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Waste Management Planned for the Advanced Fuel Cycle Facility

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WASTE MANAGEMENT PLANNED FOR THE ADVANCED FUEL CYCLE FACILITY

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The U.S. Department of Energy (DOE) Global Nuclear Energy Partnership (GNEP) program has been proposed to develop and employ advanced technologies to increase the proliferation resistance of spent nuclear fuels, recover and reuse nuclear fuel resources, and reduce the amount of wastes requiring permanent geological disposal. In the initial GNEP fuel cycle concept, spent nuclear fuel is to be reprocessed to separate re-useable transuranic elements and uranium from waste fission products, for fabricating new fuel for fast reactors. The separated wastes would be converted to robust waste forms for disposal.

The Advanced Fuel Cycle Facility (AFCF) is proposed by DOE for developing and demonstrating spent nuclear fuel recycling technologies and systems. The AFCF will include capabilities for receiving and reprocessing spent fuel and fabricating new nuclear fuel from the reprocessed spent fuel.

Reprocessing and fuel fabrication activities will generate a variety of radioactive and mixed waste streams. Some of these waste streams are unique and unprecedented. The GNEP vision challenges traditional U.S. radioactive waste policies and regulations.

Product and waste streams have been identified during conceptual design. Waste treatment technologies have been proposed based on the characteristics of the waste streams and the expected requirements for the final waste forms.

Results of AFCF operations will advance new technologies that will contribute to safe and economical commercial spent fuel reprocessing facilities needed to meet the GNEP vision. As conceptual design work and research and design continues, the waste management strategies for the AFCF are expected to also evolve.

I. INTRODUCTION

Worldwide energy demands grow each year, while the major worldwide energy resource, fossil energy, is consumed. Fossil fuels are not expected to meet worldwide energy needs in the future, as these resources become depleted and as nations seek alternative methods to curtail anthropogenic greenhouse gas emissions. Nuclear power is arguably the only viable way to meet growing worldwide energy demands in the coming decades. However, several significant barriers continue to restrict the growth of nuclear power.

Radioactive waste is a significant barrier to the growth of peaceful nuclear power. For example, the State of California banned the construction of any new nuclear power stations in the state in 1976, until the technologies exist to safely dispose or reprocess radioactive wastes. This law still stands, although it was challenged as recently as in 2007. Appropriate and safe radioactive waste management is now understood to be of considerable importance to the nuclear power generating industry.[1,2]

The U.S. Department of Energy (DOE) Global Nuclear Energy Partnership (GNEP) program has been proposed to develop and employ advanced technologies to increase the proliferation resistance of spent nuclear fuels, recover and reuse nuclear fuel resources, and reduce the amount of wastes requiring permanent geological disposal. Figure 1 describes the initial GNEP fuel cycle concept.[3] Spent fuel from light water reactors (LWRs) is to be reprocessed to separate re-useable transuranic (TRU) elements and uranium from waste fission products, for fabricating new fuel for fast reactors. The spent fuel from the fast reactors would also be reprocessed to again separate useable fuel from wastes built up in the fuel. The separated wastes would be converted to robust waste forms for disposal.

II. ADVANCED FUEL CYCLE FACILITY

The Advanced Fuel Cycle Facility (AFCF) is proposed by DOE for developing and demonstrating spent nuclear fuel recycling technologies and systems. As shown in Figure 2, the AFCF will include capabilities for receiving and reprocessing spent nuclear fuel, fabricating new nuclear fuel from the reprocessed spent fuel, and treating wastes separated from the spent fuel and generated during reprocessing and fuel fabrication.[4] This figure is based on the AFCF conceptual design, which was completed in February 2007.

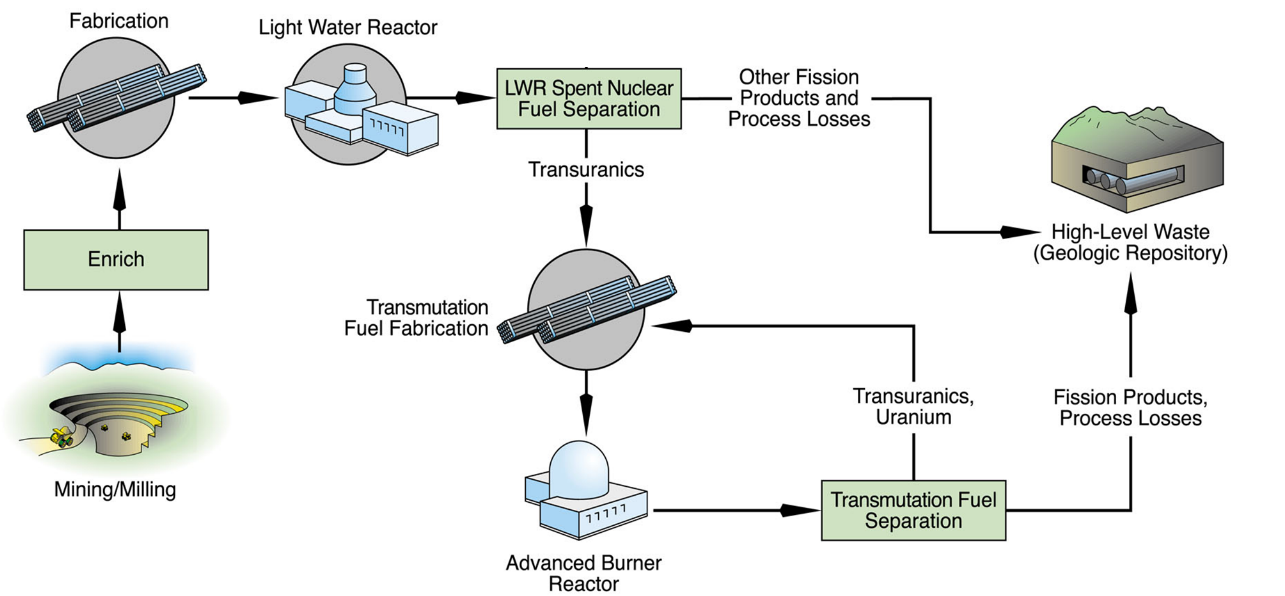

Figure 1. Initial GNEP fuel cycle concept.

The conceptual design includes functional and operating requirements for the AFCF, early conceptual process and facility designs, and the strategy for waste and product management. The UREX+1A aqueous separations process is included in the conceptual design. Electro-metallurgical processing [also called electro-chemical reprocessing (Echem), pyrometallurgical processing, or pyroprocessing] is also included in the conceptual design. Design work is continuing, resulting in some changes to the initial concept. As the design progresses, additional changes can also be expected.

Spent nuclear fuel recycling (also called reprocessing) is designed to separate useable fuel from radioactive wastes in the spent fuel, enable use of significant remaining energy content in the spent fuel, and reduce the amount of waste what would otherwise require disposal in a geological repository. Results of the AFCF operations will advance new technologies that will contribute to safe and economical spent fuel reprocessing needed to meet the GNEP vision.

III. AFCF WASTE MANAGEMENT STRATEGY

The current design for the AFCF includes spent nuclear fuel receipt, preparation (disassembly and chopping) for reprocessing, both aqueous reprocessing and Echem reprocessing alternatives, and fabrication of new nuclear fuels from the reprocessed fuels. These reprocessing and fuel fabrication activities will generate a variety of radioactive and mixed waste streams.

Spent fuel reprocessing to meet the GNEP vision provides unique challenges for waste management because of the unique and unprecedented waste streams expected to be generated. The GNEP vision challenges traditional U.S. radioactive waste policies and regulations. High level waste (HLW) is a functional designation defined in the U.S. as the highly radioactive waste derived from nuclear fuel reprocessing. It is not based on any characterization of the waste itself, and is the default regulatory category for all of the primary streams coming from spent nuclear fuel separations.

Under GNEP, however, used fuel will be partitioned further into many more streams to allow specific waste management strategies intended to extend the useful life of the geologic repository to beyond the end of this century. The very long-lived actinides will be removed to be recycled as fuel, and the most prevalent fission products, cesium and strontium, will be isolated for dedicated decay storage and eventual permanent disposal. Following decay storage, this waste stream may meet requirements for mixed low-level waste (MLLW) disposal in a repository other than a geological repository. Long-lived fission products, such as iodine and technetium, will also be isolated to be stabilized in tailored waste forms and disposed under existing regulations as Class A, B, or C LLW, or greater-than-Class-C (GTCC), depending on the concentration of the radionuclides.

Due to these additional separations, the term “HLW,” which was meant to include the lumped waste fraction from reprocessing, containing a range of intensely radioactive short half-life radionuclides as well as significant concentrations of very long half-life radionuclides, may become obsolete.

Similarly, the term “TRU waste,” which describes radioactive wastes from the U.S. military and national defense, containing at least 100 nCi/g TRU elements, is not applicable in the context of GNEP processes, which

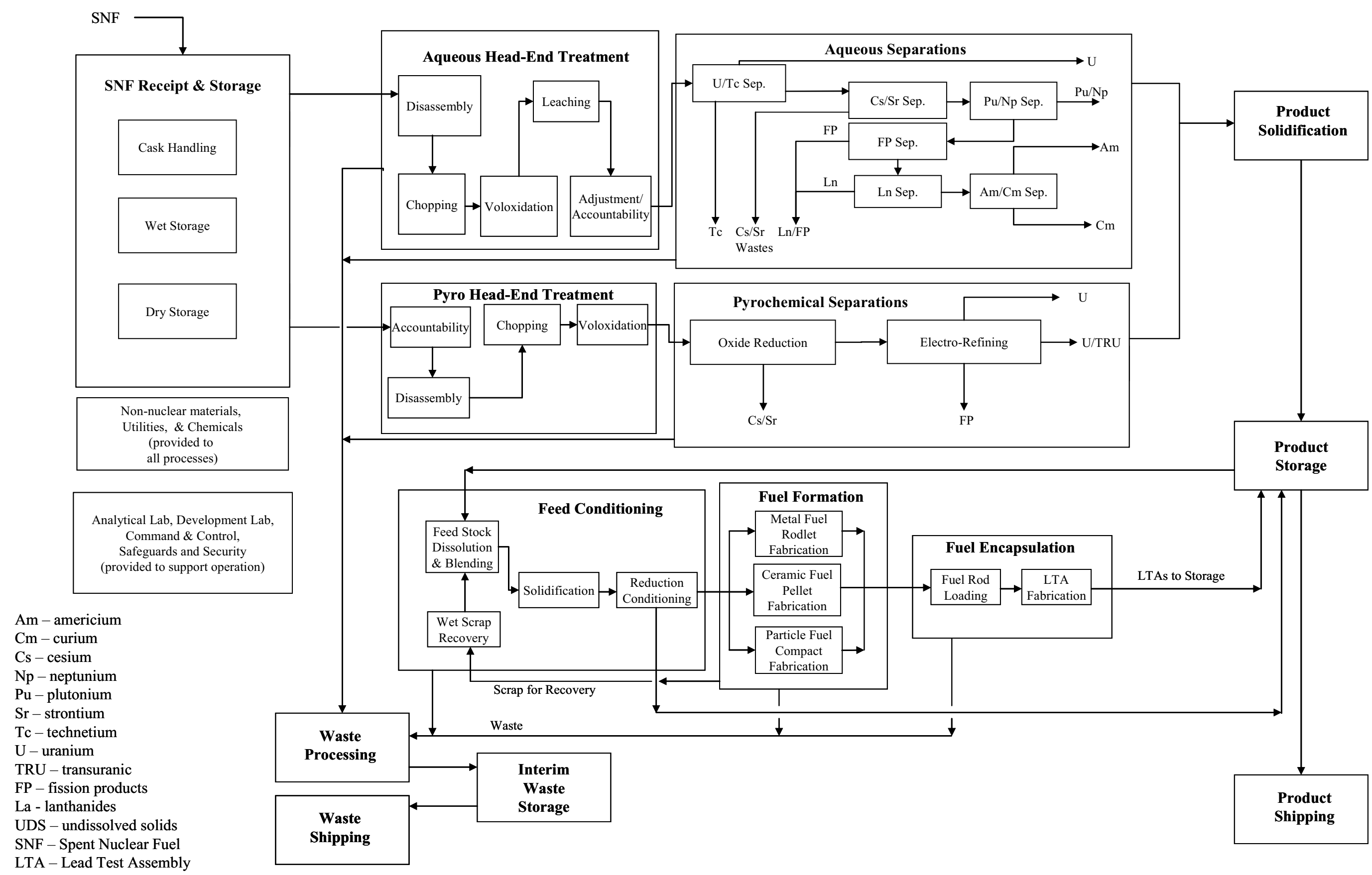

Figure 2. AFCF conceptual design.

are dedicated to commercial applications. Commercial wastes containing at least 100 nCi/g TRU are considered GTCC. Thus, the Class A/B/C and GTCC waste designations are probably sufficient for disposition of all wastes.

Strategies for managing these wastes are based on the requirement to ensure that all waste streams be treated to meet regulatory requirements, but acknowledge the GNEP strategy to reduce radioactive waste disposal in a geological repository:

- Develop final waste forms that meet existing, applicable disposal site waste acceptance criteria (WAC), and
- Tailor the waste forms to enable demonstration of alternative disposal concepts, including decay storage, followed by appropriate permanent disposal based on waste form radioactive and hazardous characteristics.

The AFCF waste forms can be used to provide data and bases for alternatives to current policies and regulations that currently prevent the use of more efficient disposal concepts. At any time, if policy/regulatory changes are determined to not be possible, then these waste forms can still be disposed in a geological repository or other disposal sites in compliance with current regulations, waste definitions, and waste characteristics. The AFCF waste streams can also be used to develop and demonstrate reuse or recycling of some radioactive materials separated from the spent fuel, such as tritium (H3), radioactive krypton (Kr85), and radioactive Zircaloy cladding.

The AFCF conceptual design imposes additional waste management requirements:

- Advance and comply with safety procedures to protect workers, the public, and the environment
- Only temporarily store waste within AFCF pending treatment and permanent disposal; no long-term storage for radioactive decay.
- Recycle or destroy where practical; capture and immobilize where necessary.
- Separate gaseous fission products (FPs) early in aqueous spent fuel reprocessing; avoid downstream contamination from H3, I129, and C14.
- Comply with all applicable current air emission regulations; but use the AFCF to demonstrate technologies needed by full-scale facilities, even if AFCF itself does not require those technologies.
- Comply with all applicable waste treatment regulations.
- Perform off-gas control as close to the source as practical.

IV. AFCF WASTE STREAM DISPOSITIONS

Table I summarizes product and waste streams determined during the AFCF conceptual design. The separation and fuel fabrication processes produce product streams, waste streams, and offgas streams. Operation of the facility produces additional waste streams such as waste chemicals, samples, spent equipment, job control wastes, and additional offgas streams. The dispositions of all effluent streams were developed using the strategy shown in Figure 3.

Definition of the effluent streams and disposition strategies is based on the current AFCF design, incorporating many assumptions regarding waste stream amounts and compositions. Currently mature waste treatment technologies and systems are used where possible, but even "mature" systems currently used commercially in other related applications must undergo development and demonstration for the unique AFCF waste streams. In some cases, "mature" technologies are not presently available. In those cases, the most plausible treatment technologies now under evaluation or development are identified for consideration, although research, development, and demonstration may still be needed to make any of these technologies sufficiently mature.

Alternate treatment technologies are still being considered for practically all waste streams. Above all, at this stage in the conceptual design, the selected treatment technologies need to be representative to the extent possible of the variety of potential technologies that might be tested in the AFCF. This provides some assurance that (a) the conceptual design will include necessary hot cell space, utilities, offgas control systems, and other support functions to provide some flexibility in eventual technology demonstrations, and (b) the AFCF cost estimate and safety basis will be sufficiently conservative. In this way, the AFCF conceptual design can proceed in parallel with research and development to advance technologies to the stage at which they can be installed in the AFCF for demonstration.

Final determinations of technologies to initially test in the AFCF will be determined based on cost, ability to meet the expected waste from acceptance criteria, and technical maturity.

The waste forms or disposal strategies considered technically suitable for the waste streams are often not consistent with current radioactive waste policies and regulations. For example, the spent hulls and other non-fuel-bearing (NFB) components might not strictly be classified as HLW requiring disposal in a geological repository, but they may contain residual contamination of TRU elements in excess of levels allowed for Class A, B, or C LLW. Such wastes may be described as GTCC

TABLE I. Expected AFCF waste streams, proposed treatment plans, and proposed dispositions.

Waste stream	Treatment	Disposition
Hulls, Tc (Echem)	Metal melter	Geological repository
SS/Hulls/Tc/UDS (aq)	Metal melter Decon/compact remainder	Tc/UDS/SS/Zr: Geological repository Decon'd SS,hulls: Geological repository or LLW SLB
FP gases (I129, H3, C14, Kr85)	Volatilize, sorb, convert to FWF (Echem: I129 and C14 will partition to Echem glass-bonded zeolite)	I129 zeolite: Geological repository C14 lime: Geological repository HTO grout: Geological repository, SLB Kr85 gas cylinder: decay, SLB
Cs/Sr (aq)	Steam reform/calcine, mineralized monolith	Decay store; MLLW SLB
Cs/Sr, FP, Na metal (Echem)	Glass-bonded zeolite	Geological repository
Ln, Other FP (aq)	Vitrify – glass or ceramic	Geological repository
Spent LLW solvents	FBSR	LLW SLB
Spent LLW IX resin		
Other organic LLW		
Waste water		
TRU-contam.LLW	TRU-contam. steam reform	Geological repository
Spent T/LLW IX resin		
Glass molds, crucibles	Ln/FP melter? Package/dispose? LLW or T-LLW FBSR?	Geological repository or LLW SLB
Spent equipment	Size reduce, decon	LLW SLB

Notes:
1. aq = aqueous reprocessing
2. decon = decontaminate
3. FBSR = fluidized bed steam reformer
4. FP = fission products
5. FWF = final waste form
6. HTO = Tritiated water
7. IX = ion exchange
8. Ln = Lanthanides
9. SLB = shallow land burial
10. SS = stainless steel
11. T=TRU or transuranic
12. UDS = undissolved solids

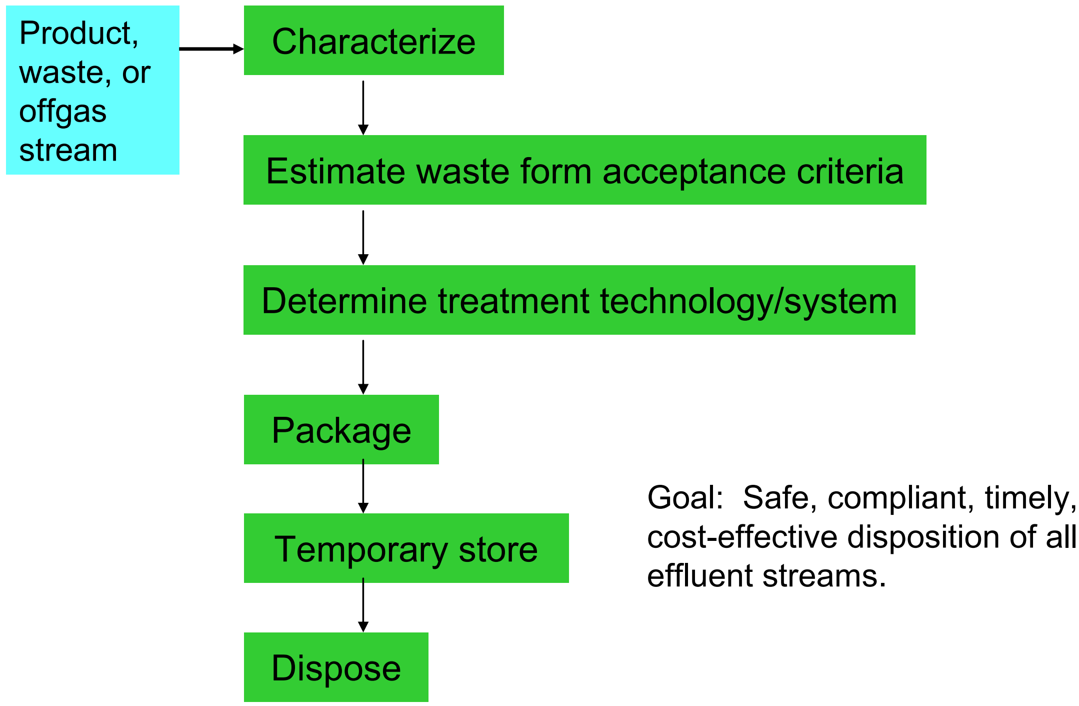

Figure 3. Strategy for AFCF waste stream, product stream, and offgas stream dispositioning.

wastes. The appropriate disposition of such a waste stream must still be determined, since a specific disposal site for GTCC waste does not presently exist in the U.S. Ultimately, if a better disposition is not developed based on the characteristics of this waste stream, then this waste stream may need to be qualified for disposal in a geological repository.

Considering the unique waste forms expected from spent fuel reprocessing by UREX+1A, time must be provided to develop the policy, regulatory, and disposal site options to enable the proposed waste form dispositions. Table II summarizes proposed durations for temporarily storing waste forms within the AFCF, to allow time for policy, regulatory, and disposal site option development, and an allowance for shipping and documentation.

V. AFCF WASTE MANAGEMENT PATH FORWARD

The AFCF conceptual design activities are continuing. Some new alternatives are still being identified for evaluation. A variety of data needs have been identified that will need to be addressed in future research and development, trade studies, technology selection, and process design. As conceptual design work and research and design continues, the conceptual waste management strategies proposed for the AFCF are expected to also evolve.

ACKNOWLEDGMENTS

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TABLE II. Proposed temporary storage for product and waste forms in the AFCF.

Product Storage	Separated TRU – 10 MT based on 10-year storage
	Separated U – 250 MT based on 10-year storage
	New (recycled) ABR fuel pellets – 2 MT based on 10-year storage
Radioactive Waste	LLW storage for 1 year
	HLW storage for 10 years
	GTCC (but < 100 nCi/g TRU contaminated) storage for 10 years
	GTCC (but > 100 nCi/g TRU contaminated) storage for 25 years
	Cs/Sr storage for 25 years
Hazardous Waste	Storage for 6 months

MT = Metric Ton

ABR = Advanced Burner Reactor