POLICY ISSUE
(Notation Vote)

March 22, 2006 SECY-06-0066

FOR: The Commissioners

FROM: Luis A. Reyes
Executive Director for Operations /RA/

SUBJECT: REGULATORY AND RESOURCE IMPLICATIONS OF A DEPARTMENT OF ENERGY SPENT NUCLEAR FUEL RECYCLING PROGRAM

PURPOSE:

To request Commission approval of staff plans for addressing the regulatory and resource implications of the spent nuclear fuel recycling program that the Senate and House Appropriations Committees have directed the Department of Energy (DOE) to develop.

SUMMARY:

In the Conference Report (H.R. Conf. Rep. No. 109-175, 109th Cong., 1st Sess., November 7, 2005) (Conference Report) for the Energy and Water Development Appropriations Act for 2006 (Pub.L. No. 109-103, 119 Stat. 2247, November 19, 2005) (FY 2006 Appropriations Act), the conferees from the House and Senate Appropriations Committees directed DOE to (1) develop a spent nuclear fuel recycling plan by March 31, 2006 (see Conf. Rep. at 156-157), and (2) initiate a competition by June 30, 2006, to select one or more sites suitable for development of "integrated recycling facilities". The target for site selection is FY 2007, and the target for initiation of construction of one or more integrated spent fuel recycling facilities is FY 2010. The conferees

CONTACT: Priya P. Yadav, NMSS/FCSS
301-415-6667

William M. Troskoski, NMSS/FCSS
301-415-8076

also separately provided research funds to DOE for the Advanced Fuel Cycle Initiative (AFCI) to be used to accelerate the design activities associated with a proposed Engineering Scale Demonstration (see Conf. Rep. at 141-142).

The Conference Report suggests that some, perhaps all, of the facilities integrated in the spent nuclear fuel recycling plan will be commercial ventures operated by private entities. The Nuclear Regulatory Commission (NRC) would have licensing and regulatory authority over any commercial facilities which are part of the integrated plan for spent nuclear fuel recycling. NRC would not have regulatory authority for, and would not license, any DOE reprocessing facility used to demonstrate the advanced recycling technology selected or any DOE facility used to reprocess commercial spent nuclear fuel. Nor would NRC regulate or license any other DOE facilities which are part of the spent nuclear fuel recycling plan unless such facilities are among those specifically listed in section 202 of the Energy Reorganization Act of 1974 (ERA).[1] Of course, it is possible that some new legislation (we know of no proposals at this time) might assign NRC a licensing role with respect to such facilities or DOE might request that NRC perform safety reviews of such a demonstration facility on a voluntary basis.

The facilities that may be required in a spent nuclear fuel recycling program potentially include a reprocessing facility, a fuel fabrication facility, a waste vitrification facility, an interim storage facility, and a fast flux facility. Since licensing of these facilities would offer new technological and regulatory challenges, as a first step, the staff believes it is essential to begin close interactions with DOE during the demonstration facility phase of a reprocessing facility and to maintain significant contact if DOE designs a full scale reprocessing facility to prepare for any appropriate future NRC rulemaking and licensing activities. One full time equivalent (FTE) has been allocated in FY 2006 and FY 2007 for the staff to track DOE's conduct of an advanced fuel recycling technology research, development, and demonstration program as part of the Energy Policy Act implementation activities (see SECY-05-0201, Attachment, 30-31). The staff will apply one additional FTE for 2006 to work closely with DOE as it formulates its spent fuel recycling plan. Staff estimates that approximately 12 FTE will be required in FY 2007 and 20 FTE will be required in FY 2008. The staff will keep the Commission informed of future developments involving DOE's plans and schedules for the spent fuel recycling facilities, as they become available.

BACKGROUND:

According to recent testimony by DOE[2], as currently envisioned, the Yucca Mountain HLW repository is not expected to have sufficient capacity for potential spent nuclear fuel produced by a

---

[1]A facility used "primarily" to store reprocessing high-level waste (HLW) pending disposal in a repository would likely be subject to licensing under section 202(3) of the ERA. It is unclear whether any potential DOE fuel fabrication facility which might be part of a spent fuel recycling plan would be subject to licensing under section 202(5) of the ERA which gives NRC jurisdiction over certain facilities used for the express purpose of fabricating mixed plutonium-uranium oxide nuclear reactor fuel for use in a commercial nuclear reactor licensed under the Act other than any such facility that is utilized for research, development, demonstration, testing, or analysis purposes.

[2]See Testimony of Dr. Phillip J. Finck before the Energy Subcommittee of the House Committee on Science, June 16, 2005.

once-through fuel cycle. Currently, the country's 103 commercial nuclear reactors produce more than 2,000 metric tons of spent nuclear fuel per year. Under the Nuclear Waste Policy Act of 1982, the Yucca Mountain repository is currently limited to 70,000 metric tons of spent nuclear fuel and DOE defense-related wastes. By DOE's estimate, by approximately 2010, the accumulated spent nuclear fuel generated by reactors operating to date and the defense-related waste will reach this limit.

According to DOE, it is technically feasible to expand the capacity of Yucca Mountain to around 120,000 metric tons. However, the spent fuel from current reactors operating over their lifetimes will take up this extra capacity. Assuming electricity generation from nuclear power increases at a rate of 1.8% per year after 2010, the 120,000 metric ton limit will be reached around 2030. Even with this expanded capacity, to accommodate this growth rate, the United States will need up to nine Yucca Mountain-type repositories by the year 2100 if utilities continue to use a once-through fuel cycle.[3] Furthermore, the United States has proposed a Global Nuclear Energy Partnership (GNEP), as discussed later in this paper. The fuel services program of the GNEP would involve receiving and reprocessing spent nuclear fuel from developing nations, thereby increasing the amount of HLW that would need to be stored in a repository.

Spent fuel has been reprocessed historically in the United States (at Hanford, Savannah River, West Valley) and is currently being reprocessed on a significant scale internationally in France, the United Kingdom, Japan, Russia, India, and China. The United States ceased reprocessing activities subsequent to President Carter's 1977 decision to defer indefinitely the commercial reprocessing and recycling of plutonium produced in United States nuclear power programs due to the proliferation risk. Although President Reagan subsequently lifted this indefinite ban, further commercial reprocessing was not pursued, primarily due to cost considerations. Enclosure 1 provides a history of domestic and international experience with spent fuel reprocessing technologies.

Recently, some members of Congress have expressed increasing interest in spent nuclear fuel recycling to reduce the volume and heat load of waste that would be sent to the potential Yucca Mountain HLW repository and to avoid a near-term need for additional HLW repositories. In the Conference Report for the FY 2006 Appropriations Act, the conferees provided DOE $50 million to develop a spent nuclear fuel recycling plan within the following timeline of related activities:

- March 1, 2006—DOE is to submit a spent nuclear fuel recycling technology plan to the Appropriations Committees (Conf. Report, pp. 141-142) (Note: Recent conversations with DOE indicate that it did not meet this target date and plans to submit the technology plan on March 31, 2006)

- March 31, 2006—DOE is to submit a spent nuclear fuel recycling plan (a detailed program plan) to the Appropriations Committees (Conf. Report, pp. 156-157)

- June 30, 2006—DOE is to initiate a competition to select one or more sites suitable for development of "integrated recycling facilities" (Conf. Report, pp. 156-157).
    - a facility for separation of spent fuel
    - a facility for fabrication of mixed oxide fuel

---

[3] Id.

  - a facility for vitrification of waste products
  - a facility for process storage

- FY 2006 (10/05-9/06)—DOE completes conceptual design under AFCI (Conf. Report, p.141)

- FY 2007 (10/06-9/07)
  - DOE makes site selection for “integrated recycling facilities” (Conf. Report, p.157)
  - DOE commences pre-engineering design under AFCI (Conf. Report, p.141)
  - By 9/07, DOE selects the preferred separations technology (Conf. Report, p.141)

- FY 2010 (10/09-9/10)—Initiation of construction of one or more “integrated spent fuel recycling facilities” (Conf. Report, p.157)

In addition to the $50 million appropriated to develop a spent fuel recycling plan, the conferees provided $80 million to DOE for AFCI. DOE will use the funds to accelerate the design activities for the engineering scale demonstration[4] so the Department can finish the conceptual design in FY 2006 and start the pre-engineering design in FY 2007. In the Senate Report, the Senate Appropriations Committee stated that the AFCI should continue to focus on developing technologies to recover energy from spent fuel while minimizing the toxicity of the final waste products and minimizing proliferation concerns and the environmental impacts of the fuel cycle. The Senate Report also states that, in addition to studying light-water reactors (LWRs), DOE will evaluate fast flux reactors that are capable of destroying long-lived actinides and other transuranics separated from the spent fuel (S. Rep. No. 109-84,109th Cong., 1st Sess., 130 (June 16, 2005)).

As part of President Bush's Advanced Energy Initiative, the Secretary of Energy announced on February 6, 2006, a $250 million FY 2007 budget request to launch the GNEP. This new initiative is a comprehensive strategy to enable the expansion of emissions-free nuclear energy worldwide by demonstrating and deploying proliferation-resistant technologies to recycle spent nuclear fuel and minimize waste. Through GNEP, the United States will work with other nations possessing advanced nuclear technologies to develop new proliferation-resistant recycling technologies in order to produce more energy, reduce waste, and minimize proliferation concerns. Additionally, these partner nations would develop a fuel services program to provide nuclear fuel to developing nations allowing them to enjoy the benefits of nuclear energy in a cost effective manner in exchange for their commitment to forgo enrichment and reprocessing activities, thereby alleviating proliferation concerns.

The GNEP has four main goals: “(1) reduce America's dependence on foreign sources of fossil fuels and encourage economic growth; (2) recycle nuclear fuel using new proliferation-resistant

---

[4] In Section 953 of the Energy Policy Act of 2005, Pub.L. No. 109-58, August 8, 2005, the Congress authorized DOE to conduct an advanced fuel recycling technology research, development, and demonstration program “to evaluate proliferation-resistant fuel recycling and transmutation technologies that minimize environmental and public health and safety impacts as an alternative to aqueous reprocessing technologies deployed as of the date of enactment of this Act in support of evaluation of alternative national strategies for spent nuclear fuel and the Generation IV advanced reactor concepts.”

technologies to recover more energy and reduce waste; (3) encourage prosperity growth and clean development around the world; and (4) utilize the latest technologies to reduce the risk of nuclear proliferation worldwide".

Based on the Conference Report for the FY 2006 Appropriations Act and the goals of the GNEP, the staff anticipates that in conjunction with operating a demonstration facility, DOE would prepare plans for the development of full scale spent fuel recycling facilities to be operated by DOE or by one or more commercial entities. This paper describes the processes which would likely be involved in spent fuel recycling and the potential regulatory and resource implications for NRC assuming eventual licensing of commercial spent fuel recycling facilities.

DISCUSSION:

The staff expects DOE to consider two technological approaches for use in its spent fuel recycling program. The first approach would involve (1) a reprocessing facility using an advanced separations step based on the UREX+ (uranium reduction and extraction) technology and (2) a limited recycle of mixed-oxide (MOX) fuel in conventional LWRs and/or Advanced Burner Reactors (ABRs) such as a liquid metal fast flux reactor. The second approach would involve full recycle beyond these two primary steps, using ABRs to close the fuel cycle and transmute the transuranic waste streams. Process flow diagrams for the stages included in each approach and the disposition of the products separated from the spent nuclear fuel are included in Enclosure 2. A detailed description of the processes involved in limited recycle and full recycle is included in Enclosure 3. A summary of the processes involved is discussed below.

The primary stages of limited recycling include spent fuel reprocessing using the UREX+ technology and limited recycle in existing LWRs and/or ABRs. The UREX+ technology is a refined solvent extraction technology that allows the separation and subsequent handling of several highly pure product streams. As shown on the process flowchart in Enclosure 2, the resulting streams from the UREX+ process follow several different paths. In addition to the UREX+ facility, a new fuel fabrication facility (that would fabricate MOX fuel) would need to be built to handle the uranium and the mixed plutonium/neptunium UREX+ output streams. DOE has recently indicated that it is considering sending the mixed plutonium/neptunium UREX+ stream directly to ABRs in lieu of LWRs, however, a final decision has not been announced. Recycling the plutonium and neptunium could potentially reduce the long-term repository heat load (integrated over time) by approximately 70 percent. It is likely that new analysis, transient and fuel design codes, as well as confirmation testing, would be needed to support licensing decisions associated with using MOX fuel designs containing recycled material. DOE would be expected to provide the data and analyses necessary to support the development and validation of these codes. Code qualification would require significant effort and would likely require contractor support.

Interim storage may be needed for several of the UREX+ output streams, especially the transuranic elements americium and curium. The remaining fission products could be separated into a stream for short-term storage and a stream for long-term storage in specialized waste forms (i.e., vitrification). A separate vitrification facility may be needed to process this waste.

Full recycling would include the primary stages of limited recycling but would close the fuel cycle loop by using ABRs (and/or possibly linear accelerators) to transmute the remaining transuranic elements into much less hazardous elements and by using pyroprocessing technologies to recycle the fast flux reactor fuel. Full recycle has the potential to significantly reduce proliferation risk by eliminating the buildup of all isotopes. The remaining waste would have a significantly reduced heat load and volume and would remain a radioactive hazard for only hundreds of years, not for hundreds of thousands of years. As shown on the process flowchart in Enclosure 2, the remaining transuranic elements (americium and curium) contribute approximately 30 percent of the long-term repository heat load (integrated over time). With full recycling, most of the transuranic elements would be transmuted and two-thirds of their heat load could be reduced. Therefore, full recycling has the potential to achieve an overall 90 percent reduction in the total long-term repository heat load.

Staff Actions Required

In the event that Congress, in new legislation, requires NRC to license limited spent fuel recycling facilities operated by DOE or a commercial entity chooses to pursue the limited recycling approach, the staff would need to create the regulatory infrastructure for licensing a reprocessing facility, prepare to perform licensing reviews of the UREX+ process and a fuel fabrication facility, and prepare for licensing vitrification and/or interim waste storage facilities. Additionally, NRC's observation of the demonstration facility would facilitate the development of appropriate regulatory guidance for licensing a future commercial facility based on the UREX+ technology.

NRC staff would have to conduct licensing reviews of any proposed commercial reprocessing facility and any commercial fuel fabrication facility used to recycle the reclaimed special nuclear material back into MOX fuel. The NRC would also conduct licensing reviews for any commercial interim storage of transuranic actinides and fission product streams emanating from the UREX+ process. If a commercial facility were deemed likely, staff liaison activities with DOE would need to start in FY 2006 and expand in FY 2007 and FY 2008 to ensure the timely development of regulations and regulatory guidance for reprocessing. The initial licensing review of a commercial reprocessing facility could potentially start in FY 2009, however, based on recent DOE press releases, this timeline may extend beyond FY 2010.

To support full recycling, additional staff would be needed to support the development of a regulatory infrastructure suitable for the process technologies selected for commercial pyroprocessing, a new commercial fuel fabrication facility for the transuranic actinides, and commercial fast flux reactors. The licensing review for a full reprocessing facility and fast flux reactor is expected to begin significantly after FY 2010.

According to the schedule laid out in the Conference Report, DOE will likely initiate planning on the limited recycling or the full recycling approach in FY 2006. If commercial spent fuel recycling facilities are utilized, either approach would require NRC coordination with other Federal agencies such as the Department of Transportation (DOT), the Environmental Protection Agency (EPA), and the Occupational Safety and Health Administration (OSHA) to ensure there are no regulatory gaps. In addition, the various approaches available to DOE would likely require internal NRC resources from the Offices of Nuclear Material Safety and Safeguards (NMSS), Nuclear Reactor Regulation (NRR), Nuclear Security and Incident Response (NSIR), Nuclear Regulatory Research (RES), General Counsel (OGC), and the regions. The exact scope of the external coordination and the internal resource demands cannot be determined at this time, but will likely evolve as DOE intentions become better defined and it becomes clearer whether spent fuel recycling will involve commercial activities.

The approximate resources required to support a spent fuel recycling program between FY 2006 and FY 2008 are summarized in the Resources section. Potential licensing activities are summarized below.

Reprocessing Facility
A commercial reprocessing facility based on the UREX+ process would be defined as a "production facility" under the Atomic Energy Act of 1954, as amended, and would currently require a license under the regulations in 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities".[5] In contrast, plutonium processing and fuel fabrication facilities are licensed in accordance with the regulations in 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material." Licensing the UREX+ facility would present a challenge because it would be the first production facility licensed in the past 40 years, and the facility's operational characteristics would differ significantly from the LWRs that are typically licensed under Part 50.

A reprocessing facility uses processes similar to those used in a MOX facility, which would be licensed under the Part 70 licensing process. In addition, Part 50 is focused on LWR design and technology and would have limited applicability to commercial reprocessing facility design and technology. That is, the design and operational safety issues associated with a commercial reprocessing facility would be very different from design and operational safety issues associated with an LWR. The current Part 50 regulations would not necessarily address all commercial reprocessing facility safety issues and, conversely, are likely to contain requirements that are not applicable to a reprocessing facility. The application of the whole of Part 50 to the licensing of a commercial reprocessing facility would present significant challenges to the applicant and to the NRC. If Part 50 is used to license a commercial reprocessing facility, the regulations would have to be reviewed to determine which apply, which do not apply, and which may partially apply. Additional requirements would also need to be established to address reprocessing facility-specific design and safety issues. Once applicability determinations are made, a possible approach to establish a licensing framework would be to use a process similar to that used for centrifuge enrichment facility licensing (e.g., LES - see *Louisiana Energy Services, L.P.* (National Enrichment Facility), CLI-04-03, 59 NRC 10 (2004), NOTICE OF RECEIPT OF APPLICATION FOR LICENSE, NOTICE OF AVAILABILITY OF APPLICANT'S ENVIRONMENTAL REPORT, NOTICE OF CONSIDERATION OF ISSUANCE OF LICENSE, AND NOTICE OF HEARING AND COMMISSION ORDER). With this approach, the Commission would establish the licensing framework by identifying specific parts of existing regulations as well as new requirements that would be applied to license a commercial reprocessing facility and reflect those requirements in the order initiating the proceeding (licensing of the production facility would include an opportunity for a hearing).

Given more time and to systematically address the hazards unique to a production facility, the staff would propose another approach—to develop a new rule or revise existing rules for a reprocessing facility. Such a rule would, to the extent practical, be risk-informed and performance-based and would be written to address the safety, technical and policy issues which are specific to reprocessing facilities. The current Part 70 would provide a good framework for such revisions or a new rulemaking. Additional staff resources would focus on the development of appropriate

---

[5]A production facility is defined in 10 CFR 50.2 generally as (1) any nuclear reactor designed or used primarily for the formation of plutonium or uranium-233; (2) any facility designed or used for the separation of the isotopes of plutonium; or (3) any facility designed or used for the processing of irradiated materials containing special nuclear material, with the exception of facilities that handle small quantities of special nuclear materials and some facilities in which processing is conducted pursuant to a license issued under parts 30 and 70.

regulatory guidance. NUREG-1718, “Standard Review Plan for the Review of an Application for a Mixed Oxide Fuel Fabrication Facility,” would be a good basis for the development of guidance for the review of a reprocessing facility.

While the staff has experience with the PUREX-based (plutonium uranium reduction and extraction) MOX aqueous polishing process and the solvent extraction uranium recovery processes utilized in the various licensed fuel fabrication facilities, the UREX+ technology involves somewhat different chemical processes and would present new chemical hazards not previously encountered. Therefore, early staff observation at a reprocessing demonstration facility phase prior to final development of a full scale reprocessing facility would be essential for timely development of regulatory requirements and guidance. Early involvement would also allow the staff to become familiar with the technology and ensure that personnel with the right skill sets for any licensing reviews are recruited and trained in a timely manner.

As part of the review of any proposed commercial reprocessing and fuel fabrication facilities, spent fuel shipment, interim site storage, and product shipment issues would need to be explored. Modification to 10 CFR Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions,” may be prudent to address the environmental impacts of transportation of spent nuclear fuel to the reprocessing facility and of product shipment from the facility.

Fuel Fabrication Facility
A commercial fuel fabrication facility would be licensed under Part 70, for which NUREG-1520, “Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility,” provides regulatory guidance. However, the staff would still have to determine whether revised regulatory requirements or additional guidance are necessary to address the recycled uranium and mixed plutonium/neptunium feed stocks. Staff involvement at the reprocessing demonstration facility phase would be desirable to ensure that appropriate regulatory guidance is established and that the right human resources are in place.

The licensing review of commercial spent fuel recycling facilities may also require a number of environmental reviews. For example, each rulemaking would require an Environmental Assessment (EA), or an Environmental Impact Statement (EIS), depending on the results of the EA and the scope of the rulemaking. Any new rulemaking for interim or long-term storage might require the same environmental evaluation approach. In addition, 10 CFR Part 51.20 identifies construction and licensing of fuel reprocessing plants as actions that require preparation of an EIS. This EIS would be expected to cover any proposed new facilities. As connected actions, the EIS might also cover storage, waste disposal, and the impacts of recycling new fuel in existing LWRs. An EA would also be prepared for manufacture and use of any Lead Test Assemblies.

In addition, the safeguards and security aspects of commercial spent fuel recycling facilities would be a significant component of the licensing review process. Staff would need to assess changes that may need to be made to 10 CFR Part 73, “Physical Protection and Plants and Materials” and 10 CFR Part 74, “Material Control and Accounting of Special Nuclear Material” to account for the unique characteristics of the facilities included in the spent fuel recycling program. 10 CFR Part 75 would also need to be implemented to determine the international safeguards and additional protocol requirements for the facilities.

Fast Flux Reactor

To support full recycling, a fast flux reactor or possibly an accelerator would need to be developed. The NRC would license a fast flux reactor using either 10 CFR Part 50 or 10 CFR Part 52. These regulations have been developed over a period of more than 40 years and reflect the experience gained from many years of LWR design and operation. The regulations contain many provisions of a generic nature (independent of reactor technology), but also contain provisions that are specific to LWR design and technology. The regulations have served as the underlying basis for licensing the current generation of plants as well as certifying the Advanced Boiling Water Reactor (ABWR), System 80+, AP-600, and AP1000. In the past, when NRC has reviewed or licensed non-LWR designs (e.g., Ft. St. Vrain, Clinch River Breeder Reactor), it was necessary for the staff to determine the applicability of the regulations to these designs and the need for exemptions and/or additional requirements to address the unique aspects of these designs. These determinations were made on a case-by-case basis and were implemented by exemptions and/or license conditions, to address those areas where the current regulations did not apply. Accordingly, it is possible to review and license future plants, regardless of the technology, using a similar case-by-case approach; however, this may not be the most efficient or effective approach for non-LWRs, particularly if there are to be more than one of a kind.

A much more extensive discussion of policy issues associated with licensing non-LWR designs is provided in SECY-02-0139, “Plan for Resolving Policy Issues Related to Licensing Non-Light Water Reactor Designs,” July 22, 2002. The staff has also initiated work to develop a technology-neutral, risk-informed regulatory framework for licensing advanced reactor designs. The staff’s most recent Commission paper on this topic is SECY-06-0007, “Staff Plan to Make a Risk-Informed and Performance-Based Revision to Part 50,” January 9, 2006.

To facilitate licensing of new reactor designs substantially different than current generation LWRs, the Commission has encouraged pre-application interactions between NRC and reactor designers early in the licensing process to identify key safety and licensing issues and a path to their resolution. The results of such interactions can then be used by the staff and the designers as guidance in the preparation and review of an actual application.

Consistent with this guidance, as additional details regarding a proposed fast flux reactor are made available by a prospective applicant, the staff will engage prospective applicants and construct a plan, including a proposed schedule and staff and contract resources required, to develop the needed technical and regulatory infrastructure to license the design. The plan will be revised as more information regarding the scope and detail of the design are provided.

Skills Required

NMSS has reviewed the Strategic Workforce Planning database to identify gaps in critical skills for supporting limited and full recycling. NRC has experts in many of the core technical areas needed for licensing reviews of facilities utilized in a spent fuel recycling program, including chemical engineers and ceramic engineers with experience in waste vitrification. Some of these experts have recent experience in reviewing license applications for related fuel cycle facilities (i.e., the MOX fuel fabrication facility). However, NRC lacks expertise in several specialty fields that would be needed for reviewing the advanced technologies used in a limited recycling facility. Specifically, NRC needs chemical engineers (with a detailed knowledge of reprocessing), actinide chemists, plutonium chemists, and radiochemists. In addition, nuclear engineers with expertise in transmutation would be required to review full recycling facilities.

NMSS would need to work with the Offices of Human Resources (HR), NRR, NSIR, and RES to develop an aggressive strategy for recruiting experts in the specialty fields needed to support the technical reviews for limited recycling facilities. The recruitment strategy would be augmented by rigorous training of existing NRC staff at Los Alamos National Laboratory and other national laboratories, as appropriate. NRC staff would also participate in meetings and site visits to become more knowledgeable about the advanced recycling technologies.

Path Forward
The staff believes it is essential to begin close interactions with DOE during the demonstration facility phase of a reprocessing facility, and to maintain significant contact if DOE designs a full scale reprocessing facility, to prepare for any appropriate future NRC rulemaking and licensing activities. In addition, NRC should begin close interactions with international entities having the most relevant experience in spent fuel recycling, including the United Kingdom, Japan, and France.

To begin these interactions, a small amount of initial resources is required, beyond those resources previously allocated. The staff will reallocate one additional FTE from within NMSS to begin interactions with DOE. This additional resource is needed to interact closely with DOE as it develops its spent fuel recycling program in order to assess the likelihood that any commercial involvement in the program is likely which could lead to the need for NRC action to develop in-house expertise in advanced recycling technologies, to evaluate what changes to the NRC regulatory infrastructure would be required to support any future license applications for spent fuel recycling facilities, and to perform preliminary environmental work to support any future environmental reviews.

In parallel, staff from NMSS will begin working with representatives from NRR, NSIR, OGC, and RES to develop a conceptual design of a licensing process for a reprocessing facility (and possibly for other co-located facilities). Developing the conceptual framework would involve the public and DOE, including workshops and making drafts available for comment on the NRC website.

As the staff proceeds with development of a regulatory framework for possible reprocessing facilities, policy issues will likely arise. These will be brought to the Commission for decision as they are identified. Some examples of policy issues are how defense-in-depth should be applied, the level of safety necessary for the group of facilities, the integration of safety and security, and the site's emergency preparedness.

COMMITMENT:

Staff will deliver the conceptual design of a licensing process for a reprocessing facility to the Commission by September 2007.

RECOMMENDATION:

The staff recommends the Commission approve:

1. The initiation of interactions with DOE and international entities through participation in workshops and meetings domestically and internationally, as appropriate, on the safety and safeguards aspects of the spent fuel recycling program.

2. The short-term resource allocations identified in the Resources section.

RESOURCES:

For FY 2006, the staff will reallocate one FTE and $100,000 of contract support for travel to support the spent fuel recycling initiative. Staff estimates approximately 12 FTE and $2,344,000 are required in FY 2007 and 20 FTE and $2,430,000 are required in FY 2008. FY 2007 and FY 2008 resource needs will be addressed in the FY 2008 Planning, Budgeting, and Performance Management (PBPM) process.

COORDINATION:

The Office of the General Counsel has no legal objection concerning this paper. The Office of the Chief Financial Officer has reviewed this paper for resource implications and has no objections.

/RA William F. Kane Acting For/

Luis A. Reyes
Executive Director
for Operations

Enclosures:
1. Domestic and International Experience With Spent Fuel Recycling
2. Process Flowcharts for Limited Recycle and Full Recycle
3. Detailed Description of Limited Recycle and Full Recycle

Domestic and International Experience With Spent Fuel Recycling

Domestic Experience

The DOE and its predecessor agencies operated several facilities that reprocessed spent fuel for the recovery of materials for defense, nuclear energy, and space programs. Plutonium was the main element recovered. Neptunium, americium, tritium, cesium, and strontium were also recovered on a significant scale. In excess of 100,000 metric tons of heavy metal (MTHM) were reprocessed at Hanford, Savannah River, and Idaho over a period of more than 40 years. Most of the spent fuel consisted of relatively small, metallic elements with a low burnup (usually less than 2,000 megawatt-days per metric ton of heavy metal (MWD/MTHM). The principal technology used was a solvent extraction technique known as the plutonium and uranium extraction (PUREX) process (and its variants). Pilot-scale facilities have used pyrochemical, metal, and eletrometallurgical technologies for reprocessing and recycling. DOE's high-level waste (HLW) is a result of these reprocessing activities.

There is limited domestic experience with commercial reprocessing and recycling. The Atomic Energy Commission (AEC) encouraged private organizations to become involved in reprocessing in the 1960s. The West Valley facility operated in the late 1960s and early 1970s, using the PUREX process. The facility nominally had a 300 MTHM/yr capacity and reprocessed about 650 MTHM. Approximately 60% of this material was metal fuel from the Hanford N-Reactor with a relatively low burnup. The remainder was oxide fuel—the highest burnup was around 20,000 MWD/MTHM. The facility also performed a demonstration on thorium spent fuel. West Valley operations generally met regulatory requirements, although exposures were not as low as reasonably achievable (ALARA) and radiation protection was a significant problem. The operator planned an expansion of West Valley to quadruple its capacity. Seismic issues were raised as part of the regulatory review and these issues increased the estimated costs by over an order of magnitude. Based on the increased costs and the potential for significant competition from other companies, the operator decided to cease operations.

GE designed and built a reprocessing facility in Morris, IL, utilizing a dry process for the main separations. The process relied on the volatility of uranium hexafluoride and was successfully demonstrated in the laboratory. Pre-operational testing at the constructed facility was not as successful and would have required major renovations. Given the projected costs and competitive reprocessing market, and increasing regulatory scrutiny (from the West Valley seismic reviews and the required safeguards), the operator decided not to pursue reprocessing at the facility. It is currently used as an independent spent fuel storage installation (ISFSI) for wet storage of commercial spent fuel.

The AGNS consortium constructed a third facility adjacent to the Savannah River Site in Barnwell, South Carolina. This facility utilized advanced PUREX technology for a planned capacity of 1,500 MTHM per year. The facility conducted uranium testing but never operated due to President Carter's decision to indefinitely defer commercial spent fuel reprocessing. The facility is currently undergoing decommissioning. Altogether, private industry invested approximately $2 billion in the Morris and AGNS facilities, however, neither facility began reprocessing operations.

Other companies were planning for reprocessing and recycle facilities. Exxon planned a 1,500 MTHM/yr facility at Oak Ridge, TN, and Westinghouse planned a Recycle Fuels Plant for approximately 600 MTHM/yr of mixed-oxide (MOX) fuel fabrication. These plans were shelved in the late 1970s and early 1980s.

All of these facilities were based upon a burnup of 30,000 MWD/MTHM typically used for spent fuel in the early 1970s. Utilities in the United States currently have about 45,000 MTHM in spent fuel, with an average burnup around 45,000 MWD/MTHM. Current spent nuclear fuel (SNF) discharges are around 55,000-60,000 MWD/MTHM burnup. Some pressurized water reactor (PWR) fuels are currently licensed for a 62,000 MWD/MTHM burnup at some sites. The maximum burnup currently licensed for a dry storage cask is 65,000 MWD/MTHM.

International Experience

Reprocessing is conducted on a significant scale in France, the United Kingdom, Japan, Russia, India, and China. Other countries (e.g., Belgium and Germany) have conducted pilot activities. As in the United States, reprocessing started in support of defense and nuclear energy programs, primarily using low-burnup metallic fuels. Subsequently, several large facilities have evolved providing commercial reprocessing and recycling services across national boundaries. The commercial reprocessing facilities are based on a nominal design capacity of 800 MTHM/yr and medium burnup (circa 40,000 MWD/MTHM) of oxide fuels, using optimized PUREX solvent extraction. To date, commercial operations have generally been economic and within regulatory requirements. Doses and discharges have decreased considerably from the late 1970s/early 1980s and now appear to have plateaued. Current trends indicate a decrease in reprocessing across national boundaries due to the startup of a new reprocessing plant in Japan, higher fuel burnups, more spent fuel storage (particularly dry storage), planned nuclear phaseouts in Germany and Sweden, limited new orders for reactors, and uncertain future plans. Separated materials (plutonium) are returned to the country of origin as MOX fuel. Commercial reprocessing facilities have indicated plans to return an amount of vitrified HLW equivalent to all the wastes generated from reprocessing a specific country's spent fuel back to the country of origin. Some vitrified HLW shipments have already been made to Belgium, Germany, and Japan.

France has two large reprocessing plants at the La Hague site, on its northern coast. The facilities are very large, occupying a space approximately 1.5 miles long by 0.75 mile wide, as shown in Figure 1. The UP-2 facility reprocesses domestic fuel for the French PWR fleet. Typical throughputs are 600-800 MTHM/yr. The French utility is intending to increase discharge burnups to approximately 50,000 MWD/MTHM. The UP-3 (sometimes called UP-3A) facility reprocesses spent fuel from PWRs and boiling-water reactors [BWRs]) for overseas customers, including Japan, Germany, and Belgium. The facility cost between $3 and 4 billion (1990 dollars) and was financed by international contracts. An additional, UP-3B facility was planned but not pursued due to the cancellation of many reactor orders in the 1980s and early 1990s.

UP-2 and UP-3A recover uranium and plutonium. Both are recycled—the plutonium in MOX fuel. Currently, the transuranics are sent with the fission products to onsite HLW vitrification facilities. Approximately 3 gigacuries of vitrified HLW canisters are in dry storage at the site (for comparison, the Hanford HLW tanks currently contain about 250 megacuries). Current French operations reduce the volume of material requiring a repository by approximately a factor of 6 compared to the estimated volume for direct disposal of the fuel.

Figure 1. La Hague Plants - Two 800 MTHM/yr plants

France operates a separate facility (MELOX, in southern France) for the manufacture of MOX fuel. MELOX has a nominal capacity of 200 MTHM/yr. In France, MOX fuel is irradiated to a burnup of 42,000 MWD/MTHM; the plan is to increase this burnup to approximately 50,000 (i.e., comparable to UO_2 fuel). MELOX also produces MOX fuel for overseas customers. France has reprocessed commercial spent MOX fuel through the UP-2 plant (primarily once through but there have been several tests with twice irradiated MOX fuel). France has conducted laboratory tests on americium and curium recycle, and has irradiated several assemblies.

French authorities and organizations have found reprocessing and MOX to be economic as waste management strategies but not as fuel management alternatives. French analyses have shown americium recycle to reduce repository dose impacts by a factor of about 40 and curium recycle to reduce dose impacts by two orders of magnitude. However, the need for a repository is not eliminated.

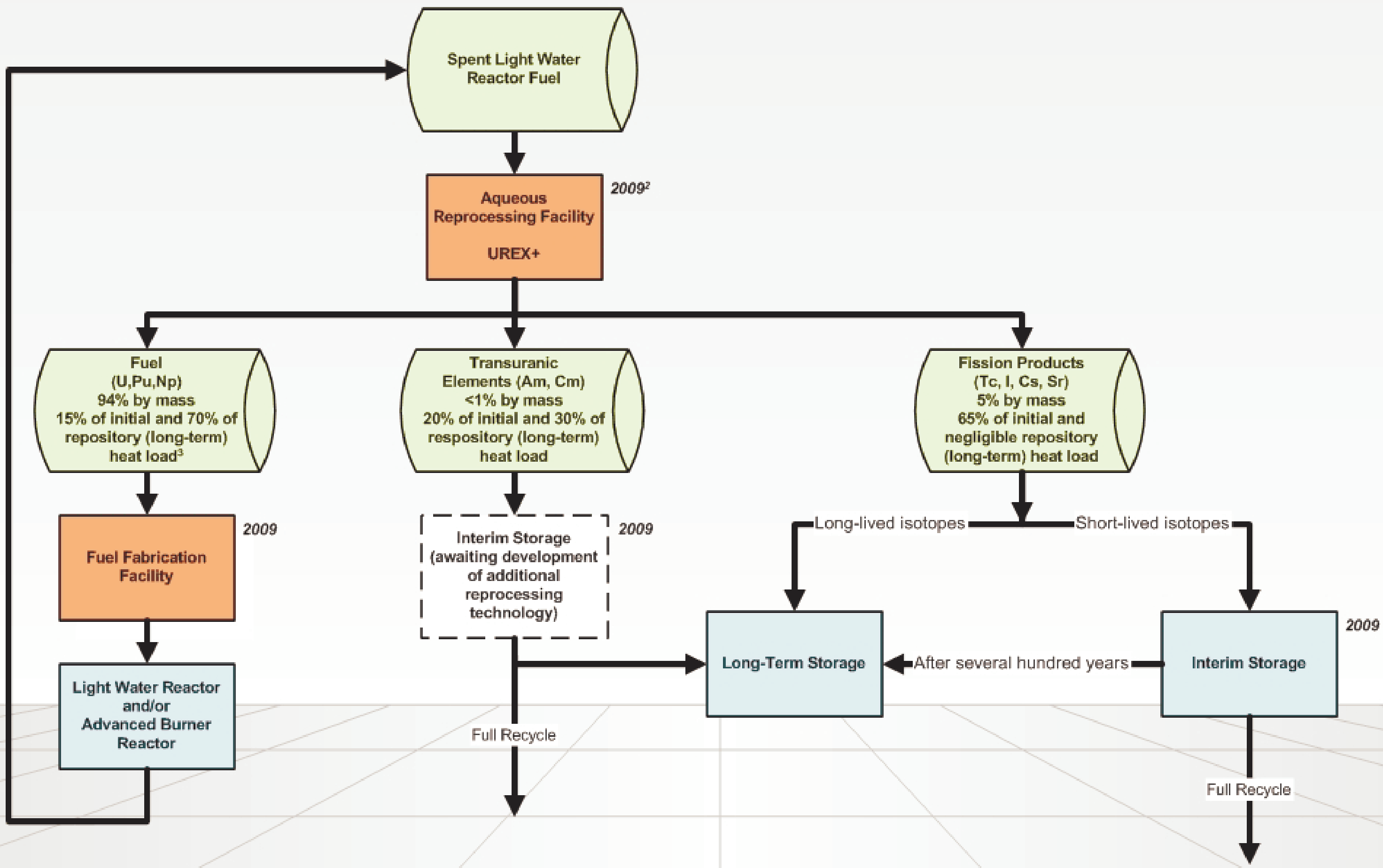
The United Kingdom (UK) operates several reprocessing facilities at Sellafield (Windscale) on the Northwest coast. These facilities reprocess low-burnup metallic fuels (approximately 6,000 MWD/MTHM from Magnox reactors) and medium-burnup oxide fuels (from advanced gas reactors [AGR] and light-water reactors [LWRs]). The B205 facility has a relatively large capacity and is used for the metallic spent fuel from Magnox reactors; Magnox reactors are approaching decommissioning, so the operations at B205 may cease in the next 10 years. The THORP facility reprocesses commercial oxide spent fuel. The facility has a nominal design capacity of 800 MTHM/yr and has been entirely financed by overseas sales contracts. The

THORP facility is the main facility of interest in the UK (the UK currently only has one LWR, and AGR fuel is now frequently stored dry). THORP has a vitrification plant that also processes HLW from Magnox spent fuel activities. Operationally, vitrification has experienced melter problems but the facility currently has some 1.5 gigacuries of vitrified HLW in dry storage. The overseas contracts at THORP expire around 2010 and there are no current plans to extend operation beyond that time.

The UK has approximately 100 tons of separated plutonium in storage from the reprocessing operations. The country is evaluating options for this material and is also reevaluating its energy options, including nuclear energy. Sellafield includes a separate MOX plant (SMP) for returning plutonium as MOX fuel to the country of origin. UK analyses of transuranic recycling revealed similar results to the French work. Only limited testing has been conducted to date.

Commercial reprocessing will begin soon at the Rokkasho-mura plant in Japan. The Rokkasho plant has a nominal design capacity of 800 MTHM/yr and was constructed at a cost exceeding $6 Billion (in 2005 dollars). The plant is undergoing uranium testing in 2006. It is designed for the production of a mixed uranium-plutonium product that can be used to produce MOX fuel for recycle in Japanese LWRs. Japan’s intention is to recycle materials as much as possible and, ultimately, to use fast neutron reactors both for energy and to manage HLW.

Process Flowcharts
Limited Recycle[1]

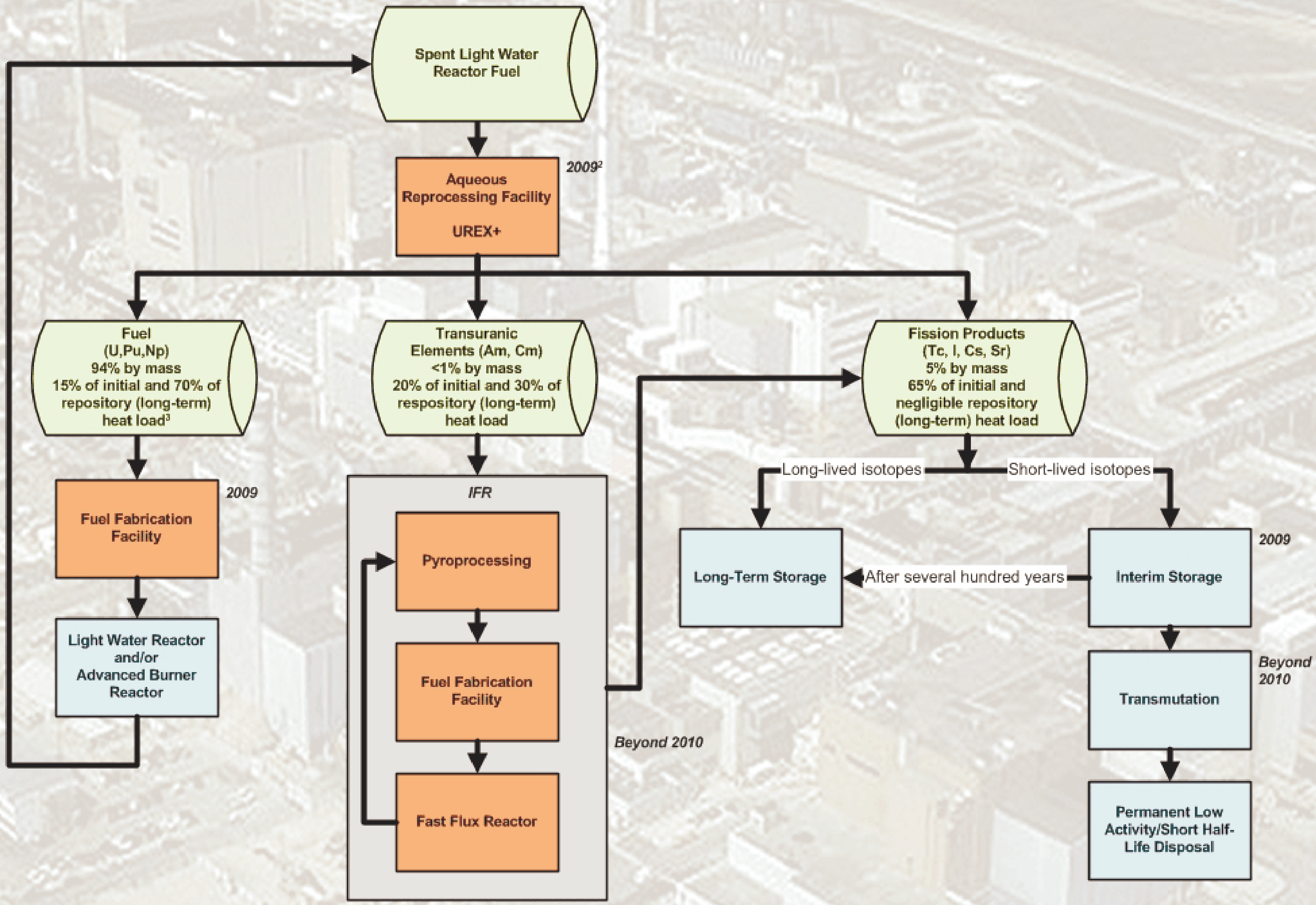


Notes: 1. This process modestly improves the use of repository space.
2. All dates listed are estimated start dates for NRC licensing review of commercial facilities.
3. The heat loads listed are estimated values only and depend on the overall process and time between steps.

Enclosure 2

Process Flowcharts

Full Recycle (the Closed Fuel Cycle)[1]



Notes: 1. This process significantly improves the use of repository space (approximately 100-fold improvement).
2. All dates listed are estimated start dates for NRC licensing review of commercial facilities.
3. The heat loads listed are estimated values only and depend on the overall process and time between steps.

Detailed Description of Limited Recycle and Full Recycle

The staff expects DOE to consider two approaches for its spent fuel recycling program that would achieve the goal of effectively increasing the utilization of repository space in a proliferation-resistant manner. The first approach would involve (1) an advanced separations step (based on the UREX+ technology, which mitigates the disadvantages of the more common PUREX process[1]) and (2) a limited recycle of mixed-oxide (MOX) fuel in conventional LWRs and/or Advanced Burner Reactors (ABRs) such as a liquid metal fast flux reactor. The second approach would involve full recycle beyond these two primary steps, using ABRs to close the fuel cycle and transmute the transuranic waste streams. A process flow diagram for the stages included in limited and full recycling and the fate of the products separated from the spent nuclear fuel is included in Enclosure 2. A summary of the processes involved is discussed below.

Limited Recycle

The primary stages of limited recycling include spent fuel reprocessing and limited recycle in existing LWRs. The UREX+ technology is a refined solvent extraction technology that allows the separation and subsequent handling of several highly pure product streams: (1) uranium, which can be stored for future use or disposed of as low-level waste, (2) a mixture of plutonium and neptunium, which can be reused as MOX fuel, (3) separated fission products that would eventually require long-term storage and disposal, and (4) the transuranic elements americium and curium. Several of the processes associated with the UREX+ technology are discussed further in the next section (on full recycle).

The performance goals of the UREX+ process are to achieve the following:

- Purity levels of uranium, plutonium, and neptunium sufficient to meet the MOX fuel specifications in ASTM C833-01

- Recovery of the fission products technetium and iodine to levels sufficient to achieve up to a 20-fold decrease in offsite dose, with sufficient separation of fissile actinides to allow future transmutation

- Recovery of the fission products cesium and strontium to a level sufficient to reduce their contribution to the heat load in the repository equal to the heat load of all other fission products and to remove sufficient transuranic content to allow decay storage and ultimate disposal as low-level waste

- The separation of americium and curium to levels that result in a 100-fold reduction of the heat load to the repository

- Produce final raffinate streams containing the rare earths and all soluble fission

---

[1]PUREX stands for plutonium uranium reduction and extraction, and UREX+ stands for uranium reduction and extraction. Both processes use liquid-liquid solvent extraction techniques. The PUREX process separates a stream of plutonium and a stream of uranium from the waste stream containing both transuranics and fission products, while the UREX+ process separates a mixed uranium-plutonium stream from a transuranic stream and fission product streams.

products (except cesium, strontium, technetium and iodine), which can then be converted into a solid form for final disposal in the repository

The advantages of the UREX+ process over the PUREX process are the potential for significant cost reductions, the elimination of the need for waste tank farms, and the ability to separate and manage very pure product streams of key elemental and isotopic constituents.

The fuel stream, comprising uranium, plutonium, and neptunium, accounts for about 94% of the total spent fuel mass and 15% of the initial and 70% of the long-term repository heat load. The transuranic elements account for less than 1% of the total mass and 20% of the initial and 30% of the long-term heat loads. The fission products make up 5% of the mass and 65% of the initial and negligible long-term heat loads.

As shown on the process flowchart in Enclosure 2, the resulting streams from the UREX+ process follow several different paths. In addition to the UREX+ facility, a new fuel fabrication facility would need to be built to handle the uranium and the mixed plutonium/neptunium UREX+ output streams. The output from the new fuel fabrication facility would be recycled as MOX fuel, resulting in the limited recycle of the spent fuel.

Some of the benefits of limited recycling would depend on when the material is recycled. For example, recycling spent fuel within the first several years of removal from the reactor would significantly limit the buildup of americium-241 from plutonium-241 decay. Limiting the buildup of americium-241 is desirable because the isotope's energetic alpha decay and relatively short half-life result in a high heat output. The presence of plutonium-241 in the spent fuel, however, would require greater shielding in the limited recycling facilities than americium-241. As shown on the process flowchart in Enclosure 2, recycling the uranium, neptunium, and plutonium stream has the potential to reduce the long-term repository heat load by 70 percent.

Interim storage may be needed for several of the UREX+ output streams, especially the transuranic elements americium and curium. The length of time the interim storage phase would need to last before the final processing of the transuranic actinides and fission products is unclear. While it is likely that the storage facility would be co-located with the UREX+ facility, some process streams might be stored at another location. The remaining fission products could be separated into a stream for short-term storage (to reduce the heat load) and a stream for long-term storage in specialized waste forms.

Full Recycle

Full recycling would include the primary stages of limited recycling but would close the fuel cycle loop by using ABRs (and/or possibly linear accelerators) to transmute the fuel constituents into much less hazardous elements and by using pyroprocessing technologies to recycle the fast flux reactor fuel. Full recycle has the potential to significantly reduce proliferation risk by eliminating the buildup of all isotopes.

In addition to the reprocessing and limited recycling of spent fuel, full recycling would involve transmutation of the transuranic elements. Transmutation occurs in the high flux field typically associated with a liquid metal cooled fast flux reactor. DOE currently has two potential technologies from which to choose: the Integral Fast Reactor (IFR), which uses metal fuel, and the Advance Liquid Metal Reactor (ALMR, also known as the GE Power Reactor, Innovative, Small Module [PRISM]), which can use either ceramic fuel or metal fuel.

The IFR system developed by Argonnne National Laboratory would use a new type of metal alloy fuel. This fuel would be recycled using a pyroprocess whereby uranium, plutonium, and other transuranic elements could be separated from the other radioactive waste and reused in new fuel assemblies. The IFR design also has the potential to burn actinides from LWRs. This would require a separate aqueous reprocessing facility to be built (i.e., the UREX+ facility). The remaining waste would have a significantly reduced heat load and volume and would remain a radioactive hazard for only hundreds of years, not for hundreds of thousands of years. As shown on the process flowchart in Enclosure 2, the transuranic elements contribute approximately 30 percent of the long-term repository heat load (integrated over time). With full recycling, most of the transuranic elements would be transmuted and two-thirds of their heat load could be reduced. Therefore, full recycling has the potential to achieve an overall 90 percent reduction in the total long-term repository heat load.

The ALMR would involve much the same fast flux reactor technology as the IFR, however, the primary difference is its ability to use ceramic or metal fuel. DOE may prefer this technology since ceramic fuel is currently more commonly used than metal fuel.

The remaining fission products from the reprocessing of the spent LWR fuel would be separated into streams for short-term storage (heat load reduction), possible transmutation, and long-term storage in specialized waste forms.