to $1.65 billion for the former, $1.35 billion to $2.15 billion for the latter in undiscounted 1996 dollars). However, the cost *uncertainty* for storage is greater because, according to DOE, it is not known what processing the stored spent fuel may have to undergo before emplacement in a repository, whereas vitrified high-level waste, the waste product from chemical separation, is expected to be suitable for the repository. The cost uncertainty for storage is $2 to $2.5 billion, while the uncertainty for chemical separation is $0.5 billion.[244] It is true that it may be costly to change the form or enrichment of HEU spent fuel if it is found that it cannot be directly disposed of in a repository. These potential future cost uncertainties are outweighed, however, by the present risks of reprocessing and the possibility that no extensive modifications are needed for the HEU spent fuel.

DOE's cost estimates, which assume that waste in borosilicate glass will be acceptable in a repository, could drive the implementation of chemical separation despite DOE's tepid preference not to reprocess. The cost estimates may be flawed, however. For example, the EIS acknowledges that the number of casks it estimates would be needed for the dry storage option is "very conservative and correspond[s] to a maximum of around 40 percent of the NRC-licensed heat loads per cask."[245] Higher heat loadings per cask would reduce the overall cost of dry storage.[246]

Reprocessing Spent Foreign Research Reactor Fuel Outside the United States

The other major alternative in the EIS involving reprocessing is to separate the foreign research reactor spent fuel at a foreign facility with U.S. "financial and/or logistical" assistance. The reprocessing could be done either in France or the United Kingdom. According to DOE, both countries "have modern fuel cycle facilities and offer a complete line of services to international customers."[247] This alternative is more likely to be implemented in the United

[243] DOE 1995c, p. 4-130, footnote 1
[244] DOE 1995c, p. 4-127
[245] DOE 1995c, p. F-91
[246] For other examples of overestimation of dry storage costs, see Costner 1995.
[247] DOE 1995c, summary, p. 24

Kingdom because its Dounreay plant in Scotland is "the sole facility currently willing and able to reprocess" spent foreign research reactor fuel.[248]

Because the British and French governments do not accept responsibility for disposing of high-level waste from reprocessing other countries' spent fuel, the wastes would have to be returned to the reactor operator, but because some countries do not have the capability to store high-level waste, some waste may have to be sent to the United States.[249] The EIS states that the cement waste form produced at Dounreay is not compatible with U.S. radioactive waste disposal standards. The United Kingdom Atomic Energy Authority is thus considering a proposal to send vitrified high-level waste from the Sellafield reprocessing facility to the United States as a substitute for the Dounreay cement.[250] The EIS indicates that vitrified high-level waste from reprocessing the full 19.2 metric tons of research reactor spent fuel would fill 16 European-size canisters, or four American canisters.[251]

The Dounreay option may be politically attractive to DOE because no shipments of spent fuel from foreign countries would come to the United States and very little waste would have to be managed in the United States. The EIS does not include the environmental impacts in the United Kingdom or France from reprocessing operations in its comparison of this option with other alternatives.[252] These impacts would of course not be eliminated but would simply be exported to another country.

In assessing the option of reprocessing abroad, the EIS explains that factors such as ensuring that any HEU produced from reprocessing is blended-down and that the reprocessing plant could be modified to handle the high-density LEU fuels that the U.S. is urging the reactor operators to use "would have to be considered."[253] DOE believes that these measures are important to wean research reactor operators away from HEU fuel and to reduce the amount of HEU in civil commerce.

However, the EIS does not categorically state that the Dounreay option would be ruled out if the U.S. could not secure these commitments. It is not at all clear that Dounreay would agree to the U.S. conditions, since implementing a capacity to reprocess high-density LEU is expensive and since there could potentially be more profit in selling the material from reprocessed spent fuel as HEU for research reactors than in selling it as LEU. Comments on the Draft EIS by the Nuclear Control Institute, a DC-based non-proliferation group, pointed out that "Despite repeated attempts, the United States has been unable to obtain *any* of these...commitments -- let

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[248] DOE 1995c, p. 4-99
[249] DOE 1995c, p. 4-100
[250] DOE 1995c, p. 4-101
[251] DOE 1995c, p. 4-100. This is much less than the 60 canisters that would be produced from reprocessing the same material at the Savannah River Site.
[252] DOE 1995c, p. 4-121
[253] DOE 1995c, p. 2-24

alone all of them -- from the UK's AEA Dounreay facility."[254] It is possible that if negotiations stall, the use of Dounreay could be seen as so politically attractive that DOE would accept less than full adherence to the conditions.

A third condition on the Dounreay option listed in the EIS is that "research reactor operators would be encouraged to convert to LEU if an LEU fuel exists or is developed that will allow such operation."[255] This condition is not sufficient. Unless Dounreay goes further than merely encouraging operators to switch and actually refuses to reprocess HEU from a reactor that is capable but does not use LEU, the goals of the RERTR program will be defeated.

Even if Dounreay agreed to all three conditions, the Dounreay option may have negative consequences for U.S. non-proliferation policy. For the past forty years the United States has been able to control a large portion of world-wide commerce in HEU by supplying HEU, taking it back in spent fuel, and encouraging reactor operators to switch to LEU. Involving another country and a facility which does not necessarily share U.S. goals may reduce U.S. control over HEU commerce and hence reduce U.S. leverage to eliminate HEU from civil commerce.[256]

Costs of Reprocessing Abroad

The EIS indicates that the reprocessing capacity of Dounreay is small and that reprocessing 19.2 metric tons of spent fuel from the foreign research reactors would take more than 22 years if the plant operated at 100% capacity.[257] To shorten this time and lower costs, the EIS explains that the Savannah River Site and Dounreay could be used in tandem. Foreign research reactor spent fuel could be reprocessed at the Savannah River Site in the near term (1997 to 2003), while the canyons are likely to operate pursuant to the Interim Management EIS, and Dounreay could be used from 1997 to 2008.[258] This would avoid having to operate the Savannah River plants solely for the research reactor spent fuel. Which spent fuel would be sent to each facility would depend on the location of the reactor, the nature of the spent fuel, and the capability of the country to take back cement waste from Dounreay.[259] According to the EIS, using the two sites in tandem would "expedite completion of the program and cost less than any United States-only alternative."[260] The total cost of this option, with chemical separation of 10,500 fuel

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[254] Leventhal and Kuperman 1995, p. 8
[255] DOE 1995c, p. 2-24
[256] DOE appeared to recognize this fact in its efforts to dissuade a German research reactor operator from sending 52 spent fuel elements to Dounreay for reprocessing during September 1995. Though the German government assured DOE that the extracted HEU would be blended down to LEU, DOE still attempted to prevent the reprocessing by agreeing to accept the spent fuel in the United States. The offer of acceptance came too late to break the reprocessing deal with Dounreay, however (see Charleston *Post and Courier*, September 13, 1995).
[257] DOE 1995c, p. 4-131
[258] DOE 1995c, p. F-299
[259] DOE 1995c, p. F-284
[260] DOE 1995c, p. F-291

elements at the Savannah River Site, 9,750 fuel elements at Dounreay, and storage of TRIGA fuel at INEL, is estimated at $1.45 billion in undiscounted 1996 dollars.[261]

The Dounreay facility currently charges $5,000 to $6,000 per kilogram of total mass of spent fuel for reprocessing, not including shipping of spent fuel to the plant or shipment of wastes from the plant but including cementing the waste.[262] If it is assumed that the roughly 50/50 split in the number of elements going to Dounreay and the Savannah River Site under the tandem option means a 50/50 split by mass, then Dounreay may reprocess about 50,000 kilograms in total mass of research reactor fuel.[263] At current charges, this would provide $250 million to $300 million to Duonreay. The Nuclear Control Institute charged that providing any financial assistance to Dounreay "would use U.S. taxpayer dollars to reopen, subsidize, and keep in business a foreign reprocessing plant, despite the stated U.S. policy of not encouraging foreign reprocessing."[264]

Conclusion about Management Options for Foreign Research Reactor Spent Fuel

There are no ideal options for managing the spent fuel from foreign research reactors. Storage of the spent fuel in the United States is opposed by some who live near potential storage facilities and along transportation routes because the United States would bear the waste burden of other countries. Reprocessing the spent fuel in the U.S. or abroad would undermine U.S. non-proliferation interests, and not taking the spent fuel from reactor operators would perpetuate civil use of HEU.

In choosing among alternatives which all have certain drawbacks, storage in the United States is the most viable option. In contrast to DOE's overall spent nuclear fuel management plan, which involves thousands of shipments of spent fuel around the U.S. with uncertain benefits, there is a clear non-proliferation benefit to the acceptance and storage of the foreign research reactor spent fuel. While storage does pose some environmental and safety risks, these risks are relatively low and far lower than reprocessing in the U.S. or abroad. A DOE decision to accept the spent fuel into the United States should be accompanied by a written and binding commitment not to reprocess it.

U.S. Foreign Research Reactor Policy and Overall U.S. Fissile Material Policy

The United States' long-standing policy of accepting U.S.-origin research reactor spent fuel and the urgency with which DOE is trying to continue this policy are indications of the U.S. commitment to limiting the civil use of HEU, which is readily usable in nuclear weapons. The

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[261] DOE 1995c, p. F-297

[262] DOE 1995c, p. F-298

[263] DOE reports that the total mass of the research reactor spent fuel is 101 metric tons, or 101,000 kilograms (p. F-296).

[264] Leventhal and Kuperman 1995, p. 11

reasoning behind this policy is sound. As a general rule it is important to keep weapons-usable materials out of civilian commerce, especially since so many countries of varying degrees of political stability operate research reactors.

It is also sound policy to approach the more serious and growing problem of civilian use of plutonium with the same urgency and commitment of resources, especially given the U.S. policy to "explore means to limit the stockpiling of plutonium from civil nuclear programs." There is much more separated plutonium in civilian commerce than HEU (180 metric tons of plutonium vs. 20 metric tons of HEU).[265] However, as stated before, the United States has not put pressure on the countries that operate civil reprocessing plants to halt plutonium extraction and it has met its uranium supply commitments to countries that have their commercial spent fuel reprocessed. An example of this discontinuity is that the U.S. government offered a Belgian research reactor operator $500,000 in 1993 to break a contract with Dounreay to reprocess spent fuel.[266] At the time, DOE was concerned that sending the fuel to Dounreay would encourage international commerce in HEU (because Dounreay would not have blended-down the extracted HEU). However, the U.S. has not taken steps to dissuade Belgium from reprocessing its *commercial* spent fuel. Belgium has already acquired over 1,170 kilograms of weapons-usable plutonium through reprocessing contracts with the French company Cogema.[267]

DOE anticipates this line of argument and offers a response in the EIS to individuals and groups who have called U.S. policy on civil plutonium and research reactor spent fuel inconsistent:

> The U.S. government believes that the growing quantities of plutonium in international commerce do present a threat to the efforts of the United States and other countries to prevent the proliferation of nuclear weapons. In countries where material control and accounting or physical protection systems are not sufficiently rigorous, there is a risk of diversion or theft of such materials. In addition, even in countries with effective nuclear weapons nonproliferation commitments, the presence of unneeded stocks of plutonium could raise security concerns on the part of neighboring countries. Accordingly, the U.S. government does not encourage the civil use of plutonium.[268]

This is a strong statement on the dangers of civil plutonium use, even stronger than the presidential pronouncements in the White House fact sheet. The statement is followed, however, by an almost inevitable "nevertheless":

> Nevertheless, the United States is also committed to being a reliable trading partner and to avoiding interference in peaceful nuclear programs... Undertaking the use of U.S. consent

[265] Albright, Berkhout, and Walker 1993, p. 197
[266] The Glasgow *Herald*, August 26, 1995
[267] Albright, Berkhout, and Walker 1993, p. 111
[268] DOE 1995c, pp. 1-5 to 1-6

> rights to block reprocessing would lead to confrontation with key allies and would jeopardize their support for the broader U.S. nuclear weapons non-proliferation agenda.[269]

This argument is not strong enough to justify ignoring the proliferation dangers DOE itself says are posed by civil plutonium programs. The RERTR program, after all, is a kind of "interference in peaceful nuclear programs." That is, the U.S. offered an incentive, taking back spent fuel, to convince countries to convert peaceful nuclear activities using a bomb-material, HEU, to activities using proliferation-resistant material. Similarly, the United States could offer an incentive to work with France, Belgium, Japan, and other countries with civil plutonium programs to convert their peaceful nuclear energy programs from a bomb-material, plutonium, to a proliferation-resistant material, low-enriched uranium. An appropriate and symbolic incentive might be to create an international reserve of low-enriched uranium, blended-down from HEU from dismantled warheads, to serve as an alternative to plutonium-based fuels.

A serious multilateral discussion of civilian plutonium issues that includes appropriate incentives does not have to lead to a confrontation with U.S. allies. Beginning to talk about alternatives to plutonium-based reactor fuel could lead to progress on what the U.S. considers to be a serious proliferation matter. Such discussions with Russia could lead to a halt in all forms of reprocessing there. Of course, the U.S. would carry much more authority in these discussions if it were not itself operating reprocessing plants.

Another, even more surprising discontinuity between the administration's research reactor policy and its civil plutonium policy is that the EIS cites HEU *in spent nuclear fuel* as a proliferation threat. In explaining the problems with the option of U.S. assistance in storing the spent fuel overseas, the EIS says:

> ...even if perfectly secure storage facilities [for the spent fuel] were built [in foreign countries], all that would be required to frustrate their function would be a coup or other change in government leaving a regime in power that is unconcerned about the proliferation of nuclear weapons. Then the spent nuclear fuel could be diverted into a weapons production program... It seems clear that the potential for such an event to occur would increase with the number of spent nuclear fuel stockpiles that are allowed to build up around the world and the length of time they exist.[270]

Weapons-usable material in spent fuel does pose a small degree of proliferation risk. U.S. concerns about a coup or change in government leading to use of HEU in spent fuel in weapons are sufficient to justify a complex program to bring the spent fuel to the United States. On the other hand, little is done to minimize the risks from the 180 metric tons of separated commercial plutonium that exist in the world today, which would not even need to be reprocessed before use

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[269] DOE 1995c, p. 1-6
[270] DOE 1995c, p. 1-7

in weapons. Plutonium-239 has a half-life of over 24,000 years, while the current "half-life" of political change in a country like Russia is on the order of a few years. Yet no similar program has been established to halt civil plutonium production in Russia or other countries. Indeed, the approximately 750 metric tons of plutonium in spent fuel at hundreds of reactor cooling pools around the world also pose some degree of proliferation risk, though less than those from HEU in spent fuel.

One final point about the administration's priorities on fissile materials issues is the disproportionality between the urgency with which it is pursuing the foreign research reactor spent fuel program and the relative lack of priority with which it has implemented its HEU deal with Russia. In the $12 billion, twenty-year deal signed in January 1994, Russia agreed to blend down 500 metric tons of HEU into low-enriched uranium for sale to the United States. Front-page stories in major newspapers in the spring of 1995 indicated that the HEU deal was in trouble due to disagreements between the Russian Ministry of Atomic Energy and the United States Enrichment Corporation over the price that will be paid for the low-enriched uranium. U.S. Commerce Department concerns about Russian uranium dumping on the U.S. market have also held up the deal. Three years after the deal was first proposed and close to two years after the deal was signed, only two small shipments of LEU have arrived in the United States. U.S. and Russian officials have recently negotiated to get the deal back on track.

The total amount of HEU in foreign research reactor spent fuel that the U.S. is proposing to manage is 4.6 metric tons, though the program itself could forestall the use of more HEU over the next several decades.[271] The HEU in spent fuel is not usable in weapons without reprocessing. This pales in comparison to 500 metric tons of weapons-usable HEU that is not in spent fuel in a politically unstable country where reports of thefts of radioactive materials are widespread and where several thefts have actually occurred. The United States government certainly needs to make the implementation of this deal a higher priority.

Final Spent Nuclear Fuel and INEL EIS

In April 1995, the Department of Energy released its *Programmatic Spent Nuclear Fuel Management and Idaho National Engineering Laboratory Environmental Restoration and Waste Management Programs Final Environmental Impact Statement* (the SNF/INEL EIS). As lengthy as its title implies, the thirteen-volume EIS outlines the alternatives for managing spent nuclear fuel from DOE sites, naval reactors, research reactors, and some commercial reactors over the next forty years until the spent fuel can be disposed of in a repository. Most of the material

[271] DOE 1995c, summary, p. 16

addressed in the Interim Management EIS and the Foreign Research Reactor EIS, which have shorter-term planning horizons, is addressed in the SNF/INEL EIS over the long-term.

The SNF/INEL EIS also outlines the alternatives for environmental restoration and waste management at INEL. The two subjects were included as a package in part because INEL figures prominently in almost all of the options being proposed for managing spent nuclear fuel. Most of the INEL waste management section of the EIS does not relate to the subject of this paper.

DOE has responsibility for roughly 2,650 metric tons of spent nuclear fuel at over 50 sites in the United States.[272] DOE's spent fuel inventory contains 53 different categories of fuel types. On May 30, 1995, DOE issued its Record of Decision (ROD) for the SNF/INEL EIS. The Department chose the "Regionalization by Fuel Type" alternative for spent fuel. Aluminum-clad spent fuel will be sent to and managed at the Savannah River Site. All other fuel types, such as naval fuel, TRIGA fuel, and zirconium-clad fuel, will be sent to and managed at INEL, with the exception of Hanford N-Reactor fuel, which will be managed at Hanford. N-reactor fuel comprises the majority of DOE spent fuel by mass.

Approximate DOE Spent Fuel Inventory in Metric Tons and by Percentage of Total in 1995 and 2035 (after Regionalization by Fuel Type)

Location	1995 Amount	2035 Amount	1995 Percent	2035 Percent
Hanford	2,133	2,103	81	76
INEL	261	426	10	16
SRS	206	213	8	8
Other sites	46	0	1	0
TOTAL	2,646	2,741	100	100

SOURCE: Record of Decision, SNF/INEL EIS, p. 13
NOTE: The 95 metric ton increase in the total inventory of spent fuel comes from future spent fuel generation from naval reactors, foreign research reactors, and other sources.

The main stated factor in the decision to regionalize spent fuel by fuel type was the capability of each site to "manage specific fuel types with respect to cladding material, physical and chemical composition, fuel condition, and adequate facilities to handle increased quantities of fuel."[273] Most of the aluminum-clad fuel in the United States is already at the Savannah River Site, and naval fuel has historically been sent to INEL for characterization, storage, and

[272] DOE 1995a, summary, p. 8
[273] DOE 1995a, summary, pp. 20-22

reprocessing. As will be shown below, a potential effect of regionalizing spent fuel by fuel type is to facilitate reprocessing the spent fuel.

Reprocessing in the EIS

The main decision that DOE made based on the EIS was where spent fuel should be shipped to and managed, but the EIS does outline and discuss potential management techniques that could be applied to its spent fuel. According to the EIS, "technology-based decisions are most appropriately made after a detailed analysis on a fuel type-specific or site-specific basis."[274] The SNF/INEL EIS lays out *possible* storage, stabilization, and processing techniques that *could* be applied to manage the spent nuclear fuel inventory, and reprocessing is one such technique. A number of the developmental processing techniques (chopping, melting, electrometallurgical processing etc.) discussed in the Foreign Research Reactor EIS and the Technology Integration Plan could also be applied to the spent fuel, and these are outlined in an appendix to the SNF/INEL EIS.

The only concrete decision on reprocessing made by DOE based on the EIS is that it will fund and demonstrate the electrometallurgical process this year under the "modified 10-year plan" for INEL.[275] As stated above, one isolated sentence in the EIS explains that R&D on electrometallurgical processing will include processing limited quantities of commercial spent fuel. This is far outside the scope of the DOE-owned spent fuel management program and should not be undertaken as it reverses long-standing U.S. abstention from commercial reprocessing and keeps the door open to a return of commercial reprocessing in this country.

Despite current uncertainties about choosing a spent fuel management technique over the long-term, there are some passages in the EIS that indicate that DOE may be likely to choose reprocessing as a major part of the spent fuel management program. For example, Appendix J of the EIS, which lists and describes developmental processing technologies such as electrometallurgical processing and the chloride volatility process, says that chemical separation is the "only technology currently available."[276] The other technologies are in the research phase, with varying times before they could be ready for full-scale implementation. In the near term (within the next five years or so), chemical separation or electrometallurgical processing, which is the most advanced of the developmental technologies, may be the only *processing* technologies available for spent fuel, though improved storage facilities could also be built in this time. Like the Foreign Research Reactor EIS, the SNF/INEL EIS does not provide sufficient data to explain the *need* to reprocess spent fuel.

The EIS also states that "Chemical separation/processing at DOE sites was evaluated under certain alternatives as a reasonably foreseeable activity as a SNF stabilization

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[274] DOE 1995a, Volume 1, p. 3-43
[275] DOE 1995a, Volume 1, summary, p. 43
[276] DOE 1995a, Volume 1, Appendix J, p. J-15

technology."[277] "Reasonably foreseeable" suggests stronger intent than merely describing chemical separation as a "reasonable" alternative to consider. The Savannah River Site volume of the EIS evaluates reprocessing in the F- and/or H-canyons as a "representative" processing technique for spent fuel. That is, the environmental impacts of reprocessing were deemed to be representative of the environmental impacts from other potential processing technologies.[278] The EIS analysis assumes that 184.4 metric tons of aluminum-clad spent fuel currently at Savannah River Site would be separated in the canyons. While the environmental impacts of dry and wet storage of spent fuel are also analyzed in this section, chemical separation of fissile materials is the only processing option for which an environmental analysis was done in the EIS.[279] Parts of the environmental analysis were prepared hastily and with inadequate documentation and calculation, as discussed below.

Operating the Savannah River Site canyons is "not necessarily the [option] that DOE would select. Detailed NEPA evaluations would be required to implement any spent fuel management plan at SRS."[280] There is already an example of DOE not living up to this claim, however. The Foreign Research Reactor EIS, which considers chemical separation at the Savannah River Site, does not provide a detailed environmental evaluation but instead often references the environmental analysis of the SNF/ INEL EIS.[281] That is, it appears that the broad preliminary environmental analysis of reprocessing in the SNF/INEL EIS has already contributed to the "path forward" to potential implementation of reprocessing at the Savannah River Site.

Regionalization by Fuel Type is Conducive to Reprocessing

As discussed above, the main goal of the SNF/INEL EIS is to decide where to ship and manage spent fuel, with decisions on management technologies to be made based on subsequent EIS's. Another way to look at this is that DOE has decided where to send spent fuel without deciding what will happen to it once it gets there, which is perhaps the more important issue. It is plausible that if one or more reprocessing plants are operating pursuant to other EIS's as spent fuel arrives at the Savannah River Site or INEL pursuant to the SNF/INEL EIS, then there will be a strong incentive to reprocess that spent fuel rather than to investigate and pay for other alternatives. DOE's reprocessing plants happen to be regionalized by fuel type in the same manner as DOE is proposing to regionalize the spent fuel. That is, the two reprocessing plants at the Savannah River Site can only reprocess aluminum-clad fuel, while the Chemical Processing Plant at INEL can reprocess all types of spent fuel.

[277] DOE 1995a, Volume 1, p. 3-43
[278] DOE 1995a, Volume 1, p. 1-23
[279] The main points of the EIS's reprocessing vs. storage environmental analysis were presented in the "interim storage" section of this report.
[280] DOE 1995a, Volume 1, Appendix C, p. 3-4
[281] See for example DOE 1995c, pp. 4-89 to 4-94

The case of the Savannah River Site is instructive. DOE's plan for the Savannah River Site under the preferred Regionalization by Fuel Type alternative is to "[r]elocate aluminum-clad fuels to Receiving Basin for Offsite Fuels; then to new wet or dry storage facilities, or move aluminum-clad fuels to F- and H-Canyon for processing."[282] While this sentence mentions storage and reprocessing options, the separations canyons at the Savannah River Site were designed to reprocess aluminum-clad spent fuel and most of the aluminum-clad spent fuel currently at the Savannah River Site is slated for reprocessing under the Interim Management EIS.

The EIS does state that if aluminum-clad spent fuel now at the SRS were reprocessed, the small amount of aluminum-clad spent fuel that would be brought in from other sites could be stored in pools because space would become available.[283] The bulk of the 184.4 metric tons of aluminum-clad spent fuel currently at the SRS is 147 metric tons of aluminum-clad Mark-31 targets. As discussed above, under the Interim Management EIS the preferred option is to dissolve the Mark-31 targets, chemically separate the plutonium, and process the plutonium to metal.[284] This is expected to be completed over the next two years.[285]

When several metric tons of aluminum-clad spent fuel arrive at the SRS from sites around the U.S. each year during this two year period or during the eight to twelve year period in which reprocessing canyons may operate for foreign research reactor spent fuel, there will be a strong incentive to reprocess it along with other aluminum-clad fuels being reprocessed even if space is available to store it. DOE's statement that reprocessing material currently at the SRS would open up storage space for material coming in the future may be true, but DOE demonstrated in the Foreign Research Reactor EIS that there is a strong economic incentive to reprocess incoming material if the canyons are operating for other purposes. DOE also may find it logistically easier to lump the newly arrived spent fuel in with spent fuel slated for reprocessing than to find alternate storage and/or stabilization techniques for it. *The point is that a decision to reprocess the Mark-31 targets, and especially a decision to reprocess both the Mark-31 targets and foreign research reactor spent fuel, makes it far more likely that nearly all aluminum-clad spent fuel in the United States, once consolidated at the Savannah River Site, would be reprocessed.* As noted above, a recent Westinghouse evaluates the cost and schedule for the option of reprocessing all aluminum-clad spent at the SRS and estimates that it would be completed by 2012, at which point all of aluminum clad spent fuel from other sites is likely to have arrived at the SRS.[286]

Chemical separation at the Idaho National Engineering Laboratory is much less likely than at the Savannah River Site. The Chemical Processing Plant, which historically performed

[282] DOE 1995a, Volume 1, Appendix C, p. 3-7
[283] DOE 1995a, Volume 1, Appendix C, p. 3-16
[284] DOE 1995b, p. A-12
[285] DOE 1995b, p. 2-12
[286] Westinghouse 1995, p. 22

reprocessing operations, is shut-down, and "activities are under way to place this facility in a permanent shutdown mode."[287] The preferred Regionalization by Fuel Type alternative does not call for re-starting the plant, and the EIS states that "DOE has no current plans to resume spent fuel reprocessing activities at the Idaho Chemical Processing Plant."[288] The EIS calculates some accident scenarios involving use of the Chemical Processing Plant under two non-preferred alternatives, Regionalization by Geography (INEL) and Centralization at INEL, because the number of spent fuel shipments to INEL would be roughly two to four times greater under these alternatives than under the preferred option.[289] According to the EIS, under these two alternatives "there could be a need to resume processing operations to stabilize degraded spent nuclear fuel operations [sic] and assure adequate storage space for spent nuclear fuel received from other sites."[290] Given that these two alternatives were rejected in the Record of Decision, it appears unlikely that reprocessing will occur at the Chemical Processing Plant, though it remains a possibility. Electrometallurgical processing, however, once demonstrated on EBR-II spent fuel at INEL, could be applied to other spent fuel currently at INEL and to spent fuel from other sites that will be shipped to INEL.

DOE Data Skewed in Favor of Reprocessing

Other sections of this report have presented evidence that some DOE data overstate the advantages of reprocessing and underestimate the advantages of storage alternatives. The most egregious example of this may be found in the SNF/INEL EIS where DOE estimates that only 23 cubic meters of high-level radioactive waste would be produced from reprocessing 184.4 metric tons of aluminum-clad spent fuel at the Savannah River Site.[291] This is a ratio of about 0.125 cubic meters of high level waste for each metric ton of spent fuel reprocessed. The Interim Management EIS, on the other hand, gives a ratio of 14.3 cubic meters of high level waste for each metric ton of Mark-31 targets reprocessed,[292] an estimate that is over 100 times greater per metric ton. Moreover, the 184.4 metric tons of spent fuel that are the subject of the waste generation analysis in the SNF/INEL EIS *includes* the 147 metric tons of Mark-31 targets.

Upon investigation, IEER discovered that the 23 cubic meter figure is not comparable to the figures for high-level waste in other EIS's. In other cases, high-level waste is defined as the *liquid* waste containing fission products that are to be discharged into high-level waste tanks. Thus, even the liquid wastes from filter regeneration are classified as high-level wastes. In the SNF/INEL EIS, however, the 23 cubic meter figure is DOE's estimate of the solid, concentrated,

[287] DOE 1995a, Volume 1, Appendix B, p. 5.15-12
[288] DOE 1995a, Volume 1, Appendix B, p. 5.15-12
[289] DOE 1995a, Summary, pp. 23-24
[290] DOE 1995a, Volume 1, Appendix B, p. 5.15-17
[291] DOE 1995a, Volume 1, Appendix C, p. 5-49
[292] DOE 1995b, p. 2-42

vitrified high-level waste that would eventually be produced after the wastes are run through a vitrification plant.[293] As discussed above in the section on the Final Interim Management EIS, reprocessing the Mark-31 targets, 80% of the 184.4 metric ton total, is expected to produce 2.1 million liters (2,100 cubic meters) of liquid high-level waste.

The 23 cubic meter figure came from a *Technical Data Summary* by DOE's Savannah River Site contractor, Westinghouse, supporting the EIS. Westinghouse began the report by issuing caveats, stating that it was prepared under "under severe time constraints" and admitting that "it is likely that careful scrutiny will reveal numerous discrepancies, inconsistencies, and omissions."[294] Further, the Westinghouse report stated:

> Due to limited time available for this study, essentially all data represents the best engineering judgment of the experienced personnel of the WSRC NMPD Planning Section. *There is little documented basis or calculations to support the data presented.*[295] [emphasis added]

It should be noted that this same report was used as the basis for waste generation and air emissions estimates throughout the Savannah River Site section of the SNF/INEL EIS. That DOE would rely on such a report for its overall EIS for spent fuel management and publish such an estimate for high-level waste generation raises serious questions not only about DOE methodology, but also about its commitment to undertaking a realistic appraisal of spent fuel management alternatives based on sound science.

Reprocessing at Hanford

A potential major new development in U.S. reprocessing policy is vaguely outlined in the Hanford section of the EIS. In preparing the EIS, DOE considered building a new reprocessing facility at Hanford to stabilize the 2103 metric tons of N-reactor spent fuel there. Under the Regionalization by Fuel Type alternative chosen by DOE, four basic management options are available for the N-reactor spent fuel. Two of the options involve direct storage, and two of the options involve stabilization before storage. Three potential stabilization technologies are roughly outlined in the EIS under the latter two options, one of which (Process Q) is chemical separation. "Process Q uses solvent extraction by which metallic defense fuels are dissolved, separating uranium and plutonium and a liquid high-level waste stream that would most likely be vitrified for disposal in a geologic repository."[296] Needless to say, "Process Q" is another example of obfuscating DOE terminology. A new "Solvent Extraction Fuel Process Facility," or a new

[293] Even so the figure of 23 cubic meters appears not to be correct because of a confusion between gross and net weight of glass in the calculation (handwritten calculations by Halliburton NUS corporation, March 28, 1995.)
[294] Westinghouse 1994, p. 2
[295] Westinghouse 1994, p. 8
[296] DOE 1995a, Volume 1, Appendix A, p. 3-8

reprocessing plant in plainer language, would have to be built for this option. DOE estimates it could build it in three years, have it operational by 2001, and once operational reprocess the 2103 metric tons of spent fuel in 4 years.[297]

As stated above, DOE's current plan is to rapidly encapsulate the corroding N-reactor fuel in the K-East basin and then move all the N-reactor spent fuel to dry storage. Construction of a new reprocessing plant at Hanford is extremely unlikely now that DOE has decided to go with dry storage. However, since reprocessing sentiment is still strong in many parts of DOE, this could change, especially if broader national political currents favor the nuclear weapons plants. The proposal therefore deserves to be discussed here, for completeness.

Construction of a new reprocessing plant in the United States would raise severe questions about U.S. intentions to dispose of plutonium and would undermine U.S. credibility to oppose reprocessing in other countries. Reprocessing the 2,103 metric tons of N-reactor spent fuel would extract about 4 metric tons of weapons-usable plutonium.[298] Five years ago, DOE considered reprocessing the N-reactor spent fuel at the existing PUREX reprocessing plant at Hanford. That particular proposal was ultimately rejected because of safety issues with the PUREX plant and because storage was shown to be a better option, but apparently the idea of reprocessing the N-reactor spent fuel at Hanford lingered within the DOE bureaucracy.

In sum, although final decisions on processing or stabilization technologies have not been made yet pursuant to the SNF/INEL EIS, it does appear that DOE is strongly considering chemical separation of fissile materials (and also electrometallurgical processing) as management options. It considers chemical separation a "reasonably foreseeable" activity because it has more data and experience with it than with any other technique. DOE's overall spent fuel management plan (regionalizing spent fuel by fuel type) is conducive to reprocessing. It should be noted again that the Foreign Research Reactor EIS states that "chemical separation of spent nuclear fuel in existing facilities is not preferred by DOE as a technology for management of spent nuclear fuel in the United States."[299] In contrast, the SNF/INEL EIS, issued one month after the draft Foreign Research Reactor EIS, does not state this negative attitude toward reprocessing and is much less explicit about the advantages and disadvantages of reprocessing, the costs involved, and the non-proliferation implications of reprocessing.

BNFL Assistance in Spent Fuel and Waste Management

The most detailed discussion of reprocessing in the SNF/INEL EIS is a fifty-page attachment analyzing the option of reprocessing Hanford N-reactor fuel at the Sellafield facility in the United Kingdom. The attachment was not in the draft version of the EIS, but British Nuclear Fuels Limited (BNFL), which operates the Sellafield facility, suggested in a comment to DOE that

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[297] DOE 1995a, Volume 1, Appendix A, p. 3-11
[298] Grumbly 1994
[299] DOE 1995c, p. 2-16

reprocessing at Sellafield could be a viable alternative to building a new reprocessing facility at Hanford (Process Q). DOE then undertook a study of this option, partially based on a paper submitted by BNFL.[300]

DOE is very unlikely to implement the BNFL option because it has chosen dry storage for the N-reactor fuel and because of non-proliferation concerns. Marilyn Meigs, BNFL Inc.'s Washington representative, said that while Hanford and DOE Headquarters personnel "showed obvious interest and enthusiasm" in BNFL's assistance with managing N-reactor spent fuel, "those same DOE representatives became extremely pessimistic when it came to discussing actually putting the BNFL option into practice. This pessimism derived from the perceived incompatibility of this option with current US nonproliferation policy objectives."[301] It was sound policy for DOE to reject BNFL's offer of assistance. The enthusiasm cited by Meigs provides some evidence of a pro-reprocessing sentiment in some parts of DOE, though this is in contrast to the view that was ultimately adopted by DOE that non-proliferation concerns are central in this case.

Again, it is useful to look at DOE's presentation of the BNFL proposal in the EIS, even though it is unlikely to be implemented, in order to gain a fuller understanding of DOE's attitude toward reprocessing. The proposal involves shipping Hanford spent fuel by road or rail to a port on the Atlantic or Pacific and then shipping by boat to the UK. The high-level waste resulting from reprocessing at Sellafield would be vitrified and returned to the United States, and plutonium and uranium would also be returned to Hanford, although "these materials could also be stored overseas until a decision is made on their disposition by the U.S. Department of Energy (DOE)."[302] There is no discussion in the EIS of the implications of allowing a foreign country, albeit a close ally, to store such large amounts of U.S. plutonium. This would be contrary to the Clinton policy of seeking to "eliminate where possible the accumulation of stockpiles of ...plutonium."

The EIS states that "an analysis of processing DOE SNF at [foreign] facilities would have to consider United States nonproliferation policy..."[303] In parallel with the F-Canyon EIS, the SNF/INEL EIS discusses only the risk that the N-reactor spent fuel or the plutonium extracted by reprocessing could be diverted. The EIS states that this risk is minimal: "Stringent safeguards exist for the overseas transportation of nuclear materials...DOE has evaluated the safety and

[300] "UK-based processing as a Spent Nuclear Fuel Management Option for US DOE," Washington DC: British Nuclear Fuels, May 1994.
[301] Meigs 1995
[302] DOE 1995a, Volume 1, Appendix A, p. B-1
[303] DOE 1995a, Volume 1, p. 3-44

policy issues associated with overseas transport of plutonium and concluded that such shipments could be made safely and securely..."[304]

One major flaw in the EIS's discussion of the BNFL option is that it does not evaluate the affect it would have on the British civil plutonium program (or plutonium programs of other countries). BNFL's paper says that the entire cost of the option, including shipping from Hanford, reprocessing, some storage of waste and fissile material pending return shipments, and shipping back to the U.S., would be $1.3 to $2 billion.[305] BNFL does not provide a cost estimate for the reprocessing step alone, but it is reasonable to estimate that it is around $1 billion. Providing this large amount of money to BNFL, one of the world's leading commercial reprocessors and a major stockpiler of weapons-usable civil plutonium, would spur British reprocessing, legitimize commercial reprocessing, and contradict the administration's policy of "not encourag[ing] civil use of plutonium."

There is some precedent for involving BNFL in waste management. In early 1995, DOE proposed to ship 183,000 gallons of nitric acid, which is used to dissolve spent fuel in reprocessing operations, from its PUREX reprocessing plant at Hanford to Sellafield for use in BNFL's commercial reprocessing operations. Shipping the nitric acid was a lower cost option than decontaminating the facility and disposing of the acid in the U.S.

The shipment was widely opposed by environmental groups and even by some DOE officials. Critics charged that the nitric acid sale would encourage BNFL's accumulation of plutonium and contravene Presidential Directive 13. DOE's Office of Arms Control and Non-Proliferation, which initially approved the proposal, eventually withdrew its support. Ken Luongo of that office wrote in an internal memorandum that:

> the transfer will constitute encouragement of civil plutonium stockpiling and use...The symbolism of providing the tools of spent fuel reprocessing could damage the credibility of the United States and begin to undermine other non-proliferation objectives. It will raise questions about the seriousness of the U.S. commitment to its policy statements. If the U.S. allows the nitric acid transfer for the purpose of saving money in decommissioning PUREX, opponents of the decision may claim the U.S. non-proliferation policy is for sale.[306]

Despite these concerns, Assistant Secretary Thomas Grumbly and Secretary Hazel O'Leary gave final approval for the shipments, which proceeded in May 1995.

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[304] DOE 1995a, Volume 1, Appendix A, p. B-50. BNFL's nuclear material safeguards were called into question in 1995 when Greenpeace protesters chained themselves to a truck carrying spent fuel to the Sellafield plant for reprocessing. The truck was left unguarded when its drivers took a coffee break (*The Herald*, March 4, 1995).
[305] DOE 1995a, Volume 1, Appendix A, p. B-55
[306] "O'Leary OK's Hanford Shipping Purex Nitric Acid to British Facility," *Weapons Complex Monitor*, October 17, 1994, p. 2

Yet another instance of DOE considering BNFL assistance in reprocessing involves the spent fuel from North Korea's 5 MWe graphite-moderated reactor at Yongbyon. A confidential annex to the Agreed Framework signed in October 1994 between the United States and North Korea is believed to call for removing this spent fuel from North Korea. It is a metal fuel, and DOE officials have acknowledged that it is corroding and unstable. At a conference in February 1995, Marilyn Meigs reported that BNFL could provide assistance in managing this spent fuel by providing "the casks, the ships, reprocessing, and the return of plutonium to the US...in a form unsuitable for weapons production..." She also indicated that "DOE has already contacted BNFL to discuss these services, despite the fact that it is unwilling to move in the same direction with its own N-reactor fuel."[307] If it did involve BNFL in disposing of the North Korean spent fuel, the U.S. would facilitate reprocessing the spent fuel that it convinced North Korea not to reprocess. Moreover, BNFL would stand to be paid a considerable sum of money, yet another subsidy for a reprocessor dependent on foreign contracts to stay in business. In June 1995, DOE wisely decided to take a non-reprocessing approach to the North Korean spent fuel, at least in the near-term, awarding a contract to Georgia-based NAC International to seal the spent fuel in corrosion-resistant containers.[308]

Reprocessing Spent Fuel From Naval Propulsion Reactors

In contrast to DOE's consideration of BNFL assistance in reprocessing, the SNF/INEL EIS rules out reprocessing spent naval reactor fuel overseas, partly on non-proliferation grounds. U.S. spent naval fuel could potentially be reprocessed in Britain and/or France, but the EIS calls this option "not a reasonable alternative" for several reasons.[309] First, the characteristics of U.S. naval nuclear fuel are classified and have never been shared with another country. Second, "[n]aval spent nuclear fuel remains highly enriched even after it has completed use in a naval reactor. As such, the Nuclear Non-Proliferation Act, implementing requirements of the Treaty for the Non-Proliferation of Nuclear Weapons, imposes severe restrictions on the transfer of such material to foreign countries."[310] Further, the EIS states that "doing such reprocessing abroad would result in the production of highly enriched uranium in a foreign country, creating concerns over non-proliferation and nuclear material safeguards."[311]

These are valid reasons to reject the option, but this same reasoning could be applied more broadly. DOE's willingness to strongly consider the Dounreay option for foreign research reactor spent fuel, which if implemented would produce highly-enriched uranium in a foreign country, is inconsistent with its policy against reprocessing naval fuel. Indeed, if DOE has concerns about

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[307] Meigs 1995
[308] *NuclearFuel*, June 5, 1995
[309] DOE 1995a, Volume 1, Appendix D, Part A, p. 3-13
[310] DOE 1995a, Volume 1, Appendix D, Part A, p. 3-12
[311] DOE 1995a, Volume 1, Appendix D, Part A, p. 3-13

Britain's or France's ability to safeguard HEU, it should also take a stronger stand against the civil plutonium programs of these countries.

Fate of Fissile Materials Separated for Spent Fuel Management

Like most of the other DOE documents discussed in this paper, the SNF/INEL EIS is quite vague about the fate of fissile material separated from spent fuel under the potential reprocessing options at the Savannah River Site and Hanford. The assumption is that fissile materials will be stored for an interim period, but there is no explicit discussion of their ultimate disposition and attendant difficulties.

There are some isolated passages in the EIS that shed some light on this issue. Volume 3 of the EIS lists responses to comments received from the public about the draft EIS. One public comment suggests that valuable substances should be separated from spent fuel for potential future fuel or other uses. DOE's response to the comment is: "As acknowledged in Volume 1, section 1.1.3, DOE is considering several specialized technologies for separating radioactive elements from SNF and radioactive wastes, *including recovery of materials that may be used to fuel nuclear reactors*. For example, Volume 1, Appendix J discusses processing SNF to remove fissile material."[312] [emphasis added] Section 1.1.3 and Appendix J of Volume 1 do indeed talk about separating fissile materials as a possible stabilization technique for spent fuel, but nowhere in these sections is there any mention of what would be done with recovered fissile materials. DOE needs to clarify whether plutonium as well as uranium recovered from reprocessing may be used to fuel nuclear reactors. This would be a reversal of current U.S. practice and a major setback for U.S. non-proliferation policy.

Another reference to potential uses for the fissile materials may be found in a section of the EIS describing the Yucca Mountain repository. Because the waste acceptance criteria for the repository have not been chosen, there is a good deal of uncertainty about what processing, if any, spent fuel may have to undergo before emplacement in the repository. According to the EIS, "Disposal in a repository, for example, may require canning, canisterization, encapsulation, or processing the fuel to create a vitrified waste form. Resource recovery requires dissolving the fuel to separate the fissile material from the waste and producing a stable waste form."[313] DOE uses a variety of terms to describe the separation of fissile material from spent fuel, but this is the only instance in all of the documents and EIS's discussed in this paper that DOE uses the term "resource recovery."[314] DOE needs to clarify in what ways it intends separated fissile material to be used as a resource. The statement could be construed to mean that DOE considers plutonium

[312] DOE 1995a, Volume III, Part A, p. 3-29

[313] DOE 1995a, Volume 1, p. 1-15

[314] As stated above, the Record of Decision for the F-Canyon EIS (p. 14) said that it would be inappropriate to characterize the extracted plutonium as a waste.

as well as uranium a resource. As stated above, such a view is contrary to public statements by the Secretary of Energy and the National Academy of Sciences.

The fate of the fissile materials is a key issue in terms of the non-proliferation implications of various environmental management technologies. DOE needs to make its intentions in this area much more transparent.

RE-STARTING PUREX: A CASE STUDY IN REPROCESSING POLICY

DOE's current interest in reprocessing as a waste management tool closely parallels a proposal made in 1989 and 1990 to re-start the PUREX reprocessing plant at Hanford to stabilize the N-reactor spent fuel in the K-East and K-West cooling pools. While international politics, public scrutiny of DOE, and DOE environmental practices have changed considerably over the past five years, the arguments used by DOE and Westinghouse, its Hanford contractor, in support of the PUREX option were remarkably similar to some of the alleged benefits of reprocessing being touted today. The flaws in these arguments and the eventual outcome of the proposal may thus be viewed as a case-study to guide DOE in its current decision-making.

The PUREX reprocessing plant, after being shut down between 1972 and 1983, was re-started in 1983 and reprocessed N-reactor spent fuel for five years until it was shut down in 1988 because of safety problems.[315] The N-reactor was placed in cold standby in early 1988 and did not operate again, and 2,103 metric tons of spent fuel from the N-reactor were left in the K-East and K-West basins. An estimated three to seven percent of the cladding was damaged due to rough handling and corrosion.[316] DOE encapsulated the spent fuel in the K-West basin in steel containers, but the spent fuel in K-East basin was left in open containers, allowing radioactive materials to seep into the water and ultimately leak into the ground near the Columbia River.

When DOE began to assess what to do with the N-reactor spent fuel in the late 1980s, four main management options were considered: reprocessing it in PUREX, shipping it to the Savannah River Site for reprocessing, continuing to store it in the basins while encapsulating the K-East fuel, and transferring N-reactor fuel to new dry storage facilities. The Westinghouse Hanford Company undertook a study of these options and concluded that "[p]rocessing of the stored N Fuel in the Hanford PUREX plant is the recommended option because the mission can be completed in the shortest time, with the minimum duration of storage in the K-basins, at lowest cost, and with the least radiation exposure to the workers and the public and the least environmental risk."[317] The study dismissed direct disposal of the spent fuel after a period of dry storage because it claimed that the pyrophoricity of the uranium metal would prevent it from complying with Nuclear Regulatory Commission regulations.

In July 1990, the Institute for Energy and Environmental Research released a report entitled "To Reprocess or not to Reprocess: The PUREX Question" in order to "provide a preliminary independent assessment of the validity of the Westinghouse conclusion that

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[315] It was run for a short period from December 1989 to March 1990 to clean-out the remnants of the aborted 1988 operation.
[316] Saleska and Makhijani 1990, p. 23
[317] Cover letter from W.G. Ruff, Deputy Manager, Defense Operations Division of Westinghouse Hanford Company, to J.R. Hunter, Director of Operations at U.S. DOE - Richland, transmitting the Westinghouse study. Quoted in Saleska and Makhijani 1990, p. 28

reprocessing at PUREX is the most desirable option for the disposition of N-fuel."[318] The report was prepared for the Hanford Education Action League, a DOE watchdog group, and was based on DOE and Westinghouse documents, technical literature, and a site visit to Hanford.

Among the major conclusions of the IEER report were:[319]

- The problem of deteriorating N-fuel was largely of DOE's own making and could have been addressed much earlier (by encapsulating all the spent fuel) had minimum prudence been used in storing the spent fuel.

- The Westinghouse study was based on distorted and incomplete analysis. It downplayed the feasibility of what may have been the least dangerous option (dry storage) and understated the risks from PUREX, notably omitting the fact that adding additional high-level waste to tanks would have increased the risk of a tank explosion. PUREX would have generated the greatest total amount of waste of all the options.

- Westinghouse cost estimates for the various options were flawed and may have been "cooked" in favor of reprocessing. In reality PUREX may have been among the most costly options for managing spent N-fuel.

- Maintaining N-reactor spent fuel in the basins in encapsulated form or in dry storage provided the greatest flexibility in the face of considerable uncertainties regarding the permanent repository at Yucca Mountain.

- Given environmental and cost considerations, PUREX should not operate, and "because preliminary information indicates that dry storage...may be the most desirable option for interim management of N-fuel, preliminary design work on dry storage facilities for N-fuel should begin as soon as possible."[320]

The IEER report, citing the Westinghouse study's acknowledgment that an added side benefit of the PUREX option is that "uranium and plutonium would be recovered in the early 1990s and be available for Department of Energy programs,"[321] charged that "clean-up" concerns behind the PUREX option may actually have been "a back-door justification for plutonium production..."[322] The report sharply criticized Westinghouse methodology and the "cavalier" attitude of the Westinghouse analysis. It quoted testimony given by DOE contractor Dana Powers on February 20, 1990 before the Advisory Committee on Nuclear Facility Safety:

> I don't know that we debated it extensively but at least we bought off on the idea it is better to process that fuel whether you need the material or not than to leave it in the K-

[318] Saleska and Makhijani 1990, p. 28
[319] Saleska and Makhijani 1990, pp. 4-8
[320] Saleska and Makhijani 1990, p. 9
[321] Westinghouse 1989, p. 9 quoted in Saleska and Makhijani 1990, p. 29
[322] Saleska and Makhijani, p. 29

> basin...Without what I would call detailed debate, we basically bought off on the idea that yeah, processing it was the best thing you could possibly do with that fuel.[323]

The release of the IEER report exposed the safety hazards and drawbacks of PUREX and highlighted the viability of storage alternatives. A June 1990 U.S. General Accounting Office report to the House Government Operations Committee, Subcommittee on Environmental, Energy, and Natural Resources generally came to the same conclusions as the IEER report:

> DOE has not demonstrated that restarting PUREX either as a producer of plutonium or as a processor of radioactive waste is a sound decision. More specifically, DOE has not demonstrated that a need exists for weapons-grade plutonium from PUREX, and it has not fully compared PUREX with other waste disposal alternatives to determine whether PUREX is the best choice.[324]

The GAO report added that DOE's "plan to restart is not supported by any detailed technical, engineering, or cost analyses that fully demonstrate that PUREX is the best option for disposal of spent fuel as waste."[325]

Immediately after the IEER study was made public, DOE announced that it would not operate PUREX for N-fuel management until a supplemental EIS was completed. This was never completed, and PUREX was officially closed down in December 1992. N-reactor spent fuel has remained in the East and West K-basins since the PUREX controversy. DOE's current plan is to move the fuel to a Staging and Storage facility beginning in December 1998 and finishing in December 2000 or earlier. There, the spent fuel will be dried and stabilized, and the fuel will then be moved to a new dry storage facility by 2006.[326] Removal of the N-fuel from the basins is now one of the highest priority projects at Hanford.

The proposal to re-start PUREX is an example of how DOE and one contractor looked favorably on reprocessing, possibly because that is what had always been done with spent fuel, without considering the risks of reprocessing and fully evaluating all alternatives. Some of the arguments that DOE now uses in favor of reprocessing were also used in the Hanford N-fuel case in 1989 and 1990. At that time DOE did not carefully consider the added risks from high-level waste storage and potential fires or explosions. IEER's review showed that DOE and Westinghouse had not done their homework on all of the alternatives, with lack of consideration for dry storage being the most glaring omission. DOE's eventual choice of dry storage after years of false starts and inaction also shows that costs and delays of spent fuel management can be much reduced by a careful consideration of options at the start. Unfortunately, in many of the

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[323] Quoted in Saleska and Makhijani 1990, p. 27

[324] GAO 1990, p. 1

[325] GAO 1990, p. 5

[326] Fulton et al 1995

EIS's and documents discussed in this report, DOE has repeated the same mistakes. On the positive side, DOE's few statements in the EIS's regarding the proliferation consequences of reprocessing are a welcome departure from its past failure to recognize this problem.

CONCLUSION

On July 14, 1995, forty-seven organizations, including the Institute for Energy and Environmental Research, sent a letter to Thomas Grumbly, Assistant Secretary of Energy for Environmental Management, regarding some of the reprocessing proposals outlined in this report. The letter expressed concern that "information will not be presented to you in a manner which allows adequate consideration of the potential cumulative impacts of your decisions." Accordingly, the letter called on Grumbly to initiate a comprehensive review of reprocessing proposals "before making any decisions other than to address immediate environmental, safety, and health concerns."[327]

As this analysis of recent DOE documents and environmental impacts statements has shown, such a comprehensive review is badly needed. At the very least, all branches of DOE need to harmonize their policies regarding reprocessing and cease making contradictory statements about its non-proliferation implications and its utility as a waste management tool. DOE reprocessing policy also needs to be brought into line with President Clinton's 1993 policy statement on non-proliferation, especially in regard to submitting fissile material extracted under the environmental management program to the International Atomic Energy Agency. The non-proliferation, environmental, and safety stakes are too high for DOE to make and implement its reprocessing policy in a haphazard manner, out of political expediency, or just because reprocessing spent fuel was long-standing DOE practice. A more clear-sighted approach to the issue would show that the non-proliferation and environmental drawbacks of reprocessing far outweigh alleged benefits.

DOE reprocessing policy is being made in piecemeal fashion in separate EIS's with no overall strategy, without sufficient analysis, and without sufficient consideration of alternatives. In some cases, DOE presents data in a manner that far overstates the advantages of reprocessing and understates the advantages of non-reprocessing alternatives. DOE terminology obscures the number of reprocessing options DOE is considering. Given the absence of a strong high-level policy that is followed at each level of the bureaucracy and given the internal debate over reprocessing, DOE reprocessing policy may depend on who is writing the document.

In the documents discussed in this paper, DOE has failed to make a convincing case on environmental and safety grounds for reprocessing spent fuel. It needs to re-evaluate its assumptions about why reprocessing may be needed, especially given the fact that it is not yet known which spent fuel can be directly disposed of in a repository, before rushing into implementing reprocessing over the next several years. Reprocessing is not a complete environmental management solution because it creates radioactive wastes that must be safely stored and disposed of, as well as weapons-usable materials that must be safely stored,

[327] Costner et al 1995

safeguarded, and disposed of. DOE should more strongly consider storage options for spent fuel, which the brief analysis in this report has shown to be feasible and less hazardous to the environment, workers and communities.

Most importantly, DOE needs to put a firm near-term end point on reprocessing because in its current drift DOE is considering options involving reprocessing through as long as 2012, and reprocessing could occur even further into the future. The indefinite, open-ended nature of reprocessing proposals is the largest drawback of DOE reprocessing policy. These proposals represent a remarkable departure from DOE's original 1992 plan to phase-out reprocessing.

The United States, the only nuclear weapon state not currently reprocessing for either civilian or military purposes, is at an important decision-making juncture. It can continue to abstain from separating fissile materials from solid spent fuel, and, once it removes the solutions from the plants, it can begin to decommission and dismantle its military reprocessing plants. On the other hand, it can embark on an environmental management program involving reprocessing for several years or even decades, a program which may be a spur to reprocessing activities abroad and to commercial reprocessing in the United States. This decision cannot be taken lightly or for the sake of political or bureaucratic expediency. It needs to made based on sound science, an awareness of potential consequences, and a full consideration of all alternatives.

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