A Project Concept for Nuclear Fuels Storage and Transportation

Fuel Cycle Research & Development

Prepared for
U.S. Department of Energy
Nuclear Fuels Storage and Transportation Planning Project
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SUMMARY

The Department of Energy (DOE) issued its *Strategy for the Management and Disposition of Used Nuclear Fuel and High-Level Radioactive Waste* in January 2013. DOE undertook studies and analyses to determine systems and design concepts as a preliminary step to further defining systems, equipment, and facilities to implement the *Strategy*. This report uses the work performed by industry and national laboratories and configures system components to meet the requirements of the *Strategy*. The project concept provides guidance for the next stage of design development as well as supporting the consent-based siting process being undertaken by DOE. The project concept includes a pilot interim storage facility, a larger interim storage facility, and the transportation system and equipment needed to move used nuclear fuel and high-level radioactive waste from current locations to interim storage and then to a future permanent geologic repository.

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ACRONYMS

10CFR50	Title 10, U.S. Code of Federal Regulations, Part 50
10CFR71	Title 10, U.S. Code of Federal Regulations, Part 71
10CFR72	Title 10, U.S. Code of Federal Regulations, Part 72
AAR	Association of American Railroads
ANL	Argonne National Laboratory
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
BFS/ES	BNFL Fuel Solutions/Energy Solutions
BNFL	British Nuclear Fuels Limited
BRC	Blue Ribbon Commission on America's Nuclear Future
BWR	Boiling Water Reactor
Canister	the inner package which contains the fuel
Cask	or over pack, the container which provides shielding to reduce radiation exposure generally different shielded containers are used for storage and transportation
CERCLA	Comprehensive Environmental Response Compensation Liability Act
CFR	Code of Federal Regulations
CHB	Cask Handling Building
CMF	Cask Maintenance Facility
CoC	Certificate of Compliance
CRF	Canister Repackaging Facility
D&D	Decontamination and Decommissioning
DBT	Design Basis Threat
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DPC	Dual-Purpose Cask or Dual Purpose Canister
DSC	Dry Storage Canister or Cask (used generally) or
	Dry Shielded Canister (used with NUHOMS systems)
ECP	Electronically Controlled Pneumatic
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ER	Environmental Report

ES&H	Environment, Safety and Health
FCRD	Fuel Cycle Research & Development
FMF	Fleet Maintenance Facility
FRA	Federal Railway Administration
FTE	Full Time Employee
GTCC	Greater-than-Class-C (category of radioactive waste)
GWd/MT	Gigawatt-days per Metric Ton (of Initial Uranium)
HLW	High-Level Radioactive Waste
HSM	Horizontal Storage Module
INL	Idaho National Laboratory
ISF	Interim Storage Facility generic term for both PILOT and larger ISF
ISFSI	Independent Spent Fuel Storage Installation
LLW	Low-Level Radioactive Waste
MCEP	Motor Carrier Evaluation Program
MDO	Management and Disposal Organization
MPC	Multi-Purpose Canister (used with HOLTEC and some NAC systems)
MTHM	Metric Tons Heavy Metal (equivalent to MTU)
MTU	Metric Tons Uranium
NEPA	National Environmental Policy Act
NFST	DOE-NE Nuclear Fuels Storage and Transportation Planning Project
NNPP	Naval Nuclear Propulsion Program
NPDES	Nationally Pollution Discharge Elimination System
NPP	nuclear power plant
NRC	Nuclear Regulatory Commission
NUHOMS	NUclear HOrizontal Modular Storage
NWPA	Nuclear Waste Policy Act of 1982, as amended
O&M	Operations & Maintenance
OCA	Owner Control Area
OCRWM	Office of Civilian Radioactive Waste Management
OFF	Oldest Fuel First
ORNL	Oak Ridge National Laboratory
Over pack	the shielded container used during storage or transportation to reduce radiation exposure, generally reffered to as a cask
PA	Protected Area

PIDAS	Perimeter Intrusion Detection and Assessment System
Pilot	Pilot Interim Storage Facility
PM	Project Management
PWR	Pressurized Water Reactor
QA	Quality Assurance
R&D	Research and Development
RA	Radiation Area
RCA	Radiation Control Area
RCRA	Resource Conservation Recovery Act
SAR	Safety Analysis Report
SCFB	Storage Cask Fabrication Building
SFP	Spent Fuel Pools
SRNL	Savannah River National Laboratory
SRS	Savannah River Site
SSC	Structures, Systems, Components
TC	Transfer Cask
TPC	Total Project Cost
TRU	Transuranic
TSC	Transportable Storage Canister (used with certain NAC and BFS/ES systems)
TSL	Transportation Storage Logistics
UFD	Used Fuel Disposition
UFDC	Used Fuel Disposition Campaign
UMS	Universal MPC System (used with certain NAC systems)
UNF	Used Nuclear Fuel
VCC	Ventilated Concrete Cask
VCT	Vertical Cask Transporter
VSC	Vertical Storage Cask
WBS	Work Breakdown Structure
WTP	Waste Treatment Project
YFF	Youngest Fuel First

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NUCLEAR FUELS STORAGE AND TRANSPORTATION PLANNING PROJECT

A PROJECT CONCEPT FOR NUCLEAR FUELS STORAGE AND TRANSPORTATION

1. INTRODUCTION

The Nuclear Waste Policy Act of 1982, as amended, (NWPA) requires the federal government to receive Spent Nuclear Fuel (now called Used Nuclear Fuel or UNF) and high-level radioactive waste (HLW) from waste generators for long term storage and eventual permanent disposal. At the request of the President, the Secretary of Energy formed the Blue Ribbon Commission on America's Nuclear Future (BRC) to conduct a comprehensive review of policies for managing the back end of the nuclear fuel cycle and recommend a new strategy. In January 2012, the BRC issued its report, which contained eight major recommendations, including:

- Prompt efforts to develop one or more interim storage facilities (ISFs); and,
- Prompt efforts to prepare for the eventual large-scale transport of UNF and HLW to interim storage and disposal facilities when such facilities become available.

On January 11, 2013, the Secretary issued the "*Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste*" (*Strategy*) citing the BRC work as a strong foundation for development of a new strategy to manage used nuclear fuel and high-level radioactive waste. The Strategy endorses a waste management system containing a pilot interim storage facility (Pilot), a larger interim storage facility (larger ISF), and a geological repository. To meet its obligations, the Department of Energy (DOE) needs to proceed promptly to develop interim storage facilities and transportation systems and equipment.

In September 2012, the DOE contracted with three teams to prepare design concept studies to investigate UNF storage and transportation. DOE was seeking alternatives to support an evaluation and possible future selection of a concept that can be developed as an option for interim storage of commercial used nuclear fuel. The concept addresses all activities required to take the commercial used nuclear fuel and Greater-than-Class C (GTCC) low level radioactive waste from its current location and configuration, transport it to a location of interim storage, prepare the fuel as needed and place it in storage, operate and maintain the interim storage facility, and prepare the used fuel for shipment to the permanent repository. The three teams were headed by Areva Federal Services, Energy*Solutions*, and Shaw Environmental and Infrastructure. The three teams completed their design concept studies and issued reports in February, 2013.

In October 2012, a National Laboratory team of Argonne (ANL), Savannah River (SRNL), and Oak Ridge (ORNL) staff issued *Used Fuel Management System Architecture Evaluation*, Fiscal Year 2012, FRDC-NFST-2013-000020, Rev. 0. This Fuel Cycle Research and Development (FCRD) report summarized system-level analyses of the overall interface between at-reactor, interim storage and ultimate disposition along with development of supporting logistic simulation tools.

The design concepts reports were prepared by three independent teams without system or design requirements provided by the contract in order to solicit unbiased opinions. While the three reports provided some overlapping materials, each report also contained original concepts. Taken together the reports are comprehensive regarding transportation and storage concepts needed.

This report developed the functions and requirements necessary to meet the framework outlined with *Strategy*. The project concept developed here differs from the previous work in three ways. First, the inventory is limited for the Pilot and larger ISF as described in *Strategy*. Second, this project concept assumes bare fuel in reusable transportation casks will be received in significant quantities for the larger ISF and not solely limited to the receipt of fuel in a dry storage canister (DSC) as is the Pilot. Third, the study recognizes that while the previous reports identified several alternative design concepts, these must be more fully developed.

2. Program Strategy and Mission Need

2.1 As-Is Condition (Mission Needs)

The NWPA requires DOE to take custody of and manage all UNF and HLW from commercial nuclear power plants (NPPs) in the U.S. starting in 1998. DOE has no facility or system in place to take custody of UNF from commercial NPPs. The *Strategy* identifies that prompt action is needed to provide interim storage and transportation capabilities while a longer-range plan is undertaken to site and develop a permanent repository for UNF.

DOE currently does not have the capability, facilities, or equipment to receive, transport, and store large quantities of commercial used nuclear fuel. The existing commercial utility storage facilities are located at operating and shutdown power plants, some of which have been decommissioned. While the current facilities are safe for interim storage as licensed by the Nuclear Regulatory Commission (NRC), DOE is ultimately responsible to remove all commercial UNF and provide for long term stewardship of this material. This interim storage capability will relieve the burden from current owners and will prove out systems and methods needed by the Department for the future. The Federal government is incurring significant penalties for partial breach of their contracts with utility companies.

2.2 To-Be Condition (Strategy)

DOE plans to develop an interim used nuclear fuel and high-level waste storage and transportation capability for commercial nuclear power plants, and government-owned HLW and used nuclear fuel. As stated in the *Strategy*, with the appropriate authorizations from Congress, the Administration currently plans to implement a program that:

- Sites, designs and licenses, constructs and begins operations of a pilot interim storage facility by 2021 with an initial focus on accepting used nuclear fuel from shut-down reactor sites;
- Advances towards the siting and licensing of a larger interim storage facility to be available by 2025 that will have sufficient capacity to provide flexibility in the waste management system and allows for acceptance of enough used nuclear fuel to reduce expected government liabilities; and,
- Makes demonstrable progress on the siting and characterization of repository sites to facilitate the availability of a geologic repository by 2048.

This report summarizes DOE design concepts for the first two elements of the near-term strategy. These design concepts will inform planned follow-on activities for further alternatives analysis and conceptual design activities.

The *Strategy* endorses a waste management system with development of interim storage and transportation of UNF from commercial nuclear power plants. The *Strategy* contains a plan for managing the back end of the nuclear fuel cycle. Figure 2-1 depicts the key elements from the *Strategy*.

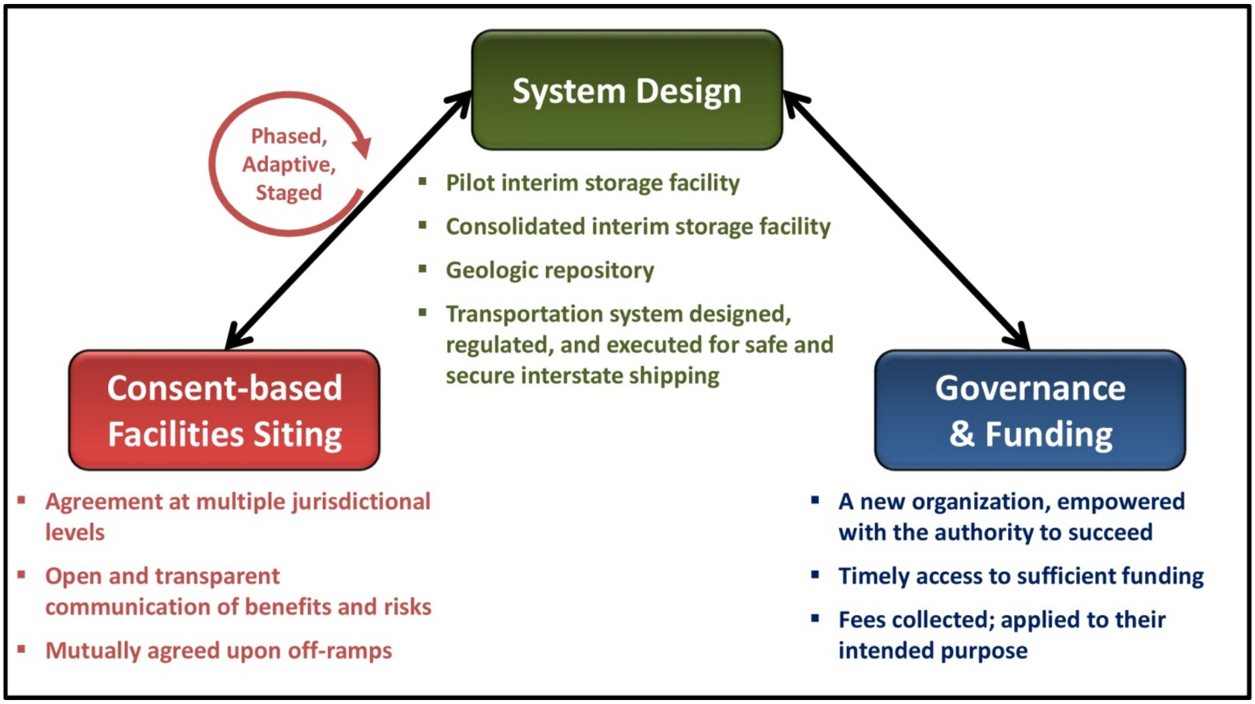

Figure 2-1. Key Strategy Elements.

As shown in Figure 2-1, the system design includes the following elements:

- A pilot interim storage facility with limited capacity capable of accepting used nuclear fuel and HLW and initially focused on serving shut-down reactor sites;
- A larger interim storage facility (called the consolidated ISF in the *Strategy*) potentially co-located with the pilot facility and/or with a geologic repository, that provides the needed flexibility in the waste management system and allows for important near-term progress in implementing the federal commitment;
- A geologic repository; and,
- Transportation systems, equipment, and infrastructure to move UNF and HLW from current locations to the Pilot and larger ISF facilities.

Figure 2-2 portrays a set of possible pathways to develop system facilities and capabilities as identified in the *Strategy*.

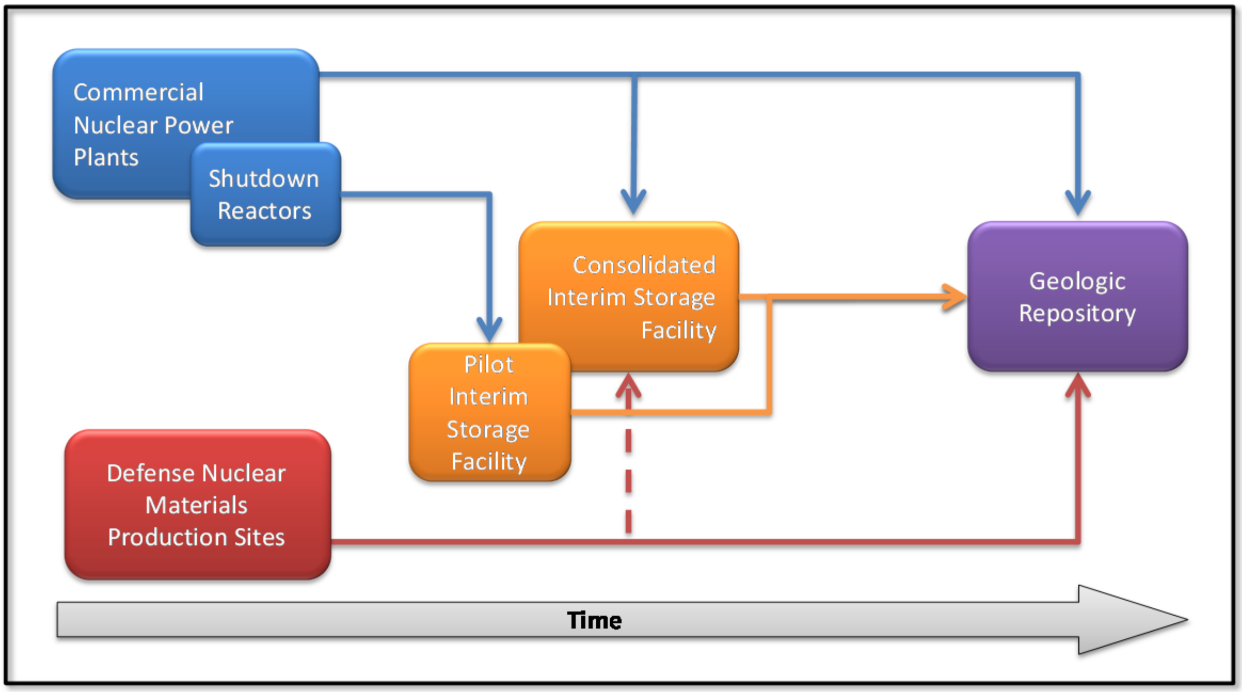

Figure 2-2. Possible System Pathways.

DOE will implement the *Strategy* and work with Congress to further define the project requirements. The *Strategy* laid out a time line for the facilities: 2021 for the Pilot and 2025 for the larger ISF. Subject to appropriate authorizations, DOE will proceed with design, siting, and licensing of the storage and transportation systems to meet these schedules. The *Strategy* also concurred with the BRC that a Management and Disposal Organization (MDO) is needed to provide the stability, focus, and credibility to build public trust and confidence. As stated in the *Strategy* pending enactment of new legislation to establish the MDO, DOE retains the responsibility to maintain progress in implementing the *Strategy*.

3. Systems Engineering Approach

Systems Engineering is the overarching, disciplined process to systematically define, evaluate and select systems to meet programmatic needs in an open, objective, and documented manner. Systems Engineering provides a disciplined approach to program management that is open and objective; provides a connection between what we're doing and why; supports budget formulation and defense; and establishes a strong foundation for and supports successful completion of demonstration projects (classical systems engineering is a project management discipline).

Figure 3-1 outlines the systems engineering and analysis approach:

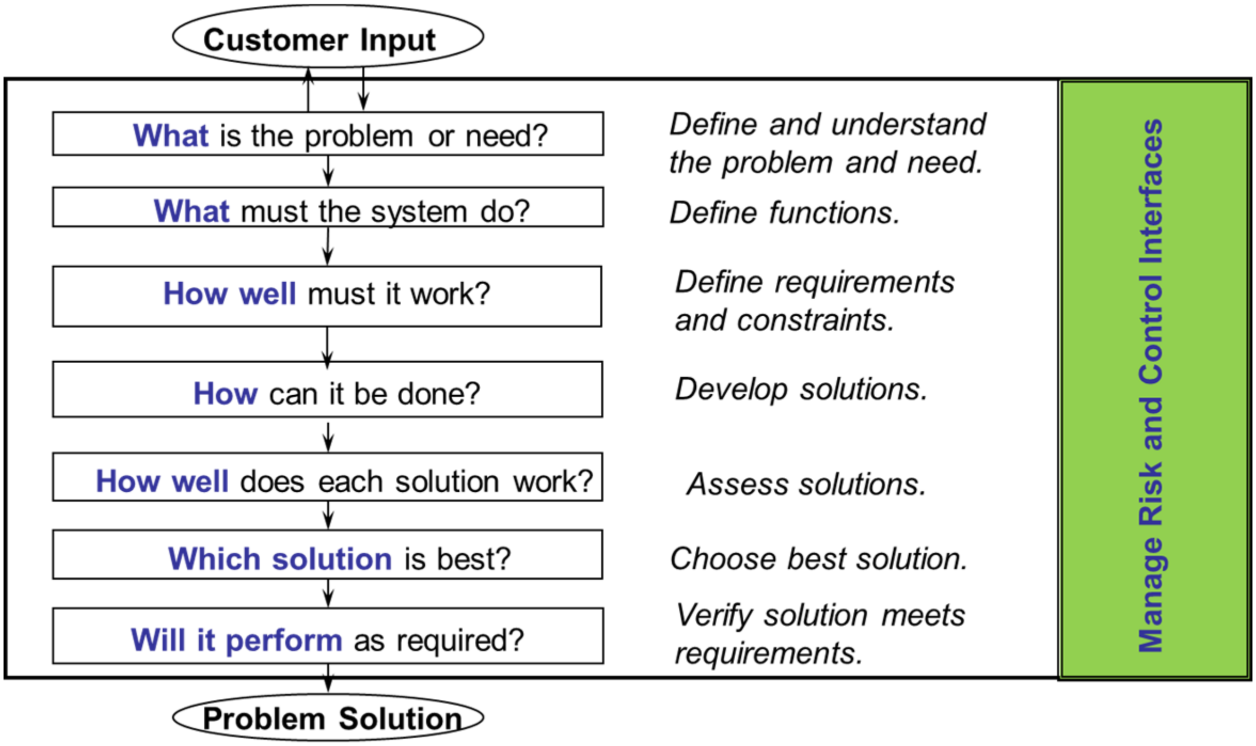

Figure 3-1. DOE NE Systems Engineering Approach

UNF storage and disposal are included in the fuel cycle analyses. DOE formed the Nuclear Fuels Storage and Transportation Planning Project (NFST) to implement the storage and transportations elements of the *Strategy*. The NFST is using this systems engineering approach to guide the selection of potential interim storage and transportation systems to implement the *Strategy*.

There are three distinct phases in a systems engineering approach that is applicable to the DOE ISF development:

1. Concept level, which produces a system concept description (usually described in a concept study)
2. System level, which produces a system description
3. Subsystem/Component level, which produces first a set of subsystem and component product performance descriptions, then a set of corresponding detailed descriptions of the products' characteristics, essential for their production

The result of these efforts is a configuration baseline which gets increasingly more complex through the development progression. Specifically for the ISF design concept stage, DOE will establish a set of defined requirements for the functional aspects of the facilities, which can then be used for the specific design concept requirements. The requirements will be used to establish the systems configuration and configuration management system. The concept must address all activities required to take commercial UNF from its current location and configuration, transport it to a location of interim storage, prepare the fuel as needed and place it in storage, address the subsequent facility storage operations and maintenance, and finally prepare the UNF, HLW, and GTCC for permanent disposition.

National laboratory experts under the direction of DOE have been using this approach to systems engineering and are using multiple tools, including advanced modeling, to evaluate a broad range of UNF management alternatives. The results of the UNF Systems Architecture Evaluation effort to date were summarized in a recent report (Used Fuel Management System Architecture Evaluation, Fiscal Year 2012, FCRD-NFST-2013-000020 Rev.0). The objectives of the ongoing UNF Systems Architecture Evaluation effort are to:

- Provide quantitative information with respect to a broad range of UNF management alternatives and considerations;
- Develop an integrated approach to evaluating storage, transportation and disposal options, with emphasis on flexibility;
- Evaluate impacts of storage choices on UNF storage, handling and disposal options;
- Identify alternative strategies and evaluate with respect to cost and flexibility; and
- Consider a broad range of factors including permanent repository emplacement capability, thermal constraints, repackaging needs, storage and transportation alternatives, and impacts on utility operations.

To date the Systems Architecture Evaluation Team has developed methods, approaches, and tools, and evaluated select UNF disposition scenarios. Specific activities included:

- Developed a framework of potential UNF disposition pathways from at-reactor storage (wet→dry) through interim storage to ultimate disposal;
- Selected disposition pathways for evaluation in FY2012;
- Determined evaluation assumptions, boundary conditions, and system inputs (acceptance rates, start dates);
- Developed Used Fuel Disposition Campaign (UFDC) Transportation Storage Logistics (TSL) simulation tool from legacy computer codes (CALVIN and TOM);
- Conducted UNF logistic evaluations of selected disposition pathways;
- Developed modular design concepts for ISFs and packaging/re-packaging plant; and
- Utilized logistic simulation results and modular design concepts to lay out facilities needed for each case evaluated.

More detailed evaluations will continue in FY 2013 taking into account the requirements of the *Strategy*.

The design concepts report will describe the functions and requirements for the facilities and transportation systems, the existing and projected UNF types and inventories, storage and transportation configurations, systems level options under consideration and analysis of each option, and a system concept for a phased Pilot and larger ISF to implement the *Strategy* based upon design concept reports submitted to DOE by three industry teams. This will provide a working concept from which further design concepts and alternatives analysis can proceed. A work breakdown structure to define the scope of the interim storage and transportation systems concept is described in section 4.

3.1 Functions & Requirements

Starting at the NFST project mission level, the functions and requirements which are both necessary and sufficient to accomplish the mission need to be developed. At each level (system, subsystem and component), sub-functions will be identified based on the functions, requirements and resulting design decisions from the previous level. As the level of detail increases, the sub-functions will be allocated to systems, subsystems and/or components. These functions and sub-functions will form the key input for the NFST's work breakdown structure (WBS).

A function is a statement of what must be done without regard to how to do it (i.e., what has to be done to meet the needs and solve the problem). Once defined, functions provide a structure to understand and manage development of the system options. Functional analysis provides a means to organize complexity, and provides a mechanism to link system needs, identify gaps and issues, and manage risk.

Software tools allow many different aspects to be tied to a function and facilitate management of the process.

Requirements describe "how well" the functions need to perform. Requirements are verifiable by testing, examination, demonstration, or analysis and should be taken from documented sources, which can be business need, law, regulation, policy, physical limits, and/or technology limits.

The mission and system level functions and requirements for the NFST design concepts are listed below. The functions and requirements for subsystems and components will be developed during the conceptual design phase of the project.

3.1.1 Functions

3.1.1.1 *Pilot Interim Storage Facility*

- Receive, handle, and store UNF and GTCC in dry storage canisters from shutdown and stranded reactor sites (listed in Section 3.2 and Appendix A) with priority given to stranded sites (decommissioned reactor; no operating reactor on the site).
- Support storage operations (monitoring, maintenance, security, administration, etc.)

3.1.1.2 *Larger Interim Storage Facility*

- Receive, handle, and store UNF and GTCC from operating reactors and any future shutdown reactors.
- Provide capability to receive, handle, and store bare fuel packaged and shipped directly from storage pools and damaged fuel.
- Provide capability to conduct research and development (R&D) on UNF, canister, and storage cask performance in the interim storage environment.
- Prepare UNF and GTCC for transport to permanent repository, including packaging in final disposal canisters, if required.
- Provide receipt, handling, and storage of government-owned UNF and HLW.
- Support storage operations (monitoring, maintenance, security, administration, etc.)
- Assumes the larger ISF will be co-located with Pilot. Otherwise some of the functions at the Pilot will need to be replicated at the larger ISF.

3.1.1.3 *Transportation Systems*

- Safely package and transport all UNF and other waste forms from existing locations to either the Pilot or larger ISF.
- Safely package and transport all UNF and other waste forms from either the Pilot or larger ISF to the permanent repository.
- Provide certified casks, rolling stock, and support equipment for safe transport of UNF and other waste forms.
- Provide transportation planning, training of first responders, and other similar tasks.
- Design, acquire, test, and obtain NRC/DOT certification and any other required certifications or approvals of transportation equipment (casks, railcars, etc.).
- Transportation infrastructure improvements needed from the current storage locations to the interim storage facilities.

3.1.2 Requirements

3.1.2.1 *Pilot Interim Storage Facility*

- Design to focus on accepting UNF and GTCC from shutdown and stranded reactor sites in dry storage canisters.
- Design to be generic, within NWPA regulations.
- Capacity in the range of 5,000 to 10,000 metric ton heavy metal (MTHM). (See also Section 3.2.1.1)
- Design receipt rate to accept and store all UNF and GTCC from current shutdown reactor sites within five years (ramping up to 1500 MTHM/year).
- Capable of receiving, handling, and storing all dry storage canisters currently licensed for storage and transportation in the existing canisters without opening the canisters.
- Able to obtain the necessary environmental, state and local permits.
- Licensed by the NRC meeting 10CFR72 requirements.
- Facility must meet security requirements of 10CFR73.
- Site to be selected using a consent-based process with the Department working with a host community, applicable tribal and state governments, and Congress.
- Facility built will be owned by DOE and operated by DOE or its contractor(s). (Note: The *Strategy* discussed the creation of a new entity (MDO) to take over management of nuclear waste from DOE. Unless and until such entity is directed by Congress, DOE will be fully responsible for any facilities developed within this project.)
- The Pilot will be operational by 2021.
- Operational life will be the time to receive and hold UNF until a repository is ready to receive shipments, including the time to ship all stored UNF to a repository. Design life is 100 years.
- Flexible design to allow for future expansion.
- The Pilot shall receive all used fuel and GTCC waste from currently decommissioned shutdown sites by the time the larger interim storage facility is ready to receive fuel (expected to be 5 years). Assumes all UNF is in dry storage casks.

3.1.2.2 *Larger Interim Storage Facility*

- One or more facilities will be built. The facility (ies) shall have sufficient capacity for flexibility (nominally 70,000 MTHM) (See also Section 3.2.1.2) to allow for acceptance of enough UNF to reduce the expected government financial liability. The larger ISF will be built in stages.
- The larger ISF annual acceptance rate should be sufficient to handle the operating plant UNF generation rate (approximately 2,000 MTHM per year) and gradually work off the current inventory. Current planning assumes an acceptance rate of 3,000 MTHM per year.
- The larger ISF will receive, handle and repackage damaged fuel and bare used fuel (used fuel not in storage canisters).
- The larger ISF may be required to accept government-owned UNF and HLW in addition to UNF from commercial reactors.
- Able to obtain the necessary environmental, state and local permits.
- Flexible design using modular concepts to allow for future expansion.
- Facility must meet security requirements of 10CFR73.
- Licensed by the Nuclear Regulatory Commission (NRC) meeting 10CFR72 requirements
- Operational life will be the time to receive and hold UNF until a repository is ready to receive shipments, including the time to ship all stored UNF to a repository. Design life is 100 years.
- Design will include a “laboratory” to periodically examine some fuel in storage to ensure the long term stability of the materials and performance, especially high burnup fuels. The laboratory may also have the capability to develop and demonstrate any repackaging techniques required to

support the repository operations. Other R&D associated with the repository will be performed elsewhere.

- The design may include a canister repackaging facility (CRF) capable of removing individual assemblies and packaging them in disposal canisters suitable for transport to the repository. Since the repository requirements are not currently known the design will investigate the impact of multiple disposal canister sizes.
- The larger ISF will be operational by 2025.

3.1.2.3 *Transportation Systems*

- The transportation system design shall be sufficient to safely package and transport all UNF and other waste forms from existing locations to either the Pilot or larger ISF at the design acceptance rates for each facility.
- Transportation of UNF and other waste forms will be under NRC/DOT requirements and regulations.
- Transportation equipment will meet NRC safety, safeguards, and security rules and regulations. Railcars will be compliant with American Association of Railroads (AAR) standard S-2043.
- Transportation mode will be principally by rail; heavy haul truck and barge transportation shall be used only when necessary to transfer the fuel from the existing location to a rail intermodal location.
- Transportation outreach and communications, route analysis, and emergency response planning shall be consistent with existing NWPA requirements.
- The project scope includes infrastructure and fuel handling improvements needed at the reactor or former reactor sites to permit removal of the fuel and/or fuel casks.

3.2 Used Nuclear Fuels and HLW Inventory

Commercial NPPs have operated in the U. S. since about 1960. There are currently 104 NPPs licensed to operate. (Four of these either ceased power generation or ceased efforts to restart in 2013, these NPPS are not included in the shutdown or stranded reactor analysis in this report). UNF from these operating plants is currently stored on site in pools or dry storage casks with disposal in a geologic repository envisioned in a once-thru fuel cycle. In addition, UNF from four shutdown reactors is stored on sites co-located with operating reactors (Shutdown Sites). UNF is also stored on 9 sites (from 10 reactors) without any operating reactors (Stranded Sites). Some commercial fuel assemblies have been transferred to the Idaho National Laboratory (INL) with ownership transferred to DOE. The General Electric facility at Morris, Illinois is currently the only NRC licensed storage facility in operation that is not co-located at a reactor site. Section 3.2.1 describes these radioactive materials. Appendix A provides additional details on these materials.

3.2.1 Commercial UNF Inventory

Commercial UNF includes irradiated fuel discharged from pressurized water reactors (PWRs) and boiling water reactors (BWRs). The fuel used in these reactors consists of uranium dioxide pellets encased in zirconium alloy (Zircaloy) or stainless steel rods. The fuel assemblies vary in physical configuration, depending upon reactor type and manufacturer.

The commercial inventory for this study is collected from DOE repository licensing efforts and fuel discharge projections based on Electric Power Research Institute (EPRI) in a 2005 study. For this NFST study, the “no burn-up increase case” was selected since a slightly larger projection for the mass of heavy metal forecast. Table 3-1 summarizes the actual fuel generated through December, 2002, the estimated quantity generated between December, 2002 and December, 2012, and the total estimated quantity forecast for the no generation scenario. This total scenario quantity is not all planned to be stored in either the pilot interim storage facility or the larger interim storage facility. This total scenario quantity is used in logistical modeling and planning development. Table 3-1 is expanded to provide a reactor by reactor UNF discharge projection in Appendix A, Table A-1. Appendix A provides additional information on the development of this inventory.

Table 3-1. Nuclear Potential Inventory for a No Replacement Nuclear Power Plant Scenario.

	Fuel Discharged Prior to 12/31/2002		Forecast Discharges 1/1/03 to 12/31/12		Forecast Discharges 1/1/13 to 12/31/55		Total Projected Discharged Fuel	
	Assemblies	Initial Uranium (MT)	Assemblies	Initial Uranium (MT)	Assemblies	Initial Uranium (MT)	Assemblies	Initial Uranium (MT)
At 104 Licensed Reactor Sites	148,225	42,648	77.450	22,401	242,475	69,983	468,150	135,033
Transferred to INL	225	70						
Away from Reactor Wet Storage	3.217	674						
Shutdown Reactors on Sites With Operating Reactors	4,328	793						
Fuel on Stranded Sites	7,651	2,813						
Total	**163,646**	**46.999**	**77.450**	**22,401**	**242,475**	**69,983**	**468,571**	**139,384**

3.2.1.1 *Pilot Interim Storage Inventory*

The Pilot will focus on the UNF at stranded and shutdown sites and any additional sites or materials based on feedback from volunteer host organizations. Table 3-2 summarizes the current storage systems used at the stranded and shutdown sites. In addition three sites are assumed to be shutdown and become stranded sites between now and 2021. The total site inventory for these shutdown and stranded sites includes 11 GTCC casks and 502 fuel casks, 18,996 assemblies and contains approximately 5,441 MTU. Appendix A provides additional tables showing the fuel assemblies and MTU for each stranded and shutdown plan. The Appendix also provides a listing of the storage systems used at each of the stranded and shutdown plants.

Table 3-2. Stranded and Shutdown Plants Dry Storage Systems.

Type of Cask System	Number of Current Stranded Site	Number of Future Stranded Site	Number of Shutdown Plants	Number of Canisters Fuel/GTCC
Transportable Storage Casks	1			5/1
Transportable Storage Casks			1[b]	4/0
Dual –Purpose Dry Storage Casks	8[a]			243/10
Dual –Purpose Dry Storage Casks		3		160/?
Dual –Purpose Dry Storage Casks			4[b]	90/?
Totals	**9**	**3**	**4**	**502/11+?**

[a] One site has 2 shutdown reactors, counted as a single plant site;

[b] One site had two different storage systems, counted in each category.

3.2.1.2 *Larger Interim Storage Facility Inventory*

The *Strategy* indicated a larger ISF (greater than 20,000 MT) is planned to become operational in 2025 and is to receive fuel at a rate greater than is currently generated at the operating plants. The discharge rate varies annually from about 2,000 to 2,400 MTU with an average of about 2,100 MTU. For this study the fuel acceptance rate has been selected as 3,000 MTU per year. The *Strategy* indicated that the repository would become operational in 2048. Therefore the larger ISF will operate approximately 23 years before shipments to the repository begin. The larger ISF storage capacity is therefore up to 69,000 MTU (rounded to ~ 70,000 MT) or approximately 50% of the total scenario inventory in Table 3-1.

UNF is initially stored at the nuclear plants in water filled pools. Most of these pools were not designed for long term storage and many facilities have run out of capacity to store all of the UNF in their pools. At these facilities, above ground dry storage systems are utilized to store the UNF. As more facilities run out of pool storage the amount of dry storage is increasing. Through February of 2013, 1720 dry storage casks have been loaded containing 68,143 assemblies of UNF. NEI estimates by 2020 over 30,000 MTU in about 2,600 casks will be in dry storage. [Store Fuel, 2011] Appendix A, Table A-10 provides the current status of dry storage.

To date UNF has been discharged with burn-ups ranging from less than 20 gigawatt-days per metric ton (GWd/MT) and projected to approach 60 GWd/MT. Appendix B, Tables B-1 through B-4 present the radionuclide decay heat for the 40 and 60 GWd/MT burn-up PWR and 30 and 50 GWd/MT BWR as representative fuels. The figures and tables provide the total decay heat and isotopic groups with similar isotopic parameters. Discharged fuel compositions (in g/MT) for representative fuels are available in Appendix C of the UFDC Inventory report.

3.2.2 Government-owned UNF and HLW

The larger ISF may also store government-owned UNF and HLW. This UNF and HLW include materials stored at DOE Hanford Site, Idaho National Laboratory, and DOE Savannah River Site. Appendix C provides details of these materials. A brief summary of the types of materials are as follows:

- DOE Used Fuel 2,500 MTHM from commercial, government reactors, DOE-supplied fuel for research reactors
- Navy Used Fuel projected at 65 MTHM by 2035

- DOE HLW from fuel processing in liquid and dry waste forms, including glass logs in canisters.

3.3 System-level and Facility-level Options and Systems Analysis

This section reflects system-level and facility-level options for consideration as part of an overall waste management system that is intended to be flexible and adaptable to various logistics, construction and operational conditions.

3.3.1 System-Level Options

Integrated trade studies with both system-level and facility-level inputs are necessary to set the configuration baseline at the end of the conceptual design phase. This section outlines a partial list of concepts for the Pilot and larger ISF which are recommended for exploration in the conceptual design period. While options will be carried until fully evaluated, the inclusion of these options is not intended to predispose the alternative(s) selected as part of the design and siting process.

3.3.1.1 *Separate or Multiple Interim Storage Facilities and Locations*

One or more larger interim storage facilities will be developed, which may be

- an extension of the Pilot (co-located),
- sited away from the Pilot, or
- at more than one location.

Selection will be based on host communities' inputs, Administration policy and Congressional guidance. Site(s) for an interim storage facility or facilities will be developed using a consent-based approach with DOE working with a host community, applicable tribal and state governments, and Congress. These alternatives may be adjusted as determined by the siting process.

3.3.1.2 *Loading, Shipping and Storage Canisters*

For UNF in utility fuel pools loading shipment and storage configurations could include:

- dry storage canisters and over packs
- bare fuel canisters
- universal transport and storage over packs

3.3.1.3 *Storage Facility Sizing*

- Current expected inventory with no new reactors
- Expanded inventory for different new reactor scenarios
- Uncertainty regarding the larger ISF, or additional early shutdown scenarios and repository start dates
- Full off-load capacity (assumes larger ISF used for storage prior to shipping to repository)
- All UNF passes through the ISF to the repository or bypasses ISF once repository ready to accept UNF.

3.3.1.4 *Packaging for Final Disposal*

- Disposal canister package size (e.g. 4/9, 12/22, or 21/44 PWR/BWR assemblies each)
- Located at the repository, and/or
- Located at the larger ISF,

3.3.1.5 *Acceptance Queue*

- Oldest Fuel First (OFF) from reactor sites
- Youngest Fuel First (YFF)

- Pooled Fuel First
- Dry Stored Fuel First
- Other acceptance scenarios to be determined

3.3.2 Facility-Level Options

3.3.2.1 *Pilot Interim Storage Facility*

A Pilot would have limited capacity capable to accept commercial used nuclear fuel and GTCC stored in dry storage casks. The Pilot would focus on serving shutdown and stranded reactor sites.

Facility-Level Options to consider for the Pilot IFS include:

- Dry storage systems (Section 3.3.2.3 and Section 3.3.2.6).
- Transportation systems (current designs (baseline) or universal design(s)).
- Provision for a fuel remediation facility (Section 3.3.2.7)
- Provision of support laboratory capabilities. (see section 3.3.2.5)
- Provision to handle selected government-owned HLW and/or UNF.
- Receipt of fuel from operating reactors in existing dry storage canisters.
- Other capabilities requested by the host community.

3.3.2.2 *Larger Interim Storage Facility*

Facility-level Options for the Larger ISF include:

- The dry storage systems to be deployed will be investigated. The same alternatives will be investigated for the DSC as for the Pilot. (Section 3.3.2.3)
- The larger ISF will receive bare and damaged fuel in re-useable transportation casks. The storage method for bare fuel will be investigated Potential systems include: pool storage (both high and standard racks), bare fuel vaults, and loading the fuel into DSC for storage(Section 3.3.2.5).. The receipt rate will need to be investigated as part of the systems level analysis but may range as high as half the total acceptance rate. (Section 3.3.2.8)
- A Canister Repackaging Facility will have the capability to open all the DSC and package the used fuel and other materials into disposal containers. (Section 3.3.2.9)
- Dry storage vaults (bare fuel (Section 3.3.2.), fuel in damaged fuel canisters, or dry canister) for fuel storage until repackaging for transportation to disposal site.
- Complete laboratory capability for testing and examination of stored fuel and fuel packages. (Section 3.3.2.6)
- Fabrication facilities for metal canisters, casks, and other equipment. (Section 3.3.2.9)
- Other capabilities requested by the host community.

3.3.2.3 *Storage Systems Used for Dry Storage Canisters*

The storage systems to be deployed will be investigated. Potential canister storage systems include:

- The currently deployed above grade vertical and horizontal storage systems associated with each DSC design (current baseline for this report),
- DSC standardized storage casks (Section 3.3.2.4)
- DSC below grade storage, (The primary feature of this option is the use of DSCs that are a component of the typical used nuclear fuel dry cask storage systems employed at most commercial power reactor sites. DSCs would be placed into a below ground storage module consisting of a below-grade cylindrical vertical storage cavity and closure lid that provides radiation shielding and structural protection during storage.)Vault System above and/or below grade. (The primary feature of this option is below grade vault storage designed as a hardened

reinforced concrete with an above grade structure providing an operating area for canister placement, storage, and removal via floor plugs. Natural ventilation would cool the UNF during storage. The storage spaces would be designed to accept all currently licensed canister configurations. Above grade vault would be similar to below grade alternatives.)

3.3.2.4 *Dry Storage Canister - Universal Storage Over pack*

Another alternative to using the various storage systems is to use a single type of "universal" or standardized storage over pack (cask) that could house any dry storage canister. The purpose for this would be to provide consistency for storage, DPC loading operations and over pack construction, maintenance and monitoring.

Currently the concept is to store each canister within its licensed storage over pack (cask) or module. Using the storage over pack for which the canister is designed alleviates the need to design and license new storage alternatives. But it also means that the larger ISF has to be designed to process and store several different types of storage over over packpacks; the cask handling building (CHB) transfer cells have to accommodate various sized over packs; the Vertical Cask Transporters (VCTs) have to be able to transport different over packs with unique lifting arrangements; and the concrete pads have to support each over pack and be designed to meet their Certificate of Compliance (CoC) requirements.

Use of a single universal over pack could reduce the design and operation variables and permit a more simplified process that is consistent and therefore potentially safer.

3.3.2.5 *Storage Systems Used for Bare Fuel Received in Transportation Overpacks*

The larger ISF will receive bare fuel, most likely in re-useable shipping casks. The storage method for bare fuel will be investigated. Potential systems include:

- pool storage (both high density and standard racks),
- bare fuel vaults (The primary feature of this option is below grade vault storage designed as a hardened reinforced concrete structure with an above grade structure providing an operating area for UNF sleeve placement, storage, and removal via floor plugs. Natural ventilation would cool the UNF during storage.)
- loading the fuel into DSCs for storage as described above.

3.3.2.6 *Laboratory Facility*

A Laboratory facility would support the primary missions for UNF and GTCC materials storage. In addition, this facility could also be used in support of fuel performance activities for operating reactors. A hot cell facility would provide for the unloading and opening of select canisters, unloading of UNF assemblies, and analyses of the UNF and select canisters.

Key features of the Laboratory facility may include:

- A pool to allow for the non-destructive examination (wet) of the UNF prior to transfer of the UNF to another licensed canister
- An interim storage pad for performing accelerated aging tests on cask systems
- A hot cell to allow for the destructive and non-destructive examination (dry) of UNF from a canister or cask
- Laboratories capable of performing non-destructive examinations and post-irradiation examinations
- Computational facilities to model performance of UNF and cask system components
- Demonstration capability of repackaging for disposal canisters.

The report includes estimated costs for a typical laboratory facility, separately identified.

3.3.2.7 *Fuel Remediation Facility*

The Fuel Remediation Facility would be used for

- repair of UNF that is
    - suspected to be damaged during transport or
    - develops indications of damage or failure during storage
- removing UNF from DSCs for inspections and R&D purposes.
- packaging of small quantities of bare fuel received from utilities not in dry storage canisters,

The final sizing of the pool and number of casks requiring simultaneous handling will be part of systems and alternatives analyses. The pool would also have a fuel repair/canning area and provide sufficient space for temporary storage of one DSC's complement of UNF. A small remediation/bare fuel loading pool is part of the larger ISF baseline for this report. The final sizing of the pool and number of casks requiring simultaneous handling will be part of systems and alternatives analyses.

The laboratory, canister repackaging and fuel remediation facilities may all contain a storage pool of various capacities and are expected to deploy on different schedules within the life of the larger ISF. Consideration will be given to a combined facility concept as part of follow-on design activities and alternatives analyses. The Canister Repackaging Facility may also contain a pool for UNF handling.

3.3.2.8 *Bare Fuel Receipt Facility*

The bare fuel receipt facility provides a production scale capability to receive and process bare fuel transportation casks. The fuel storage method is being investigated but for this study a pool is assumed to load dry storage containers. This facility may be a "stand-alone" facility or combined with the fuel remediation facility and/or laboratory facility. It may be built an additional stage with these other facilities.

3.3.2.9 *Canister Repackaging Facility*

This facility will have the capability to open all the DSC and package the fuel into disposal containers. Since the repository requirements are not determined design alternatives will include various disposal container sizes including: 4PWR/9BWR assemblies, 12PWR/22BWR, and 21PWR/44BWR assemblies. Likewise the fuel blending capability needs to meet any final repository disposal canister thermal limits. The facility design will examine alternatives for lag storage. The facility will be capable of loading these disposal containers in transportation over packs (casks) and loading onto rail cars for transfer to the repository. This repackaging may be done in a wet pool or hot cell. This facility is not expected to be operational until approximately 2 years prior to the start of the repository emplacement operations begin, design concepts should be modular to allow for a phased deployment of this capability. This capability may be at the larger ISF and/or the repository as determined by system alternative analyses. The Repackaging Facility is not part of the larger ISF baseline capability for this report, although some pre-conceptual design concepts and cost data can be found in Nutt 2012.

3.3.2.10 *Metal Component Fabrication Facility*

The concept of the Metal Component Fabrication Facility is to provide a non-radiological area with a purpose of manufacturing various types of metallic equipment required to transport and store the UNF. While these types of facilities are currently located at vendor shops, it may be cost-effective to have DOE (or the host community) develop these types of facilities. This facility is not part of the baseline for this report.

3.3.3 Alternatives Analysis

Alternatives analysis is one of the initial activities performed in the conceptual design phase of a project to provide guidance to the conceptual design activities. The alternatives analysis may be presented to the decision makers along with a conceptual design (or designs) or may be used to allow decision makers to select one or more preferred alternatives for completion of conceptual design. Figure 3-2 depicts a typical alternatives analysis done as part of a pre-conceptual design process. The alternatives analysis process includes preparing evaluation criteria using both requirements and desirable attributes (cost, dose to public and workers, security considerations, etc.). Initial screening of alternatives is performed using the required functions and design requirements. For the remaining alternatives, pros and cons (advantages and disadvantages) and relative risks are then determined. Scoring is conducted and the preferred alternative or alternatives are recommended to the decision maker(s). The conceptual design is then completed for the selected alternative(s).

The conceptual design process is an exploration of concepts, specifications and designs for meeting the mission needs, and the development of alternatives that are technically viable, affordable and sustainable. The objective of the conceptual design process is to ensure that a solution or alternatives are not only responsive to an approved need, but also technically achievable, affordable and will provide the best value to the Department. The recommended alternative should provide the essential functions and capabilities at an optimum life-cycle cost, consistent with required cost, scope, schedule, performance, and risk considerations.

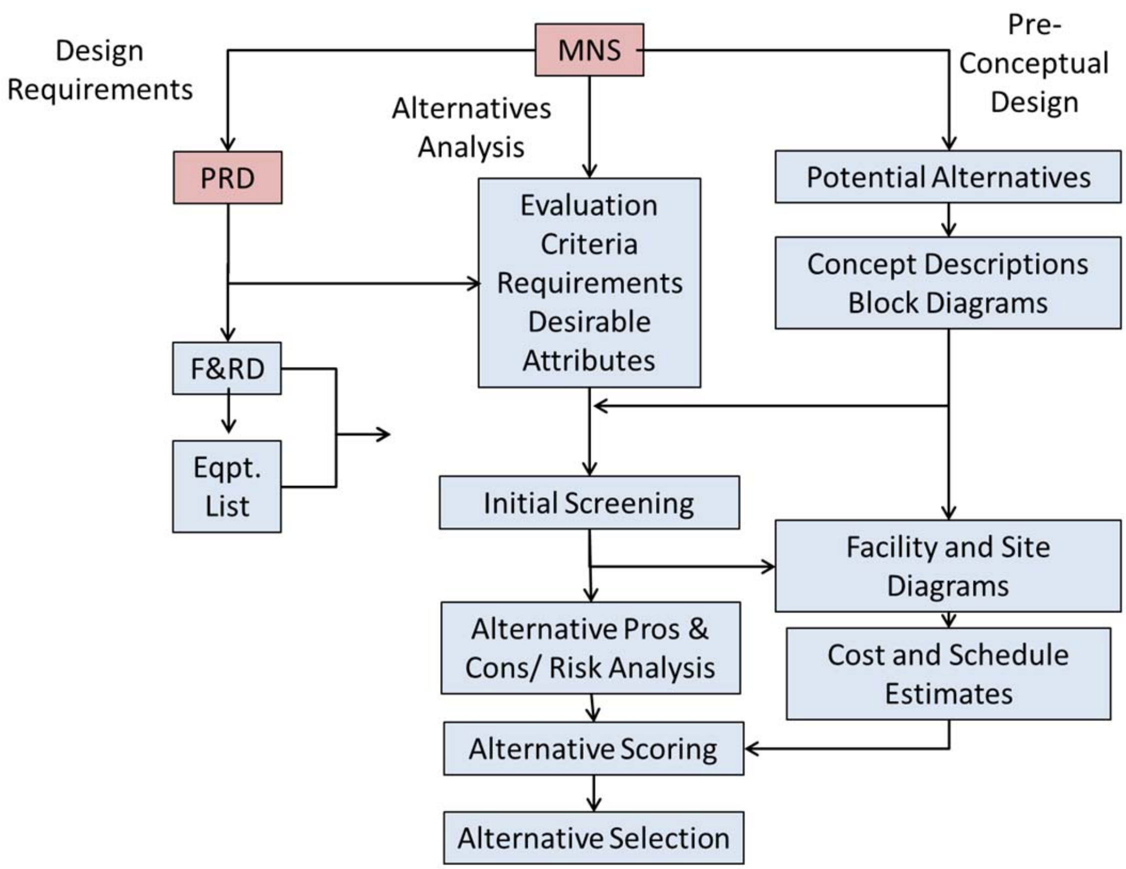

Figure 3-2. Example Alternatives Analysis Process.

3.4 Baseline Project Concept

For this project concept report, DOE is using the following concept to identify an approach and provide cost and schedule estimates. This approach is not a DOE decision. Prior to any decisions, the host community will be integral in the concept selection process and the system level alternatives analysis described above.

A system configuration meeting the minimum requirements of Section 3.1 is identified for this report, namely:

- A Pilot sized between 5,000 and 10,000 MTHM with a maximum receipt rate of 1,500 MTHM per year handling UNF and GTCC from stranded and shutdown sites, built in sequential stages as described in Section 3.4.1
- An larger ISF sized for nominally 70,000 MTHM handling commercial and government-owned UNF, GTCC, and HLW of all types currently known, with a Laboratory Facility and wet pool for handling bare and damaged fuel and loading into dry storage canisters (Fuel Remediation Facility and Bare Fuel Receipt Facility). The larger ISF would be co-located with the Pilot. The larger ISF would initially be built for 20,000 MHTH (size used for the larger ISF cost estimate) with a receipt rate of 3,000 MTHM per year as described in Section 3.4.2.
- Transportation systems for rail, heavy haul truck (and barge, if needed) for the used fuel and other materials identified for the Pilot and larger ISF.

3.4.1 Pilot Sequential Development

Pilot Operation: The Pilot provides facilities and infrastructure needed to transfer DPCs from transportation casks into dry storage casks. Priority would be given to DPCs from stranded sites, followed by DPCs from the shutdown plants. The specific priority has not been determined and will be the subject of systems wide analysis. Consideration will be given to multiple scenarios including:

- Early receipt of Transportable Storage Canisters (TSCs). This early capability to start consolidating UNF would require only a limited amount of infrastructure for receipt and transfer of TSCs to a storage pad. TSCs are selected for initial receipt since they require the minimum equipment and interfaces for transportation and storage,
- Completely removing both fuel and GTCC waste from a given site in a single loading campaign to eliminate future financial liability,.
- and others.

This Pilot concept includes building and operating a Canister Handling Building, Canister Transfer Facility, a Storage Cask Fabrication Facility, an Administration Building, Visitors Center, and expanded storage capacity. Some of these facilities may be included in the initial stage. The capacity is estimated at 5,000 MTHM at an average receipt rate of 1,000 MTHM/year with a maximum of 1,500 MHTH/year.

Pilot Expanded: The Pilot may provide expanded storage capability such that additional UNF could be handled from other shutdown and/or operating reactors that have DPCs (and TSCs) available to ship. This expanded capacity is estimated at up to 10,000 MTHM.

3.4.2 Larger ISF Sequential Development

Larger ISF Dry Storage: A larger ISF, assumed to be co-located with the Pilot and/or with a geologic repository, would provide the needed flexibility in the waste management system and allow for important near-term progress in implementing the federal commitment. The larger facility could have a nominal capacity of 70,000 MTHM. This larger facility would initially continue to handle dry storage systems If not co-located with the Pilot, the larger ISF will need all the support facilities and infrastructure described for the Pilot, sufficiently sized to handle larger ISF processing rates. If co-located with Pilot, the facilities and infrastructure originally developed for the Pilot may require expansion to provide the increased capacity.

Larger ISF Full Capability: The fully capable larger ISF would provide the facilities and infrastructure needed to handle bare fuel (fuel not packed in storage canisters) and damaged fuel. This fully capable facility would handle all other types of UNF, HLW, and GTCC (commercial and government-owned). The storage capacity required would grow to the full size, nominally 70,000 MTHM, or greater, depending on availability of the repository to receive shipments. The method to store and handle bare fuel will be determined by systems alternative analyses. For this report, we have assumed bare fuel will be packaged into canisters (in the Bare Fuel Receipt Facility) and stored in above grade dry storage casks. Other alternatives are described in the previous section, 3.3.

4. Work Breakdown Structure

Appendix D provides the Work Breakdown Structure (WBS) and the WBS explanation descriptions as have been designed to capture and define the total scope of work for the Pilot and larger ISF. The WBS reflects elements of the three preliminary design concepts submitted for the project and breaks down each portion of the scope into mutually exclusive elements of the project. This WBS is product-oriented and captures all the elements of design, construction, and commissioning required for each segment of the project. A typical breakdown for these elements is at Level 5, as shown in the first WBS element (1.01.01.01.01) in Appendix D.

The intent of this WBS is to create a single document that can be used to plan, organize and report project progress across each stage of the project. While this iteration of the WBS may contain elements that are not in the final project plan or elements that will need to ultimately be modified to fit the final project plan, the attached WBS is a framework upon which these changes can be readily made.

Following the generally accepted practice for the construction of a WBS, the WBS has been built to distinctly identify each element of the project regardless of subcontractor, element type or construction sequence. The numbering convention for the WBS begins at the project level and then organizes each output element hierarchically.

The WBS is built so that it captures each of the major elements of the proposals submitted for the larger ISF. Each element is mutually exclusive to ensure that there is clarity around the expectations for each element of output. While there may be some changes to the specific sub-elements captured in each major element, the WBS makes clear what the expectations are for each section. For example, it can be discussed whether the perimeter fence falls under the Security element or the Siting element, but the WBS makes it clear that the perimeter fence does exist as a portion of the scope of work. We have broken out the major elements of the WBS into various sections to honor the stages of the construction of the larger ISF, e.g. the expansion of the Waste Management Facility is a separate element from the initial construction of the Facility.

5. Phased Design Concepts

As stated in Section 3.1, the Pilot and larger ISF and transportation systems will need to perform specific functions and meet certain requirements in order to carry out the mission of the NFST project. Based on review of the system-level options and analyses in the referenced reports, DOE has developed a working concept for the NFST system from which further conceptual design can proceed as described in Section 3.4. Figure 5-1 depicts the process flow for the stages of ISF (PILOT plus ISF) development.

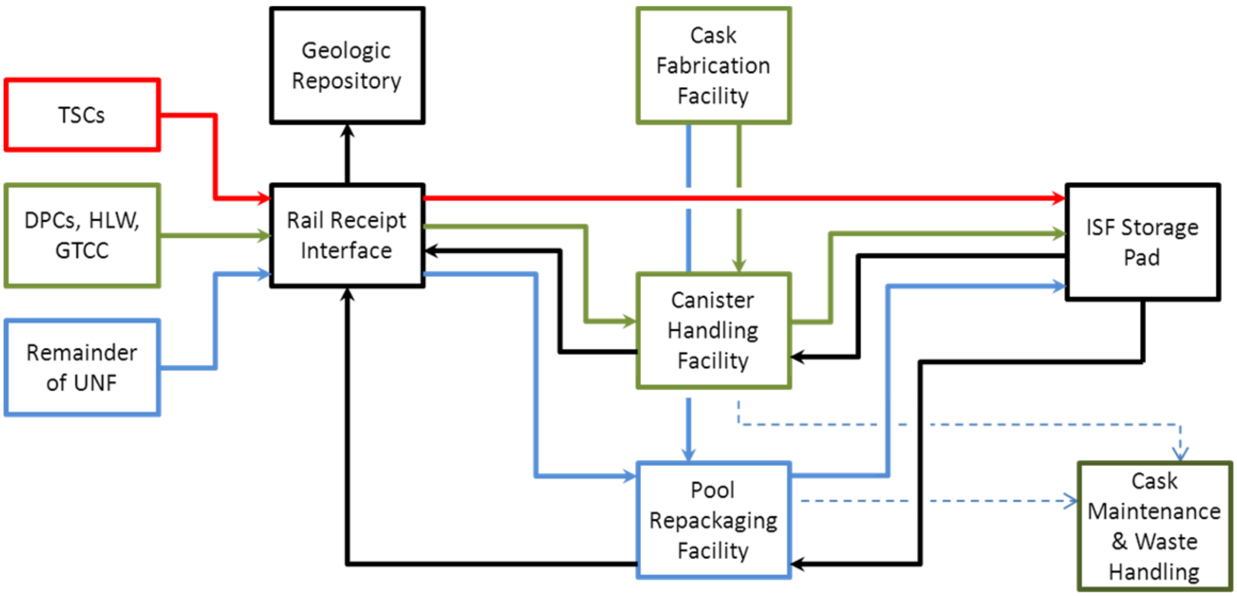

Figure 5-1. Process Flow Diagram showing Interim Storage Facilities Stages of Construction and Operation.

The next sections describe the Pilot and larger ISF, and transportation system in more detail.

5.1 Pilot Interim Storage Facility

As a first step in the development of an interim storage capability, DOE would acquire the capability to receive used nuclear fuel from stranded and shutdown plant sites, as stated in the *Strategy*. This first step, or Pilot, would be sized to handle current and expected used fuel and GTCC from these shutdown and stranded plants at the time of Pilot operation, or approximately 5000 MTHM of UNF and GTCC waste stored in dry storage casks. Section 3.2 discussed the source sites and types of dry storage systems in use at these sites. The initial capability of the Pilot could be also expanded to accept up to 10,000 MTHM of used fuel until the larger ISF is available. Section 6 discusses design considerations for the facility.

5.1.1 Pilot Capabilities

The Pilot provides facilities and infrastructure needed to transfer Dual Purpose Canisters (DPCs) from transportation casks into dry storage casks and handle TSCs. The Cask Handling Building (CHB) would be included in the fully operational stage to allow unloading of transport casks and loading into vertical or horizontal storage casks. A Storage Cask Fabrication Building (SCFB) would also be constructed to fabricate the concrete storage casks or modules on site.

The expanded capacity stage would handle additional DPCs from the remaining shutdown sites and possibly operating plants if desired or required. These could be received and stored at the Pilot since the infrastructure would already be in place, except for additional storage pads.

5.1.2 Principal Features of the Pilot

The principal features of the Pilot consists of a cask handling building, storage pads, rail yards, security building, protected area (PA), radiation area (RA), balance-of-plant (BOP) utilities and structures, office building, and visitor’s center. Balance of plant utilities and structures include electrical switch gear and transformers, chillers, mechanical cooling towers, a fire suppression system, underground utilities, meteorological tower, security equipment, yard lighting, a concrete batch plant, drainage structures and systems, etc.

Figures 5-2 and 5-3 show the expansion of the Pilot and progression of additional facilities and infrastructure.

5.1.2.1 *Cask Handling Building*

The CHB would provide the capability to accommodate the transfer of transport casks from railcars to transfer trailers (horizontal-type dry fuel storage systems (DFSSs)) and the transfer of canisters from transport casks to storage overpacks. The building will also provide physical protection of the canisters and radiation shielding to the workers.

The CHB would be a reinforced concrete structure with thick walls to protect all UNF casks, canisters and over packs, and cask handling equipment housed within the building from the effects of earthquakes, tornado winds, tornado-generated missiles, fire, and explosions in accordance with 10 CFR 72.122.

Figure 5-2 illustrates how the Pilot would expand to include the capability to receive transport casks and store UNF and GTCC in DPCs with the receipt rate ramping up to 1,500 MTHM per year.

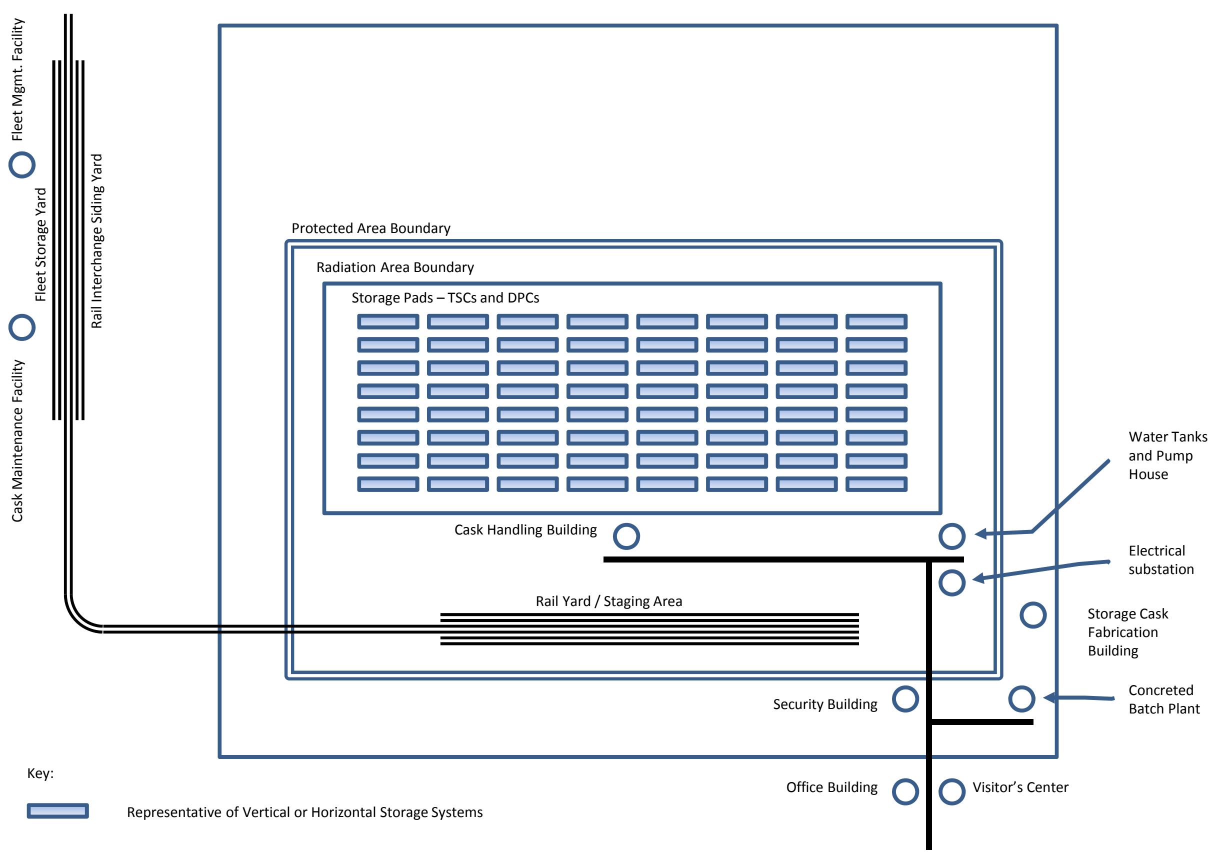

Figure 5-2. Pilot Interim Storage Facility.

5.1.2.2 *Storage Pads*

The Pilot would have reinforced concrete storage pads to support all of the vertical storage over packs and horizontal storage modules that are loaded with UNF canisters. The storage pads would be designed to ensure adequate safety and to mitigate the effects of site environmental conditions, natural phenomena, and accidents in accordance with 10 CFR Part 72.

The size of the storage pads depends on the type of storage system (horizontal or vertical), the number of storage units to support, and the shape and limitations of the physical space where the pads are to be placed. Horizontal storage systems would use a concrete module with a rectangular footprint, while vertical storage systems would use a concrete or steel cylinder-shaped over pack that stands on end.

As the Pilot facility grows, it would continue to use reinforced concrete storage pads to support the Horizontal Storage Modules (HSM) and Vertical Storage Casks (VSC) that are loaded with UNF and GTCC canisters from stranded and shutdown reactors. A capacity of approximately 5,000 – 10,000 MTHM is expected when fully operational.

5.1.2.3 *Rail Yards*

On-site and off-site rail systems will be constructed along with a Fleet Management Site to support the fleet of rolling stock being fabricated during initial construction. Off-site rail improvements may include a spur from the nearest railhead to the site, or upgrades to an existing rail spur. The Fleet Management Site will consist of a Fleet Management Facility (FMF), a Cask Maintenance Facility (CMF), Rail Car Maintenance Facility, and outdoor storage areas for rolling stock, truck cask trailers, and transport casks. During pilot operations railcar maintenance is assumed to contracted services provided by others.

5.1.2.4 *Security Building*

A security building would provide access to the PA and house security force personnel. The security building would also house security records and security equipment, as well as communications and electrical equipment required for the operation of security systems. A backup emergency generator for security equipment would be located further inside the RA at a location central to the security system's needs.

5.1.2.5 *Protected Area*

The purpose of the PA is to prevent unauthorized persons from entering the facility where UNF is processed and stored in accordance with 10 CFR Part 73. The PA provides physical protection of UNF and consists of an area large enough to encompass the site rail yards, CHB, and storage pads. The PA would expand in size as required to accommodate new storage pads. See Section 6.4, Security, for further discussion.

5.1.2.6 *Radiation Area*

The purpose of the RA is to limit personnel movements in the vicinity of the Vertical Storage Casks (VSCs) and Horizontal Storage Module (HSMs) that house the UNF and GTCC waste. The RA boundary would be designed to encompass areas with a radiation dose rate of 5 mrem/hr or more in accordance with 10 CFR 20.1902 and 10 CFR 20.1003. The UNF storage pads and a portion of the CHB, as well as areas of major cask handling activities, would be located within the RA. The RA would expand in size as the number of storage pads increases to accommodate more UNF. The boundary of the RA would consist of a chain-link fence with gates requiring authorized access.

5.1.2.7 *Balance of Plant*

Balance of plant equipment and systems includes fire protection, potable water, sanitary drains, electrical power and distribution, diesel fueling station, and communications. A concrete batch plant and concrete trucks would provide local access to concrete during each stage of construction.

5.1.2.8 *Office Building*

An Office Building located outside the PA would provide space to personnel not required for operations inside the PA. This includes management, personnel, administrative, engineering, licensing, health physics, and records management functions.

5.1.2.9 *Visitors Center*

A Visitors Center outside the PA would provide members of the public the opportunity to view the storage facility and learn about its operations. The center could include visual displays and information to educate visitors of the importance of the facility. The Visitors Center could also include a large lecture room for meetings open to the public.

5.1.3 Expanded Capacity for Pilot

If needed the Pilot could be expanded to receive, handle, and store DPCs for any additional shutdown plants plus some operational plants. The facilities would be the same as for the fully operational Pilot. Additional rail yard and unloading capability may also be added.

Figure 5-3 shows the Pilot with expanded capability to 10,000 MTHM capacity.

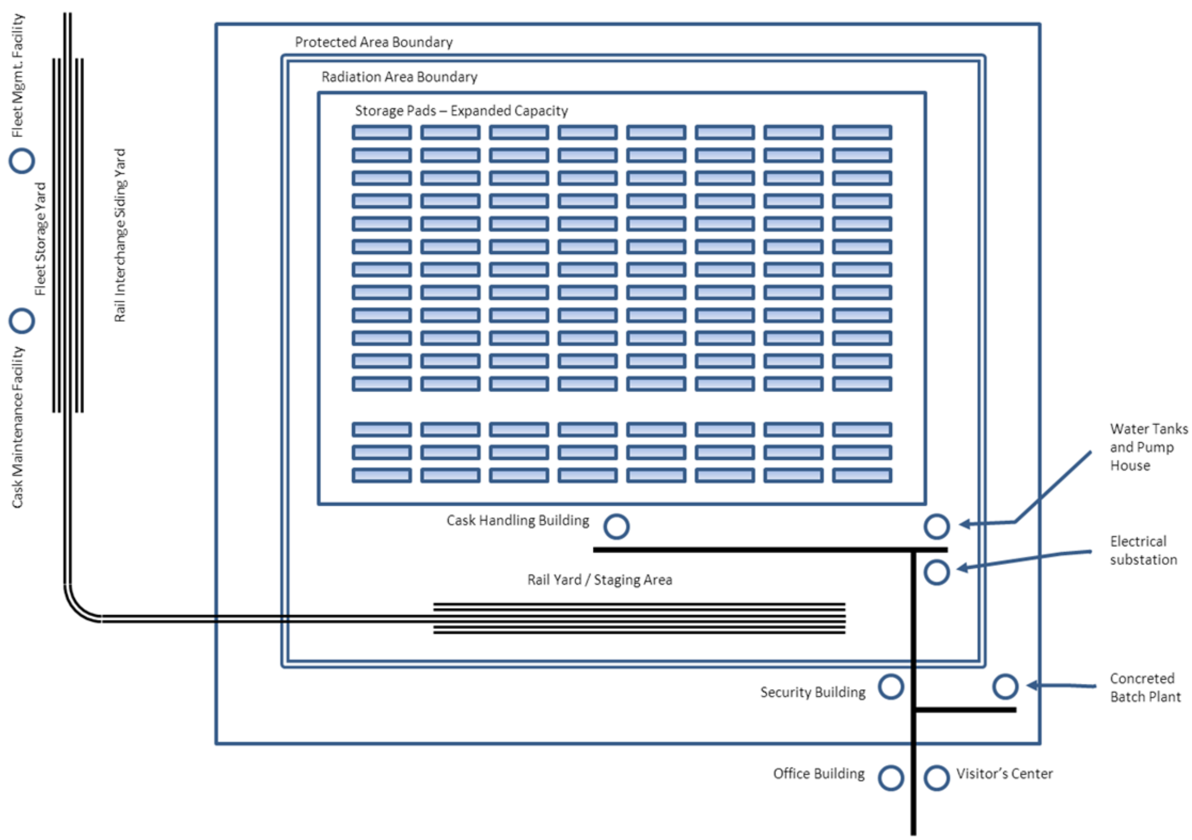

Figure 5-3. Pilot Interim Storage Facility – Expanded Capacity.

The expanded capacity Pilot would continue to use reinforced concrete storage pads to support all of the HSMs and VSCs that are loaded with UNF/GTCC canisters. However, the total storage area capacity inside the PA would be increased to accommodate additional casks/modules depending on the licensed quantity of UNF for the Pilot.

5.2 Larger Interim Storage Facility

For this report, we assume that the larger ISF is located on the same site as the Pilot and only one site will be developed. In addition to handling TSCs and DPCs, it must have pool or hot cell capabilities in order to transfer bare and damaged fuel to storage containers. An on-site R&D/Laboratory facility will carry out the necessary testing to ensure the behavior of UNF is acceptable over a long storage period.

The larger ISF will have capabilities to handle and store all forms of UNF and GTCC waste from shutdown and operating commercial reactors and government-owned UNF and HLW. It will prepare UNF and HLW for transport to a permanent repository. Much of the infrastructure would be built into the Pilot and expanded as necessary for the larger ISF. Most of the supporting facilities would be expanded to handle the additional receipt rate.

We used 70,000 MTHM as an estimated maximum ISF capability based on the repository opening date of 2048 specified in the Strategy. We used 3,000 MT/year acceptance rate for the larger ISF which is about 1.5 times higher than the current UNF generation rate at operating plants, which would ensure inventory drawdown and reduce government liabilities for continued on-site storage. The Pilot plus larger ISF site could be anywhere from 640 acres (one square mile) to 1000 acres, which would provide contingency for future expansion.

Since the Pilot will become operational before the larger ISF, Pilot siting, design, licensing and construction experience will help guide the larger ISF design and construction schedule.

5.2.1.1 *Laboratory Facility*

A Laboratory capability would be added to support the primary missions of transportation, extended storage, and future disposition for UNF and GTCC materials. In addition, this facility could be utilized in support of fuel performance activities for operating reactors. The laboratory would have the capability for testing and examination of stored fuel and fuel packages. The laboratory will allow support development of the packaging methodologies needed to prepare fuel for transportation to the repository. The laboratory is assumed to include a hot cell for examinations and may be connected to or co-located with the remediation pool and cask handling facility. Costs (Section 8) are identified separately for this laboratory facility.

5.2.1.2 *Additional Larger ISF Facilities*

The larger ISF will contain the following additional subsystems:

- Significantly larger dry storage pad area. For example, the larger ISF would need the capacity to store an estimated 7,000 storage over packs/modules for 70,000 MTU based on a mix of low capacity DPCs (approximately 10 MTU per DPC) already in service and high capacity DPCs (approximately 13 MTU per DPC) expected to be used in the near future.
- Expanded cask handling capability within the existing or additional cask handling buildings.
- Remediation pool for packaging/repackaging damaged fuel (Fuel Remediation Facility)
- A capability to receive bare PWR and BWR fuel and transfer this fuel to a storage configuration to be determined (Bare Fuel Receipt Facility). For this report, we have assumed and developed cost and schedule ranges with loading only dry storage casks.
- Additional infrastructure that may be required to prepare or repackage casks for transport to the permanent repository (not included in this report baseline costs.)

- Additional infrastructure may also be needed if storage is accomplished by other methods, such a pools, dry vaults, standard canisters and storage systems, etc. (This report baseline concept assumes dry storage canisters only.)

Figure 5-4 shows a conceptual arrangement diagram for the initial construction of the larger ISF. The large footprint for the storage pads would be built in the larger ISF but have an initial the capacity for 20,000 MTHM with room for expansion to nominal 70,000 MTHM. The total site area needed ranges from 640 to 1,000 acres.

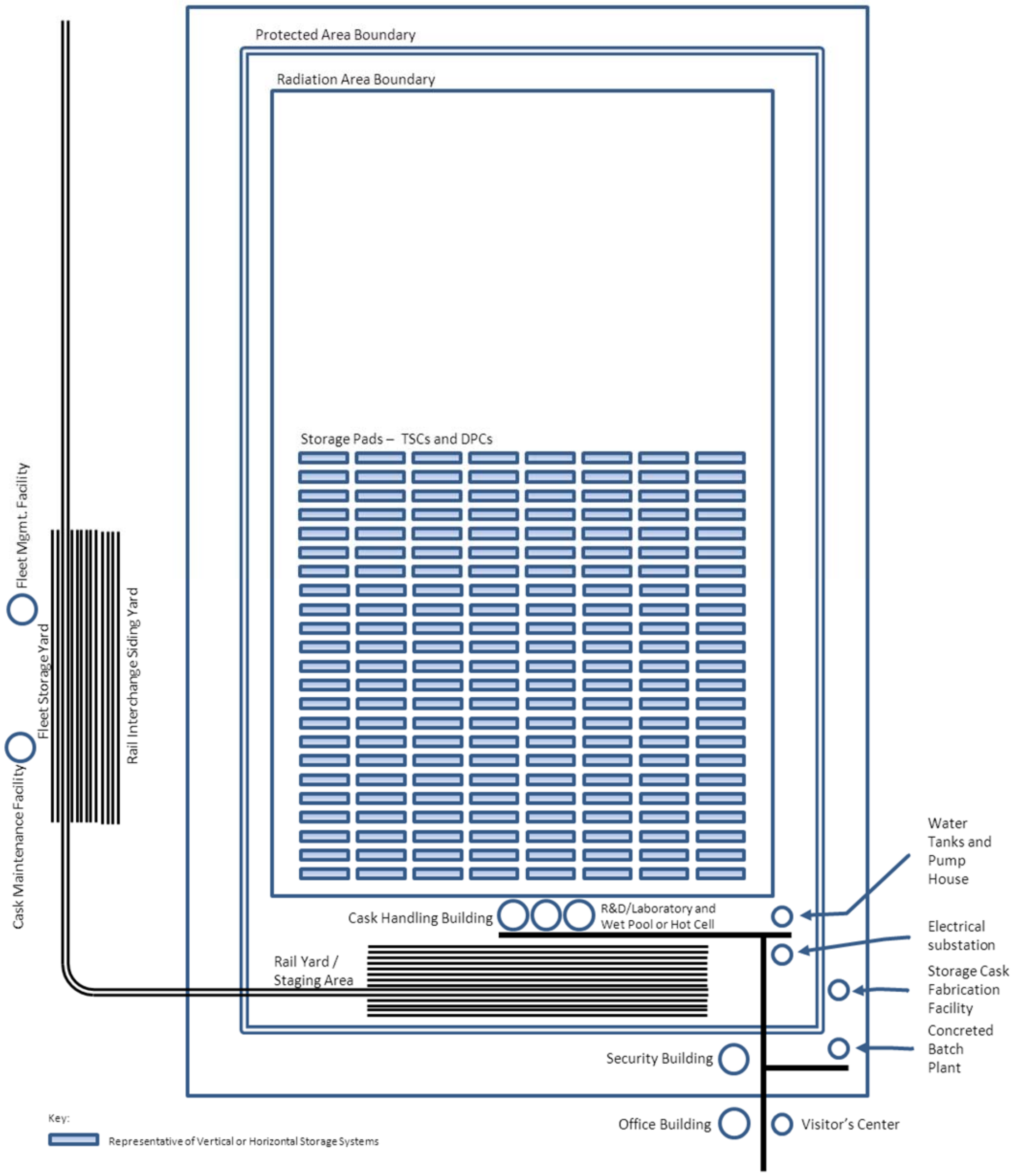

Figure 5-4. A Conceptual Arrangement of an Larger ISF Site.

5.3 Transportation System

The Transportation System includes the following key parts:

- Rolling Stock – cask cars, buffer cars, and escort cars
- Used Fuel Transportation Casks –truck; rail
- Infrastructure – roads, railway,
- Institutional – route selection and interface, training for emergency response
- Operations – security, route management, pickup and loading, cask transfer,

Each element of the Transportation System will be required for the Pilot with the quantity of equipment and operations growing for the larger ISF facility.

5.3.1 Rolling Stock

Rolling stock for the rail transport system consists of locomotives, buffer cars, cask cars, and escort cars. Railcars will be designed, certified and fabricated by DOE for their specific purposes. Road locomotives are included for reference purposes but they are expected to be provided by the hauling railroad under service agreements. Figure 5-5 shows a sketch of the rolling stock used for a typical consist.

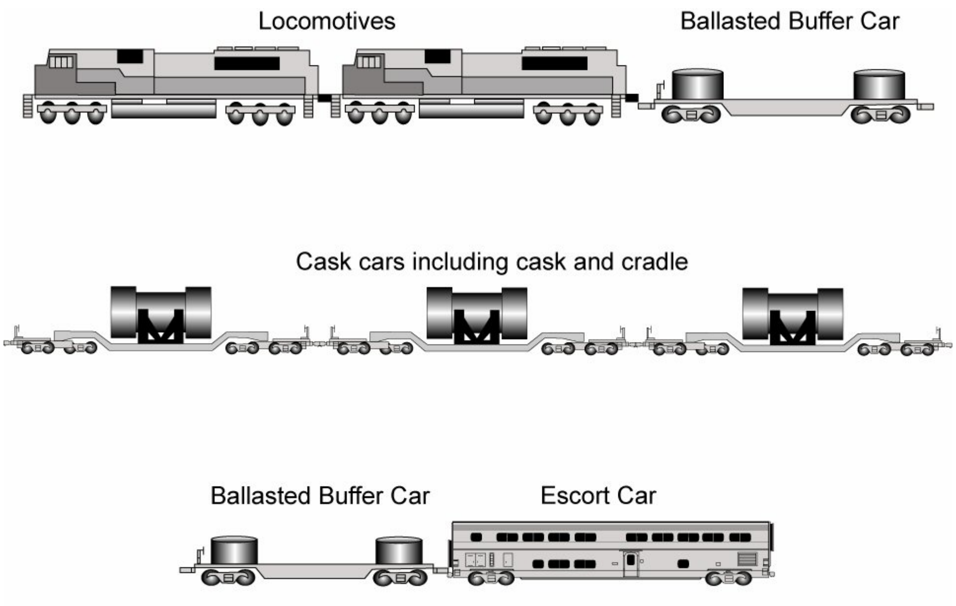

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Figure 5-5. Typical Rail Consist.

To operate on most railroads, the railroad companies will require that rolling stock meet performance standards, including the AAR Performance Specification, S-2043, *Safety Performance Specifications for Trains Used to Carry High-Level Radioactive Material*. Principle technical requirements include:

- 1,000,000 lb. buff strength for car designs
- Performance monitoring for the dynamic status of the cars
- Electronically Controlled Pneumatic (ECP) braking equipment on all cars
- Truck and suspension redesign and optimization to improve steering, reduce truck warp and provide good wheel load equalization
- Prototype cars (1 ea.) will go through single car testing and consist testing for a period of 16 –18 months

The project would purchase the rail cars and most likely contract for the road locomotives as part of the railroad services used to move the consist to the ISF. At the storage site, a smaller transfer or yard locomotive(s) would be used to switch the cask cars for unloading and re-assembling the consist. A rail car maintenance facility will provide services to maintain the railcar fleet. The baseline concept assumes that railcar maintenance supporting pilot operations will be contracted while a rail car maintenance facility will be constructed for the larger ISF operations. Routine yard locomotive maintenance services would be provided on site. Significant yard locomotive maintenance would be done at other locations (contract service). Railroads would provide for the service of their locomotives. Yard locomotives may be purchased, leased, or contracted, depending on future business-case analyses. For this concept report, the yard locomotives are assumed to be purchased.

In addition to the preferred rail transfer method, truck and barge transport are expected to be required for some used fuel shipments. This method would require either legal-weight truck casks or heavy-haul truck casks, depending on the transportation infrastructure and used fuel to be moved. These methods would most likely interface with the rail transportation system at a loading station (railhead) for transportation to the ISF.

5.3.2 Used Fuel Transportation Casks

Transportation Casks are used to provide an over pack for used fuel canisters that meet US NRC and US DOT rules and regulations to movement over public highways, navigable waterways, and railroads. Currently, most used fuel in dry storage casks are designed to be “dual purpose” such that the design will accommodate storage and transportation of the used fuel canister (DPCs). Some used fuel is currently stored in a TSC such that the canister does not need to be transferred to a transportation cask. Pacific Gas and Electric’s Humboldt Bay plant in northern California used the TSC design.

For the currently stranded plants, all the fuel is in either TSCs or DPCs. Transportation casks will need to be procured for these plants using the currently approved designs or in a compatible standard transportation cask. US NRC approval will be required if currently approved designs are not used.

For operating plants, fuel currently stored in DPCs may be moved similar to the used fuel from stranded plants. A few plants have the fuel stored in dry cask systems that are not approved for transportation. Either this fuel will require repackaging into an approved transportation system or the canister system will require analysis and approval by the NRC for the transportation to the storage site. See section 3.2 for details on used fuel locations and storage systems.

In addition to the casks, cradles to attach the cask to the rail car and impact limiters on either side of the cask will be required. This equipment will be specific to the transport cask design. Also, handling equipment will be required to load/unload casks.

DOE high-level waste and used fuel will also require transportation casks to be designed, licensed, and fabricated.

5.3.3 Infrastructure

Many of the currently shutdown/stranded plants do not have rail access at the site. For those sites, heavy-haul truck and/or barge to rail intermodal transportation will be required.

5.3.4 Institutional

Routing can be identified from the known shutdown and operating plant sites to major transportation corridors. Routing beyond that will require specific storage site locations. The National Transportation Plan, currently being updated discusses the institutional requirement, potential routing, and other considerations. NWPA Section 180 (c) discusses emergency preparedness programs and related requirements.

5.3.5 Operations

The Department is planning to use dedicated trains, that is, the train consist would move as a unit and not be combined with other rail shipments. Security would be provided by federal agents.

5.3.6 Pilot Transportation System

The Pilot will require sufficient rail consists to transport the dry casks to the facility in approximately 5 years. Assuming 2-year ramp up and 3 months per round trip, five consists are required by the third year of operations. Table 5-1 shows the rolling stock units required for the Pilot. In addition, some heavy weight truck equipment will be needed. Tractors and trailers will be a contract service provided item as will road locomotives.

Table 5-1. Rolling Stock Required for Pilot.

Rolling Stock	Units per Consist	Total Units
Road Locomotive*	2	10
Cask Car	3-5	15-25
Buffer Car	2	10
Escort Car	1	5
Yard Locomotive		1
*Road locomotives are expected to be provided by the transporting railroad under a service contract		

5.3.7 Larger ISF Transportation System

The larger ISF will require additional rail consists to meet the 3000 MTHU per year requirement for input to the storage facility. This requirement will be ramped up over the first three years of operation for an estimated total of 15-25 additional consists plus spares. Table 5-2 shows the estimated total additional unit requirements at full capacity. Requirements for the Pilot are not included in these numbers.[a] Note: The quantity of units also depends on whether bare fuel is packaged and shipped or only transportable storage canisters. Also, a difference will occur if the final packaging for repository disposal is performed at the repository or at the interim storage facility. If all fuel is repackaged at the storage facility the number of train consists potentially increases depending upon the disposal canister physical size and weight.

[a] These numbers do not include any additional transportation equipment for shipping to the repository, assumed to open in 2048.

Table 5-2. Estimated Rolling Stock Required for Larger ISF.

Rolling Stock	Units per Consist	Total Additional Units (Case 1)	Total Additional Units (Case 4)
Road Locomotive**	2	28	50
Cask Car	3-5	42-60	75-100
Buffer Car	2	28	50
Escort Car	1	14	25
Yard Locomotive*		3	3

Note: Cases 1 and 4 are described in further detail in the Used Fuel Management System Architecture Evaluation, October 2012, page A-51. Case 1 is for canisters only with re-packaging at the repository; Case 4 is for canisters and bare fuel with re-packaging at the ISF. Assumes largest disposal canister size. All cases are for 3000 MTHM per year.

*Yard locomotives not part of consist. Based at ISF.

**Road locomotives are expected to be provided by the transporting railroad under a service contract

6. Design and Operational Considerations

This section discusses a variety of design and operational considerations with respect to the design concepts, including design processes.

6.1 Special Used Fuels and Materials Handling

Nuclear fuel in the United States has been fabricated by multiple fuel vendors using different structural material, cladding material, skeleton designs, fuel pin arrays, burnable poisons, handling arrangements, etc. In addition, there is a spectrum of initial fuel enrichment and subsequent fuel utilization (power level and burnup) used by the operating plants. Recent consolidation within the nuclear fuel fabrication business has reduced these variations. However, all of these historical variations, including the limited number of lead test assemblies, must be addressed by the design and licensing of the ISFs and associated transportation system. In addition, the ISFs must address the repackaging requirements established for the final repository and its associated transportation and regulatory requirements. How these are addressed will have an impact on the design of the ISFs. (See Section 3.2.1 and Appendix A)

While the design and licensing of the ISFs must address all of these differences, the two properties that have the biggest impact are the physical dimensions of the fuel and the fuel utilization.

6.1.1 Storage of UNF at the ISFs

The dimensions of the fuel set the size of the canisters and subsequent over pack design and the specialized handling tools. The dimensional issues have already been addressed, or will be addressed, by each utility for storage of their UNF at their sites in their spent fuel pools (SFPs) and dry cask storage. If a variety of dry cask designs are to be used at the ISF, then all of these individual fuel dimensional type issues have been or will be addressed by the utilities and can be incorporated into the site specific ISF design and licensing. If a new standardized dry storage system is developed for the ISF, then the individual design and licensing issues can be used as a guide to help streamline the design and licensing process.

The fuel utilization affects the heat load and dose rates that must be accommodated by the UNF storage systems. If the ISF uses the same dry cask storage systems as the utilities now use, then the heat load and dose rates have been addressed, or will be addressed, by the utilities and the ISF can incorporate their licensing into the site specific ISF licensing. If the UNF is loaded into canisters directly from the fuel pool, there is no new heat load or dose issues as long as the fuel meets the utilities' existing heat load and dose limits for their on-site dry cask systems. Waiting for fuel at reactor sites to decay to meet current heat loads and dose rates will require longer holding times at the reactor sites but would reduce or eliminate the need to design, develop and license new transportation and dry cask systems.

Using existing or planned utility dry cask storage systems will increase the complexity of moving and storing the UNF at the ISF and require several different sets of handling equipment, with associated increased storage or laydown area. Whether the ISF uses only existing dry cask systems or develops a new standardized system, the variations in UNF dimensions and utilization does not represent a significant challenge to the design, development, licensing and operation of the ISF.

6.1.2 Transportation of UNF

There have been virtually no shipments of UNF from reactor sites, so the design, development and licensing of transportation casks and handling tools must be completed in order to load and transport UNF to the ISF, as discussed in Section 5.3. While there are several licensing, testing and performance issues that must be addressed before a transportation system can be approved, the physical dimensions of the fuel do not significantly increase the complexity of the design or approval process outside of the need for several different casks to handle the different sized fuel or a new multi-purpose standardized transportation cask.

The impact from the fuel utilization can be significant on the transportation systems as they generally are more restrictive with respect to heat load and dose. This directly affects the holding time at the utility, either in their SFP or dry cask systems. However, the current licensing of transportation systems bound most historical fuel utilization strategies used by utilities and does not represent a significant barrier to obtaining approval of transportation systems.

6.1.3 Extended Fuel Utilization (High Burnup Fuel)

The current burnup limit on fuel in dry cask storage and transportation systems is 45,000 MWd/t assembly average burnup. In contrast, the maximum one pin burnup limit on in-reactor fuel is 60,000 MWd/t to 62,000 MWd/t. There are test assemblies currently in reactors that are attempting to drive fuel to 70,000 MWd/t. Along with these extended fuel utilization limits are new fuel cladding and assembly skeleton materials. Experimental data over the last twenty years suggest that fuel utilizations as low as 30,000 MWd/t can present performance issues including cladding embrittlement under accident conditions as well as normal operations. The NRC is actively seeking rulemaking to address cladding performance for loss of coolant accidents and reactivity insertion accidents. These cladding performance issues need to be addressed before extended fuel utilization fuel can be loaded into dry casks and transportation systems. Section 9.1 discusses needed R&D.

6.1.4 Pilot

The proposed mission for the Pilot initially limits the fuel types to those located at stranded nuclear sites and those that may be shutdown in the near future thus meeting the definition of a stranded site. All of the fuel stored at these stranded sites meet current dry cask storage licensing requirements, which include dimensional characteristics and fuel utilization used at these reactors. Whether the Pilot uses only existing dry cask and transportation systems or develops new standardized systems, the variations in UNF dimensions and fuel utilization do not represent a significant challenge to the design, development, licensing and operation of an ISF.

6.1.5 Government Owned UNF and HLW

See Section 3.2.2 and Appendix C for a discussion of the Government Owned UNF and HLW. There are a lot of unknowns about the types of used fuel and high level waste to be received from DOE sources to be sent to the Central Storage Facility and the UNF and HLW from other government agencies. DOE high-level waste and used fuel will also require transportation casks to be designed, licensed, and constructed.

6.2 Safety

Both DOE and NRC have a legislative mandate to provide for protection of the public regarding nuclear activities under their authority and state their nuclear safety requirements through federal regulations and accompanying implementing requirements and guidance documents. In the case where a DOE nuclear facility is to be licensed by the NRC, the DOE nuclear safety requirements of 10 CFR 830 Nuclear Safety Management are excluded for the project. However, if the NRC licensed facility is to be located on an existing DOE site, there will inevitably be interfaces between the NRC license requirements and conditions and the existing DOE site infrastructure (e.g., emergency response site plans). These interfaces normally would be negotiated during the license application development.

The nuclear safety requirements of the NRC license development process result in facility design features that can provide for adequate protection to workers and the public during normal operations, operational upset conditions, and accidents. Accidents must include consideration of facility process accidents such as equipment drops, accidental criticality, and fires; external man made hazards such as aircraft crashes; and natural phenomena hazards such as earthquakes, flooding, tornadoes, etc.

A safety analysis is developed, integral with design development, and documented (in the case of NRC) in a Safety Analysis Report (SAR). DOE has similar requirements. The SAR is submitted as part of a license application for NRC review and approval. NRC has Regulatory Guides and NUREG documents that provide guidance for a SAR. These documents are available for an Independent Spent Fuel Storage Facility Installation.

The process for the development of the information required for presentation in a SAR is common to both DOE and NRC. The process involves development of a comprehensive hazard analysis that identifies possible initiating events that could lead to a release of hazardous materials as the first step. Based on the hazards analysis, safety functions and safety structures, systems, and components (SSCs) that could prevent or mitigate the accident progression are identified and selected for incorporation into facility design. This is an iterative process through conceptual, preliminary, and final design between safety analysis and design. Design reviews, including the development of the SAR, are normally held at the completion of each design stage so as to provide confidence that the end product (a license application) can be approved by NRC. It would be a prudent management practice for a DOE nuclear facility to be licensed by NRC.

Information and analyses that must be developed and presented in a SAR to support the development of a safety analysis include:

- Site description and characteristics important to safety analysis including location and layout, meteorological data and geology and seismology, flooding potential, etc.
- Facility and operations description

- Description of safety SSCs, design criteria, and evaluation of the capability of the SSCs to perform their intended safety functions when called upon
- Accident analyses and comparison with acceptance criteria

Additional information to be included in a SAR includes proposed operational Technical Specifications, a description of a quality assurance program, a decommissioning plan, a security plan, and information on normal operations and design to accommodate regulatory requirements such as radiation protection for workers.

The effort needed to develop a SAR and license application is a function of the scope of the project. For the Pilot, where the only operations are receipt of UNF and emplacement in storage, the effort is much less than for the larger ISF, where facilities for dealing with damaged fuel, repackaging, and research and development are part of the operations. However, in the case where it is intended that the larger ISF be collocated with the Pilot, the siting aspects and requirements for the larger ISF need to be considered in the development of the SAR and license application for the Pilot.

Safety aspects and licensing for preparation of UNF for shipping from operating reactor sites would be covered under the license for the operation reactor. The license conditions for UNF at decommissioned reactor sites would have to be examined to see if it is covered there. If not, the safety analysis and license application would be similar to considerations of those operations at the Pilot.

Transportation safety is handled under NRC and DOT requirements, in large part dealing with approval of the shipping container(s). This involves specification of conditions that the shipping container must accommodate, and testing to verify satisfaction of those conditions.

It is possible to scope out the hazard controls for the facilities associated with the various design concepts based on professional experience and judgment. For example, certain of the associated facilities will require safety features such as active confinement ventilation, emergency backup power, a level of seismic structural classification and design, etc. These will be a function of the activities to be conducted within the facilities, which for the most part are common to all of the design concepts (receipt of UNF, transfer to storage pads, the capability to deal with damaged UNF, and R&D activities). As a result, it is not expected that safety considerations would play a significant role in differentiating among design alternatives. A possible exception to this is if storage of UNF is to be below ground level, then the susceptibility to release of radionuclides from an aircraft crash accident would be much lower than for above ground storage. This could affect the size of the overall site (distance to site boundary), considering siting requirements relating to radiological doses to members of the public.

The NRC licensing requirements just described involve a safety analysis process that will result in the actual classification and associated safety design specifications of the safety structures, systems, and components that will be required for the individual facilities.

6.3 Security

At the present time an independent spent fuel storage installation (ISFSI) containing UNF, GTCC, and HLW requires physical security protection measures given in 10 CFR 73.51 (As well as provisions of 72,73.20, 73.50, and 73.67). Both the Pilot and larger ISF will be substantially larger than any licensed offsite UNF storage facility in the US. These large amounts of material will require the physical security systems at both facilities to be robust and the designs will have similar requirements, even if ISF ends up being several facilities at different locations. Depending upon the final Design Basis Threats (DBTs), and final NRC and DOE regulations, these designs will have the objective of providing high assurance that activities involving used nuclear fuel and HLW do not constitute an unreasonable risk to public health and safety. To ensure compliance with current federal security regulations the facilities are required to have three distinct areas with each outer area fully encompassing the next inner area. The innermost area is the

Radiation Control Area (RCA), which is located within and fully enclosed by the Protected Area. The outer most area, the Owner Control Area (OCA), contains the Protected Area and all other buildings and structures needed to operate the site. The baseline assumption is that armed security guards with the appropriate support are provided on site.

The OCA is the land owned and access controlled by the owner. It is to provide a minimum security response distance and public safety distance, typically 100 meters, from all storage and handling operations in accordance with 10 CFR 72.106. With perhaps the exception of the main rail yard, all buildings and structures for the Pilot or larger ISF will be located within the OCA. Security operations for the OCA should typically involve “No Trespass” signs, or similar warnings, displayed prominently around the property. Access to the OCA will be actively controlled by the onsite security staff with guard stations and is to be fenced.

Activities involving the waste material including storage, cask handling, any pool work, hot cell work, etc. is to be conducted within a PA. This area is designed to protect against loss of control of the facility that could be sufficient to cause a radiation exposure exceeding the dose as described in part 72.106. According to part 73.51 the protected area shall be defined by a Perimeter Intrusion Detection and Assessment System (PIDAS) consisting consist of two physical barriers offering substantial resistance to penetration, spaced typically 20 feet apart with illumination adequate to assess unauthorized penetrations of these barriers. The PA is to be equipped with an exterior intrusion detection system with sensors such as microwave, ground based terrain- following radar, electric field, buried cable and active and passive infrared systems. Appropriate, timely maintenance is provided for this and all security equipment. Backup on-site power including a UPS and dedicated generator are part of the Security System and is located within the PA.

In keeping with current NRC requirements all plant vital areas must be located within the PA and have restricted access above and beyond that needed for the PA. Vital areas are typically accessed only with permission from both the operations and security staff. A vital area is any place in the PA where equipment, system, device or material are located and failure, destruction or release of which could directly or indirectly endanger the public health and safety by exposure to radiation. In addition, any equipment or systems which would be required to function to protect the health and safety following such failure, destruction or release is to be located in vital areas. The building containing the on-site backup power generators would be a vital area as would emergency ventilation within the Cask Handling Building. For the Pilot and the larger ISF, most of the RCA needs to be evaluated against requirements for vital areas.

Bullet resistant enclosures are to be situated at strategic locations within the PA to provide protected locations for security force personnel during a security event. A redundant Central Alarm Station located within the PA staffed with at least two security force personnel is to be provided. These stations have bullet-resisting walls, doors, ceiling and floor. These stations monitor the exterior intrusion detection system, all entry portals, the cask handling building, pool, hot cells, and bullet resistant enclosures located throughout the PA, as well as other active security components.

Any unauthorized penetration of the PA and or unauthorized activities within the PA are detected and promptly assessed by an on- site, armed security force. This security force is trained to respond to the DBT and other threats and is managed in such a manner that maintains its effectiveness, including regular testing and assessment for performance effectiveness. As part of the maintenance of the PA, the security force conducts daily random patrols. Response to unauthorized penetration or activities within the PA is fully integrated with local law enforcement authorities whose roles may vary depending upon provisions of any consent based siting agreements. This includes, but is not limited to routine and emergency support such as traffic control, investigatory and criminal follow up, pursuit, etc. that can be expected from external sources during a security event. Redundant communication capabilities will be maintained with all external accountable entities during a security event to allow appropriate support from these entities.

The RCA is contained completely within the PA and is separated from the PA by chain-linked fence or other barriers with limited entry points. The purpose of the RCA is to limit movement in the vicinity of the UNF, radiological waste material and the buildings and structures that house them. By limiting movement the RCA seeks to achieve occupational dose rates as low as achievable. In addition, it controls the creation, storage and potential spread of any radioactive waste. Access to the RCA is controlled by onsite personnel trained in health physics and by security. Except during transport, all radioactive material and operations with this material is contained within the RCA.

Roadways approaching all security portals will be designed to slow the speed of approaching vehicles by means such as turns, speed bumps, or a serpentine design. Deliveries of UNF by rail will be checked for authorization and visually for explosives by the security force. All individuals, vehicles, and hand-carried packages entering the facilities will be checked for proper authorization and searched for explosives. Portals will be equipped with CCTV cameras to assist in the inspection of vehicle undercarriages.

Documentation is maintained on security procedures, liaison with local first responders, training, exercises, unauthorized activities, maintenance of security equipment, individuals granted access to the PA, security personnel screening records, etc. as required by NRC regulations. All three areas, the OCA, PA and RCA are addressed by a Physical Security Plan (PSP), which is part of the facility licensing package. 10 CFR 72 and 10 CFR 73 specifies the requirements that are addressed in the PSP.

6.4 Environmental

The *National Environmental Policy Act* (NEPA) requires that potential environmental impacts of proposed federal actions and the reasonable alternatives to that action be considered prior to making any such decisions. These are documented through a set of decision documents (Finding of No Significant Impact, Environmental Assessment or Environmental Impact Statement) in order to inform the public and the decision-makers regarding the impacts of the action. In accordance with the direction in the Strategy document the NFST Planning Project is contemplating at least two new facilities for interim storage of UNF from commercial nuclear power plants and possibly DOE owned UNF and HLW: a Pilot focused on handling and storage of UNF from shutdown reactor sites, and a larger ISF. Assuming the alternatives analysis to be conducted during the conceptual design phase concludes that new interim storage capability is the correct path forward, the project would commence work on an EIS for the ISF starting in FY 2014.

Current planning is to prepare one Environmental Impact Statement (EIS) for the Pilot, presuming that the larger ISF will be collocated upon demonstration of safe and secure operations of the pilot. DOE NE would prepare a Site-Specific EIS, which would inform specific agency decisions such as where to locate one or more ISFs while still requiring the consideration of a no action alternative, therefore still requiring consideration of the full range of alternatives that must be addressed. The Site-Specific EIS would be developed in parallel with the phased CBS process but information on the analysis of a site could not be completed until after one or more communities willing to host an interim storage facility has been identified.

In accordance with the strategy, the Pilot and the larger ISF are assumed to be located at a single site. Only if communities are found that are willing to host the entire interim storage capacity would this be a preferred alternative in a Site-Specific EIS. Additional alternatives would be analyzed such as different sites for the Pilot and the larger ISF, and multiple sites for ISFs. A No Action alternative would also be analyzed, whereby commercial and DOE UNF and HLW would remain at the site at which it is generated and no consolidated interim storage capability developed.

The site(s) for the interim storage facilities has not been selected yet. Once a specific site(s) has been selected, the site specific information and analysis will be included in the EIS before it is finalized. Because the facilities will be licensed by the NRC, the EIS would form the basis of an environmental report (ER) prepared by DOE and submitted to the NRC with the license application. The NRC would be responsible for reviewing the ER and issuing a final EIS before a license is issued.

The Administration has recommended that a new organization be formed to manage UNF in the U.S. DOE will work on the EIS for the ISF until such time as a decision is made on a separately managed UNF disposition organization. Since the ISF will be licensed by the NRC, the responsibility for the EIS will be with the NRC. Based on past experience with the Yucca Mountain project, it is most likely that the NRC would accept the DOE EIS as meeting the NEPA requirements.

DOE NE is aware and understands that it can begin planning for interim storage and undertake NEPA review, but it does not have legal authority to proceed with constructing a consolidated storage facility for commercial UNF. The Nuclear Waste Policy Act, as amended, allows the government to construct a storage facility with limited capacity, but only after construction authorization of a nuclear waste repository has been approved. Nonetheless, DOE NE believes it appropriate and timely to undertake NEPA review by proceeding so that there can be a timely development of a Pilot ISF once Congress authorizes the activity.

6.5 Regulatory

The regulations associated with constructing and operating a facility for the independent storage of UNF and GTCC waste involves federal, state, Native American tribes and local regulations, permits and certifications.

6.5.1 Federal Regulations

The ISF will be licensed in accordance with the site specific provisions of the Nuclear Regulatory Commission's (NRC) Title 10 of the CFR (CFR) Part 72 "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater than Class C Waste." Initial planning and fact-finding meetings will be scheduled with the NRC staff during the development of the conceptual and preliminary design activities. Approximately two years prior to a license application, the potential licensee will notify the NRC of the schedule for application submittal to allow the NRC to plan for licensing activities. Upon the receipt of the application the NRC will initiate the formal licensing process. It will publish the time frame for the process, the site location and whether there will be public hearings or proposed actions. If requests for hearings and contentions are received by the NRC, it will establish an Atomic Safety Licensing Board (ASLB) for review. Depending on the request or contention, they could be litigated through the review of documents by the petitioner or may require court testimony and/or document submittals. These hearings would take place in parallel with the technical review. The NRCs Safety Evaluation Report (SER) and the Environmental Impact Statement (EIS) may be completed independently of the hearing process but cannot be issued until all contentions have been resolved.

In addition, the ISF siting will have to address:

- The Federal Clean Water Act which tasked the Environmental Protection Agency (EPA) with the role of developing a National Pollution Discharge Elimination System (NPDES) permit program. The Federal Water Quality Act allowed EPA to authorize states to implement the NPDES permitting. As a result of this act, some states are now the permitting authority of the NPDES program, whereas in other states the EPA remains the authority, but the EPA continues to maintain oversight of the program in all states.

- The Clean Air Act which requires EPA to set National Ambient Air Quality Standards (40 CFR Part 50) for pollutants considered harmful to public health and the environment. States are delegated by the EPA to implement New Source Performance Standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAP).
- The Federal Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) which provide guidance to the EPA for the management of solid and hazardous wastes. States are delegated by the EPA to permit the transportation, storage, treatment, and disposal of these hazardous wastes.

6.5.2 State and Local Regulations

As discussed above, depending on the state where the ISF is to be located, many of the federal environment regulations are implemented by the individual states. In addition, the ISF construction and operation will have to obtain:

Water permits to address water pollution control, protection of the drinking water, and water conservation and to ensure there is no impairment to existing rights, that the intended use meets state and local water conservation efforts, and that the intended use is not detrimental to the public welfare. This includes any water discharges, storm water, and waste water systems, limits and quality.

Air quality permitting will be required to demonstrate compliance with NESHAP requirements as detailed in 40CFR6. State regulations require the issuance of construction and operating permits, impose limits for particulate matter and gaseous point and fugitive source emissions, and set minimum acceptable ambient air quality levels.

If a concrete batch plant is to be licensed as part of the ISF, then the air quality permit must also consider the contribution of this activity to the air emissions. The on-site backup power generators will need to be permitted under 40CFR52 “Prevention of Significant Deterioration”

6.5.3 Hazardous and Solid Waste Permits

Hazardous and solid waste disposal and their allowed concentrations are listed in the regulations under RCRA (40CFR261). This regulation also specifies the managing and disposal procedure for the hazardous waste. A State may require a permit to allow for the storage of hazardous waste. States may also require permits for the transport of hazardous wastes, which terminate and/or originate within the state. States with an agreement with the NRC (known as Agreement States) will also require permitting of facilities that receive, use, transfer, or dispose of any radioactive material/waste. In addition, States may require permits for the storage of wastes in underground tanks covered under CERCLA.

Additional permits/certificates may be required (usually at the local level) to construct, operate, access, or limit access to the ISF.

6.5.4 Security

Security requirements for UNF storage and transportation are addressed in 10 CFR Part 72, Subpart H, Physical Protection, 10 CFR Part 73, Physical Protection of Plants and Materials, and 10 CFR Part 74, Material Control and Accounting of Special Nuclear Materials. See Section 6.3 for additional information on security regulations.

6.5.5 Transportation

Due to the diversity of site locations with UNF and GTCC waste many different transportation systems and combination of systems will be needed to transport the material to the ISF, whether at one location or several locations. While NRC 10 CFR 71 certified transportation casks will be used to ship the UNF in storage at the NPP sites to the ISF, each shipment is subject to a distinct set of Federal and State safety inspection protocols. This will require interface with carriers, States, Tribes, local officials, and other key stakeholders to identify routing criteria and to ensure the criteria are consistent with best practices and regulations.

Rail carriers will be Federal Railway Administration (FRA)-regulated short-line or regional railroads that operate over one or more discrete sections of track, or Class 1 (main-line) railroads with national rail networks.

For truck shipments, commercial trucking firms that are certified under the DOE Motor Carrier Evaluation Program (MCEP) can provide DOT-certified drivers qualified for UNF shipments.

The U.S. Coast Guard issues regulations regarding the movement of barge shipments of UNF, including the use of particular facilities, waterways, and vessel and port security procedures.

6.6 Siting Requirements

The BRC recommended a consent-based siting process as the best prospect to achieve the necessary public and political support for both a repository and a storage site for nuclear waste in the United States. This recommendation has been endorsed by the Secretary of Energy and is the basis of the planning for a storage facility. That Pilot may or may not be expanded into a larger ISF depending on the wishes of the host community. Because the larger ISF is planned for operation within 4 years of the start of operations of the Pilot, there is the likelihood for both siting efforts to be underway at the same time. However, there is the possibility that multiple sites will be identified in the initial sting effort and multiple sites will remain in consideration to permit selection of more than one site (one Pilot and one larger ISF) if necessary.

6.6.1 Overview of the Consent-Based Siting Process

Siting will require DOE to engage with local communities, Native American Tribes and States throughout the process. At a macro level, the siting process has the following major phases:

- An initial campaign to engage the public and formulate a siting process based on public input. This is referred to as the “process to define the process.”
- Following agreement on the process, a screening and evaluation process will commence that is designed to solicit and screen volunteer sites and advance toward selection
- After initial screening, a negotiation process with the host or hosts will continue to arrive at major characteristics, acceptable to the host and DOE, such as the design capacity, critical features to be included or left out, and the potential to expand beyond the Pilot to the larger ISF.
- The last step in the selection process is the DOE decision to use that site under the negotiated terms and conditions leading to a binding agreement with off-ramps defined for both DOE and the host. This will then permit final design, application for a license to the NRC, construction and operations of the Pilot and the larger ISF possibile at multiple sites.

6.6.2 Issues and Considerations

Current NRC regulations limit the capacity and location of an ISF.[b] Since there is no identified "candidate site for a HLW repository" subsections a) and b) may not be applicable, however the size and location restrictions of subsections c) and d) may apply without new legislation. This needs to be factored into requirements for the site.

Other considerations include avoidance of obviously unacceptable locations such as National Parks, flood plains, heavily populated areas, etc. A short list of exclusion criteria will be developed as part of the siting process in consultation with the interested parties that respond during the first and second rounds of discussions.

6.6.3 Coordination with Design and Environmental studies

The conceptual design will help define the minimum land area required for the Pilot and the larger ISF, collectively the ISF. The site is expected to be in the 640 to 1000 acre range, assuming maximum storage at the ISF of 70,000 MTHM. That information will be necessary for discussions with potential hosts. In addition, desires of the host, in a consent-based siting process, may affect the design and some features of the ISF. In addition, the development of the needed EIS will need inputs from the candidate sites and the design contractor. The design, siting and EIS will be proceeding in parallel and will need close coordination. The final sizing and the final design will be an iterative process.

6.6.4 The Siting Process Will Be Defined In Consultation with Interested Parties

Siting "requirements" are fluid at this time because the recommended approach, Consent-Based Siting, requires an iterative process with interested parties rather than a top-down process. As a result, many of the requirements for siting and the criteria for selection are yet to be defined. The most important steps at this time are to identify absolute minimum requirements for siting and identify the individuals that will make up the integrated siting team to interact with the public and develop the consent-based process.

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[b] 72.96 Siting Limitations a) An ISFSI which is owned and operated by DOE must not be located at any site within which there is a candidate site for a HLW repository. This limitation shall apply until such time as DOE decides that such candidate site is no longer a candidate site under consideration for development as a HLW repository.

(b) An MRS must not be sited in any State in which there is located any site approved for site characterization for a HLW repository. This limitation shall apply until such time as DOE decides that the candidate site is no longer a candidate site under consideration for development as a repository. This limitation shall continue to apply to any site selected for construction as a repository.

(c) If an MRS is located, or is planned to be located, within 50 miles of the first HLW repository, any Commission decision approving the first HLW repository application must limit the quantity of spent fuel or high-level radioactive waste that may be stored. This limitation shall prohibit the storage of a quantity of spent fuel containing in excess of 70,000 metric tons of heavy metal, or a quantity of solidified high-level radioactive waste resulting from the reprocessing of such a quantity of spent fuel, in both the repository and the MRS until such time as a second repository is in operation.

(d) An MRS authorized by section 142(b) of NWPA (101 Stat. 1330-232, 42 U.S.C. 10162(b)) may not be constructed in the State of Nevada. The quantity of spent nuclear fuel or high-level radioactive waste that may be stored at an MRS authorized by section 142(b) of NWPA shall be subject to the limitations in § 72.44(g) of this part instead of the limitations in paragraph (c) of this section.

6.7 Waste Management

Low Level Radioactive Waste (LLW) typically consists of contaminated personal protective equipment, wiping rags, mops, filters, water treatment residues, and maintenance equipment and tools. The radioactivity can range from just above background levels found in nature to very highly radioactive in certain cases such as parts from inside the reactor vessel in a nuclear power plant. Low-level waste is typically stored on-site by licensees until amounts are large enough for shipment to a low-level waste disposal site in containers approved by the Department of Transportation.

All actively operating fuel storage facilities must deal with the generation, control and storage of LLW in solid and/or liquid form as a result of normal operation or in response to accidents or emergency response. The type and volume of LLW is highly dependent on the facility mission, building construction, staff training and operating procedures.

6.7.1 Pilot Waste Management

The goal for the Pilot is to generate a relatively small volume of LLW. This includes ventilation exhaust filters, spent ion exchange resin, and other solid and liquid LLW from operations, maintenance and decontamination activities. UNF and GTCC waste will be received in welded canisters, which will not need to be opened in order to store the waste on the storage pads. The canisters will be transferred from the transport over packs (casks) to the storage over packs or modules without having to inspect or handle the individual UNF assemblies or GTCC waste. Keeping the canisters sealed avoids the potential for fuel activation products from that fuel on the outside of the fuel cladding (i.e., “crud”) or through fuel defects to make their way into the waste stream.

To minimize the generation and cost of LLW at the Pilot will require that each utility thoroughly decontaminate their canisters before loading them into transportation casks prior to shipment to Pilot. The Pilot will need to maintain strict acceptance criteria and administrative procedures to ensure that the canisters, containers, and other packages received at the site are free from contamination.

While the Pilot is expected to have low volume of LLW, the facility must still be designed to handle radioactive surveys and decontamination activities including a wash down area. This would be located within the RCA and have coatings on all exposed surfaces to minimize absorption of radiological contaminates into the building structures. There must be facilities to store all solid LLW until sufficient volume is accumulated suitable for shipping offsite to licensed disposal site. Liquid waste is not included for the Pilot because any liquid waste is assumed to be able to be filtered to very low concentrations and released from the facility or reused. Based on the reference studies, estimates for the volume of solid waste generated over the life of the Pilot range from 1,000 ft^3 to 3,000 ft^3.

6.7.2 Larger ISF Waste Management

The larger ISF can be operated in much the same way as the Pilot if storage of the UNF and GTCC waste is done using the as shipped canisters from the utilities. As with the Pilot, the UNF and GTCC waste will be received in welded canisters, which will not need to be opened in order to store the waste on the storage pads.

However, the larger ISF will require a means to repackage UNF and GTCC waste into a storage configuration or DPCs for storage at the ISF and/or shipment to a final repository. This would require either a storage pool and/or a hot cell facility. Transport casks will be transferred to the pool or hot cell and then will be unloaded of their individual UNF assemblies or GTCC waste and placed into the storage pool and/or hot cell to await repackaging for further disposition. The UNF assemblies will release crud into the pool water or hot cell air, making it a source of contamination. The UNF pools and/or hot cells will require cooling, reactivity management and filtration systems. The equipment supporting these functions will become contaminated. Filters and the resins will require periodic replacement, creating another solid waste stream. The metal components will become LLW when they are replaced via maintenance if they cannot be sufficiently decontaminated to a level below concern. The operation of cooling systems will also require periodic maintenance generating LLW.

The facilities that handle all contaminated material, solid or liquid, must be located within the RCA and have coatings on all exposed surfaces to minimize absorption of radiological contaminates into the building structures. Due to the direct handling of UNF and GTCC waste the facility will have accident mitigation equipment and systems. Typically, facilities to store all solid LLW until sufficient volume is accumulated suitable for shipping offsite to licensed disposal site will be provided. Liquid waste is not included for the ISF because any liquid waste is assumed to be able to be filtered to very low concentrations and released from the facility or reused. Estimates for the volume of solid waste generated over the life of the ISF range from 20,000 to 30,000 ft^3. The amount of waste will depend on the number of UNF assemblies stored in these facilities and the storage time.

6.7.3 Non-Standard Storage Canisters

The continued use of non-standard canisters would be the largest single source of LLW. Currently each utility procures and uses any number of storage systems and canisters for their on-site dry cask storage of UNF and GTCC waste. Whether a standard canister is used at the ISF or only for the shipment and storage at the final repository, these non-standard canisters will become LLW and have to be packaged and shipped to a licensed disposal site. As an upper limit, if all current UNF in storage were shipped in non-standard fuel canisters, they would generate about 300,000 tons of LLW. The ISF would need controlled access storage areas for all of the canisters and equipment to compact the LLW for shipment.

Government owned UNF and HLW may add to this volume depending on the final storage canister designs.

6.7.4 Storage Overpacks

All storage and transportation over packs used at the ISF are a potential source of LLW. When empty, storage and transportation over packs would be surveyed to determine activation and contamination levels. Storage and transportation over packs with contamination or activation levels above the applicable NRC limits for unrestricted release would be dismantled, with the activated or contaminated portions segregated to minimize the quantity of LLW, and disposed of as LLW. This can be minimized by strict compliance with administrative procedures to ensure that the canisters are free from contamination prior to loading into the storage over pack.

Government owned UNF and HLW may add to this volume depending on the final storage canisters design.

6.8 Decommissioning

The objective of decontamination and decommissioning activities at the end of the ISF life is to remove all radioactive materials having radioactivity levels above the applicable NRC release limits, in order that the site may be released for unrestricted use, the NRC license terminated, and the site restored to its original green field condition without radiological restrictions.

In 10 CFR 72.130, the NRC requires that an ISFSI be designed for decommissioning, with provisions to facilitate decontamination of structures and equipment, to minimize the quantity of radioactive wastes and contaminated equipment, and to facilitate the removal of radioactive wastes and contaminated materials. In addition, The Environmental Report (ER) that is submitted with the License Application must address the environmental impacts of the decommissioning. Each facility must have a decommissioning plan, as required under 10 CFR 72.30, and contain sufficient information on proposed practices and procedures for decontamination of the site and facilities for the disposal of residual radioactive materials.

Planning for the ISF must include consideration for decommissioning. The layout and design of the site must minimize the handling of all potentially contaminated material and control access and migration from contaminated areas to "clean" areas and prevent cross contamination with hazardous waste. The decommissioning plan must show that the facility is designed to accommodate decommissioning by:

- Selection of materials and processes to minimize waste production
- Minimizing materials that are susceptible to neutron activation
- Use of reinforced concrete structures, that facilitate demolition techniques
- Use of construction materials and surface finishes to minimize porosity, crevices, and rough machine marks on structures, systems, and components
- Use of smooth or special protective coatings or polished stainless steel metal surfaces, where applicable, that preclude penetration into porous materials by radioactive material
- Use of stainless-steel-lined UNF canisters and pools
- Use of confinement systems to contain and minimize the spread of potential radioactive contamination
- Incorporation of features to contain leaks and spills to minimize the number and extent of contaminated areas
- Use of exhaust ducting and HEPA filters for the exhaust ventilation system of areas that may become contaminated

For this study, we identified facility decommissioning costs for use in a life-cycle cost estimate, see Section 8.1, Costs. We assumed the design planning for decommissioning, as discussed above, are included in the normal design and engineering costs.

7. Concept of Operations

This section will take a broad look at the operations of the ISF, starting with construction of the facility, then looking at the loading, transporting and unloading of the containers and then discuss the actual operation of the site. Each section will look at the requirements for the Pilot and then the larger ISF.

7.1 Construction

As discussed previously a phased approach to construction will be used allowing for the facility to be expanded as needed. A Pilot is estimated to provide approximately 150-250 local construction jobs for at least 18 months before starting initial operation. Once the facility commences operation construction resources are anticipated to remain on site as construction proceeds during the subsequent phases until total build-out is completed (up to 20 years for an ISF capable of receiving all UNF and GTCC). The level of manpower will depend on the schedule that is established based on the storage need and construction optimization during this time period. The level of personnel during subsequent phases are expected to be less than or equal to that of the initial construction (approximately 150 personnel).

The ISF, when completed, will typically consist of storage pads, concrete batch plant, rail yard, cask handling building, hot cell research facility, security building, fleet management facility, administrative office building, and visitors' center. Later phases of the build-out would include wet pools to be used to transfer UNF between canisters to prepare for ultimate geologic disposal.

The Pilot will be built to accept transportable shipping canisters in the initial phase and dual purpose canisters in a second phase. Following this the larger ISF will be constructed as needed to support fuel receipt.

7.2 Loading, Transporting and Unloading

When the ISF is ready to accept UNF, the shipping casks will be transported from the existing storage sites to the interim storage facility.

Rail shipments will be the preferred method of shipping, however in some locations it will be necessary to use truck or barge shipments to move the UNF to the nearest railhead. A truck convoy includes the cask trailer, a transport tractor (semi-truck cab), and a shipment security escort vehicle. This would result in a minimum of 6 personnel (two security officers in a lead vehicle, two drivers and 2 security officers in a follow vehicle) per shipment, more if multiple trucks are included in one shipment. Manpower for barge shipments would be similar.

Section 5.3 discusses preliminary fleet estimates to meet operating capability for rail transport.

Transportation of the UNF, HLW, and GTCC is expected, at the height of transportation, to require about 130 FTE for Case 1, Table 5-3. Table 7-1 shows the rail transport and train crews to support the number of shipments that are scheduled for one scenario. Depending on the actual scenario chosen, these numbers will vary.

Table 7-1. Example Breakdown of Staff for Transportation.

Activity	FTE
Transport Security	50
Logistics Coordination	5
Transportation Planning	23
Transportation Management	28
Shipment Tracking	6
Notifications & Communications	8
Security Planning & Management.	8
TOTAL	**128**

7.3 Site Operations

When a rail shipment arrives at the ISF rail yard, the shipment will undergo incoming security and radiological inspections. The transportation casks will then be removed from the train for processing. The cask cars, buffer cars, and security escort cars will then be moved to the maintenance facility for inspection, maintenance, and any necessary repairs in preparation for subsequent shipments. The processing for the casks involves them being unloaded, decontaminated, and certified for public transportation. The casks will then be moved to the maintenance facility for outbound shipment preparation.

At the maintenance facilities they will focus on maintenance of both the transportation equipment and the maintenance of the cask. For the transportation equipment the maintenance operations personnel at the non-radiological location will focus on the repair, reassembly, and final inspection of transporters and equipment. These functions can include maintenance operations; minor repair of rail cars, and any maintenance/repair of any other equipment; replenishment of parts; equipment storage; status tracking of all transport equipment; and records management. Any heavy haul transport truck trailers that arrive at the site will also be maintained by this facility.

The second focus is on reconfiguring the cask to prepare for the next shipment, routine maintenance, and repair when needed. Much of this work will be performed at the on-site cask maintenance facility, which accommodates low-level radiological decontamination. If extensive maintenance or repair activities are required on the cask, they may need to be performed at an off-site vendor facility.

At full operational capacity, the ISF should be planned to be able to process six casks at a time. Receipt, processing, and return of transportation casks should take about take five days per cask. Table 7-2 shows the operational staffing.

Table 7-2. Example Breakdown of Staff for Operational ISF.

Activity	FTE
Rail Yard / Canister Transfer Facility / Storage Pad	64
Management / Engineering / Admin	61
Security Planning & Management	125
TOTAL	250

7.3.1 Used Fuel Pool and Hot Cell

A pool is included in the larger ISF to process bare fuel into canisters or repackage canisters. This pool is sized to support the temporary storage of UNF removed from transportation casks until it can be repackaged for interim storage. It is anticipated that pool operation will be similar to those at the Nuclear Power Plants as far as the handling, shipment and disposal of filters and ion exchange resins are concerned. In addition this pool can be useful for performing R&D activities if needed. During peak operation of the pool and hot lab, pool maintenance, repackaging of UNF and R&D, is expected to add an additional 100 full time employee (FTE).

Currently it is planned to have one larger ISF. If multiple ISFs are employed, more people will be required than for a single ISF because the administrative and other support functions will need to be duplicated. Operations, maintenance, health physics, and security supervision will need to be duplicated at each facility. However, the size of the working staffs will be proportional to the amount of fuel being received and stored at each facility.

7.3.2 Pilot Staffing

Manpower for the Pilot during operation and receipt of fuel would be less than needed for the larger ISF, presented above, due to the lower acceptance rate. It is estimated that it would require approximately 150-200 FTE operations and maintenance staff during operation plus the 100-150 FTE security staff and about 50 FTE during the caretaker phase, which is dominated by the security force requirements.

8. Cost and Schedule Estimates

8.1 Cost

8.1.1 Scope of Cost Estimate

The scope of this project is interim storage and transportation for UNF, GTCC waste, and HLW in two stages – Pilot and larger ISF. The cost estimate includes the management, engineering, design, regulatory/licensing, procurement, construction, and startup of facilities, processes, equipment, and transportation networks to safely transport and store UNF, GTCC, and HLW. The end point of the construction projects is Approve Start of Operations. Specific facilities for which construction estimates are provided include:

- A Pilot with limited capacity capable of accepting used nuclear fuel and high-level radioactive waste and initially focused on serving shut-down reactor sites;
- A larger ISF, potentially co-located with the Pilot and/or with a geologic repository, that provides the needed flexibility in the waste management system and allows for important near-term progress in implementing the federal commitment;
- Transportation systems, equipment, and infrastructure to move UNF from current locations to the Pilot and/or larger ISF.
- Laboratory facility (hot cell)
- Fuel Remediation facility
- Bare Fuel Receipt Facility.

The construction cost estimate includes:

- A Total Project Cost (TPC) range for the Pilot. This TPC includes an initial transportation system and 2 years of storage casks.
- A TPC for the initial phase of the larger ISF including transportation and 2 years of storage casks.
- TPCs for the laboratory, bare fuel receipt, and fuel remediation facilities. These costs are separated from the costs for the larger ISF since they are likely to be managed as separate design and construction projects, and the deployment schedule is uncertain.

8.1.2 Construction Cost Estimate

The organization of the cost estimate, summarized below, is based on five (5) separate and distinct projects – Pilot, and larger ISF, laboratory, fuel remediation facility, and bare fuel receipt facility. The cost for the Pilot includes the activities required to provide the surface structures, improvements (roads, utilities), and initial transportation system to proceed with pilot operations in 2021. Transportation costs for rolling stock and rail/truck casks will be incurred concurrent with construction costs of the Pilot during the first phase. The cost estimate includes the number of pieces of rolling stock identified in Table 5-2, which provides the minimum necessary for the Pilot. The Pilot estimate includes all system engineering, design and engineering, quality assurance, project management, construction management, environment, health, and safety (ES&H), licensing/permitting fees, and contractor fees. Contingency/management reserve is also included at 30%.

The larger ISF includes those activities required to expand the Pilot, referred to as the second phase and roughly occurring between 2021 and 2025. Also, the additional transportation costs needed during construction of the larger ISF are included, along with the soft costs (PM, QA, etc.) and contingency/management reserve. The cost estimate includes the number of pieces of rolling stock identified in Table 5-2, Case 1, which provides the full complement needed for the ISF.

The costs for the laboratory, fuel remediation facility, and bare fuel handling facility are segregated from the other ISF costs. At this time, these facilities are envisioned to be managed as separate projects in parallel with the larger ISF. The schedule for these facilities may be the same as the larger ISF, depending on licensing and other factors.. Table 8-1 summarizes the estimated rough order of magnitude (ROM) cost ranges. Appendix E provides some additional details for the construction costs using the project WBS.

Table 8-1. Interim Storage and Transportation Concepts Construction Cost Estimate Summary in 2012 $ ($M).

	Low	Point Estimate	High
Pilot with Transportation Equipment	705.2	1,007.5	1,511.2
ISF with Transportation Equipment	1,603.1	2,290.2	3,435.3
Laboratory Facility	748.7	1,069.6	1,604.4
Fuel Remediation Facility	453.4	647.8	971.6
Bare Fuel Receipt Facility	1,073.5	1,533.6	2,300.4

8.1.3 Operations Cost Estimate

Total operations costs are reported here for 1) annual Operating & Maintenance (O&M) costs associated solely with the interim storage facility, and 2) transportation costs associated with moving UNF from the generator sites to the interim storage facility. These costs are reported on a fiscal year basis for the duration when the Pilot is in operation (~2021 - 2026). Projections are also made for operations costs post-2026, when the ISF operates.

8.1.3.1 *Annual Facility O&M Costs.*

The O&M estimate includes:

- Cask handling
- Storage system monitoring
- R&D
- Maintenance
- Security
- Program management

At full complement, facility staffing includes about 240 personnel. This staffing ramps up during Pilot, beginning with about 165 people in 2021. Staffing includes the full complement of 125 security personnel starting in 2021. In addition to labor, O&M costs include materials, spare parts, utilities, supplies, taxes and insurance, and a 15% contingency on annual operating expenses.

8.1.3.2 *Annual Transportation Costs*

The Transportation cost estimate includes logistics, planning, utility coordination, loading of fuel onto transport rail, intermodal transport from plant site to rail heads, railroad contracts, transport security, and all other costs associated with the transport of UNF from the plant sites to the ISF, including road locomotive leasing. Funding to states and Native American tribes to support planning and emergency response is included. The full complement of Transportation staffing includes about 180 personnel, including 50 transport security people. As with facility O&M costs, transportation staffing ramps up during Phase I. In 2021, the staffing begins at about 40 people.

8.1.3.3 *Summary Operations Costs*

Table 8-2 is a summary tabulation of annual Operations.

Table 8-2. Annual Operations Costs ($M) in 2012$, Unescalated.

Item	2021	2022	2023	2024	2025	2026	Post-2026
O&M Costs[1]	36.5	43.6	46.7	49.7	53	53	53(1)
Transportation	18.5	24	29.3	34.7	40.1	40.1	40.1
Total	55	67.6	76	84.4	93.1	93.1	93.1

[1] O&M costs increase to $685M per year from 2033-2055 due to purchase of 9000 DFSS Canisters/Overpacks.

Table 8-3 provides a summary tabulation of annual FTEs used for the cost estimate.

Table 8-3. Annual Full-Time Equivalents (FTEs).

	2021	2022	2023	2024	2025	2026	Post-2026
O&M	165	187	195	203	212	212	212[1]
Transportation	40	50	64	77	90	90	180
Total	205	237	259	280	302	302	

[1] 240 people needed starting 2035.

8.1.4 Decommissioning

The estimate for decommissioning the ISF at the end of useful life, including supporting facilities, is $480M. This cost is in 2012 dollars and is included for evaluation of facility life-cycle cost estimates. This cost is not included in the facility capital costs.

8.2 Schedule

The schedules for development of the Pilot and larger ISF are part of the NFST Project Plan. Table 8-4 provides key milestones for the design, construction, and operation of the Pilot and ISF and the supporting facilities.

Table 8-4. Key Milestones for Pilot and Larger ISF (Notional Schedule).

Activity	Pilot	Larger ISF and supporting facilities
Pre-Conceptual Designs Completed	FY14	FY14
Approve Mission Need / Approve Alternative and Cost Range	FY14	FY17
Approve Project Baseline	FY15	FY19
Complete Siting Process – Record of Decision	FY16	--
Approve Start of Construction	FY16	FY21
Approve Start of Operations	FY 20	FY24

Table 8-5 is a notional schedule for developing the transportation equipment to support the Pilot and larger ISF.

Table 8-5. Key Milestones for Transportation Equipment for Pilot and Larger ISF (Notional Schedule).

Activity	Pilot	Larger ISF
Pre-Conceptual Designs Completed	FY14	FY14
Approve Mission Need / Approve Alternative and Cost Range)	FY14	FY17
Approve Project Baseline	FY15	FY18
Approve Start of Construction	FY16	FY20
Approve Start of Operations	FY19	FY23

9. Next Steps

The first objective of this section is to provide information on the research and development needs that would support the ISF program, which cover a broad range of subjects, many of which are related to the recommendations of the BRC. A second objective is to outline the project management strategy, with particular emphasis on a Tailoring Strategy. This discussion focuses on a plan to phase the overall NFST program into smaller, more manageable projects.

9.1 R&D Needed

The Office of Fuel Cycle Technology (in DOE-NE) established the UFDC to conduct the research and development activities related to storage, transportation, and disposal of used nuclear fuel and high-level radioactive waste. All R&D prioritization and execution will be overseen by UFDC and not the NFST Planning Project. The mission of the UFDC is to identify alternatives and conduct scientific research and technology development to enable storage, transportation, and disposal of used nuclear fuel (UNF) and wastes generated by existing and future nuclear fuel cycles. The Storage and Transportation activities within the UFDC are being developed to address issues regarding the extended storage of UNF and its subsequent transportation. The near-term objectives of the storage and transportation task are to use a science-based, engineering-driven approach to develop the technical bases to support the continued safe and secure storage of UNF for extended periods, subsequent retrieval, and transportation.

While both wet and dry storage have been shown to be safe options for storing UNF, the focus of the program is on dry storage of commercial UNF at reactor or centralized locations. Because limited information is available on the properties of high burnup fuel (exceeding 45 gigawatt-days per metric ton of uranium [GWd/MTU]), and because much of the fuel currently discharged from today's reactors exceeds this burnup threshold, a particular emphasis of this program is on high burnup fuels.

DOE Used Fuel Disposition Campaign issued *Review of Used Nuclear Fuel Storage and Transportation Technical Gap Analyses*, FCRD-USED-2012-000215, July 31, 2012. This report identified a collective total of 94 technical data gaps identified by the various reports to support extended storage and transportation of UNF. This report focuses on the gaps identified as Medium or High in any of the gap analyses and provides the UFDC's gap description, any alternate gap descriptions or different emphasis by another organization, the rankings by the various organizations, evaluation of the consistency of priority assignment and the bases for any inconsistencies, and UFDC-recommended action based on the comparison. Gaps that are ranked Low by all organizations and countries are not evaluated in this report.

As stated in the UFDC Gap Analysis (UFDC 2012a) and UFDC Gap Prioritization (UFDC 2012b) reports, as more data are obtained, all gaps are subject to reevaluation of priority. Continued collaboration with other organizations and countries will ensure that the UFDC is pursuing the proper course to obtain the data and analyses necessary to develop the technical bases for continued safe and secure storage.

NFST will monitor the R&D program results and reflect necessary items in changes to the project baseline.

9.2 Project Planning by Phases

9.2.1 Acquisition of Capital Assets

The ultimate objective is to deliver every project at the original performance baseline, on schedule, within budget, and fully capable of meeting mission performance, safeguards and security, quality assurance, sustainability, and environmental, safety, and health requirements.

The Project Management Strategy establishes principles and processes that translate user needs and technological opportunities into reliable and sustainable facilities, systems, and assets that provide a required mission capability. The project is organized by project phases and staged decisions progressing from broadly-stated mission needs into well-defined requirements resulting in operationally effective, suitable, and affordable facilities, systems, and other products.

9.2.2 Phasing

An important strategy to consider in planning a large, complex program such as NFST is the concept of project phasing. Phasing refers to breaking the scope of the program down into smaller, related, complete and useable facilities.

Subsequently, each smaller project would be further phased into smaller subprojects, each with its own distinct performance baseline) with clearly defined technical scope, cost, and schedule. As each subproject progress further, each would receive separate approvals to proceed into construction, and approval to start operations.

9.2.3 Next Steps

The NFST will be performing additional design activities to further define the possible design solutions to meet the project mission need. These activities will occur in parallel with the consent-based siting process to further the implementation of nuclear fuels interim storage and transportation systems to allow the Federal government to meet its legal and contractual obligations.

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Appendix A

Commercial Used Nuclear Fuel Inventory

Commercial UNF assemblies are categorized by physical configuration into 22 classes: 16 PWR and 6 BWR fuel assembly classes. Commercial UNF data have been collected by the Energy Information Administration for the Office of Civilian Radioactive Waste Management (OCRWM). Additional details on these fuel assembly classifications can be found in Fuel Cycle Potential Waste for Disposition (Used Fuel Disposition Campaign (UFD) Inventory [Carter 2012]). See Section 6.2 for impact on the design and operation of the ISF.

The source of current inventory data for this study is information collected in support of the OCRWM (DOE-RW) efforts for licensing the Yucca Mountain Repository. [DOE, 2008] Information collected from RW-859 forms is available on an assembly basis for UNF discharges from 1968 through 2002.

To develop an inventory estimate through 2012, fuel discharge predictions developed for the Nuclear Energy Institute in 2005 were used to estimate the number of assemblies and metric tons of uranium. [Gutherman, 2009] To estimate the average enrichment and burn-up through 2012, projections made by utilities as part of the RW Form 859 surveys were used. These projections are documented in OCRWM's "Calculation Method for the Projection of Future Spent Fuel Discharges", February 2002. [OCRWM, 2002] These projections identified a burn-up increase of 2.38% per year for BWR fuel and 1.11% per year for PWR fuel through 2010. The enrichment increased at the same rate as burn-up. Comparison of these projections made in 1998 to actual data collected through 2004 show very good agreement (PWR - actual 46,950 MWd/MTU vs. projected 46,922 MWd/MTU; BWR - actual 43,447 MWd/MTU vs. 42,787 projected MWd/MTU). However, more recently the number of reactors obtaining approved thermal power "uprates" has decreased and the corresponding burn-up increases are less than the percentages indicated above.

Current UNF inventory estimates and future discharge forecast will vary depending upon the selection of values for key factors in the estimating calculations and upon assumptions regarding the number of NPP and their operating lifetimes.

The NFST project has selected a NPP scenario assuming only existing plants (no new NPPs). The existing plants, except for three NPP with owner announced shutdown dates, are assumed to have one 20 year life extension and will be decommissioned after 60 years of operation. Applying these assumptions the last nuclear generator finishes operations in 2055. See Table 3-1.

In FY2012 the UFD Campaign sponsored multiple UNF projections for this scenario as a part of the logistical modeling update effort. As part of this work different assumptions were used for the major variables that affect the projection. [Kalinina, 2012] These parameters effectively provide a range for the forecast fuel quantities that will be generated by the no replacement scenario. The results of four cases indicate a range of about 10%.

Since 2002 essentially all fuel generated has remained on the generating reactor sites in either pool or dry storage. Prior to 2002 some discharged UNF was transferred to other locations. Approximately 70 MT was transferred to the Idaho National Laboratory (INL) for research and development purposes such as fuel rod consolidation and dry storage demonstrations. Table A-9 provides additional details on fuel transferred to INL. This fuel has been transferred to the DOE and is not stored in NRC licensed facilities and will not be considered further in this study, however, it could be considered as government-owned fuel to be handled in the ISF at a later date.

Five reactors transferred some of their discharged fuel to the pool storage facility at Morris, Ill. Table A-1 details the transfers to Morris which totals 3,217 assemblies and approximately 675 MTU. This fuel will be considered for transfer to the larger interim storage facility.

Table A-1. UNF Transferred to Pool Storage at Morris, Illinois.

		Discharges as of Dec 2002		Transferred to Morris		Remaining Inventory	
Reactor	**Reactor Status**	**Assemblies**	**Initial Uranium (MT)**	**Assemblies**	**Initial Uranium (MT)**	**Assemblies**	**Initial Uranium (MT)**
Dresden 2	Operating	3,741	678.72	753	145.19	2,988	533.53
Cooper	Operating	2,593	447.01	1,054	198.02	1,539	278.99
Monticello	Operating	2.400	434.25	1,058	198.19	1,342	236.07
San Onofre 1	Shutdown	665	244.61	270	98.41	395	146.21
Haddam Neck	Stranded	1.102	447.17	82	34.48	1,020	412.70
			Total	3,217	674.29		

The Pilot will focus on the UNF at stranded and shutdown sites and any additional sites or materials based on feedback from volunteer host organizations. Table A-2 details fuel at the nine stranded sites was discharged from 10 reactors. The current stranded site inventory includes 7,651 assemblies and contains approximately 2,813 MTU.

Table A-2. Fuel at Stranded Reactor Sites.

		Discharges as of Dec 2002		Transferred to Morris or INL		Remaining Inventory	
Reactor	**Shutdown Date**	**Assemblies**	**Initial Uranium (MT)**	**Assemblies**	**Initial Uranium (MT)**	**Assemblies**	**Initial Uranium (MT)**
Big Rock Point	8/29/1997	527	69.53	85	11.48	442	58.05
Haddam Neck	12/5/1996	1,102	447.17	83	34.89	1,019	412.29
Humboldt Bay 3	7/2/1976	390	28.94			390	28.94
LaCrosse	4/30/1987	334	38.09			334	38.09
Maine Yankee	12/6/1996	1.434	542.26			1.434	542.26
Rancho Seco	6/7/1989	493	228.38			493	228.38
Trojan	11/9/1992	780	358.85			780	358.85
Yankee Rowe	10/1/1991	533	127.13			533	127.13
Zion 2	2/21/1997	1,143	523.95			1,143	523.95
Zion 1	9/16/1996	1,083	495.49			1,083	495.49
Total Stranded		**7.819**	**2,859.79**			**7,651**	**2, 813.42**

In addition, utilities have announced that 3 of the currently licensed NPP will be shutdown before the planned start of the Pilot. Crystal River was last operated in 2009 and will not be restarted, Kewaunee will be shutdown in the second quarter of 2013 and Oyster Creek will be shutdown in 2019. Table A-3 provides these details. These additional plants will bring the total stranded inventory and the minimum inventory planned for transfer to the Pilot to 14,926 assemblies containing approximately 4,800 MTU.

Table A-3. Fuel at Future Stranded Sites.

		Discharges as of Dec 2002		Forecast Future Discharges		Forecast Discharged Fuel	
Reactor	**Announced Shutdown Date**	**Assemblies**	**Initial Uranium (MT)**	**Assemblies**	**Initial Uranium (MT)**	**Assemblies**	**Initial Uranium (MT)**
Crystal River 3*	2009*	824	382.32	311	149.59	1,135	531.90
Kewaunee	2013	904	347.60	338	135.09	1,242	482.69
Oyster Creek	2019	2,800	503.51	1,840	316.48	4,640	819.99
Total Future Stranded		4,528	1,233.43	2,489	601.15	7,017	1,834.58

* 2013 announcement: Crystal River 3 will not be restarted; last operated in 2009

As this report was being finalized San Onofre announce that units 2 and 3 would not be restarted, these quantities have not been included here

The sum for both current and expected future stranded plants is: 14,668 assemblies and 4,648.00 MT (initial Uranium).

Table A-4 details four shutdown reactors co-located on site with operating reactors. The shutdown reactors discharged 4,601 assemblies with 3 assemblies transferred to INL and 270 assemblies transferred to Morris. The remaining shutdown reactor inventory is 4,328 assemblies containing approximately 793 MTU.

Table A-4. Fuel at Shutdown Reactor Sites (with operating reactors at same site).

		Discharges as of Dec 2002		Transferred to Morris		Remaining Inventory	
Reactor	**Shutdown Date**	**Assemblies**	**Initial Uranium (MT)**	**Assemblies**	**Initial Uranium (MT)**	**Assemblies**	**Initial Uranium (MT)**
Dresden 1	10/31/1978	892	90.86	3	0.26	889	90.59
Indian Point 1	10/31/1974	160	30.58			160	30.58
Millstone 1	7/21/1998	2,884	525.62			2,884	525.62
San Onofre 1	11/30/1992	665	244.61	270	98.41	395	146.21
Total Shutdown		**4,601**	**891.68**			**4,328**	**793.01**

As this report was being finalized San Onofre announce that units 2 and 3 would not be restartedthe SONGS 1 quantities wiil be moved to the future stranded category in later revisions

This stranded fuel is currently stored in a combination of pool and dry storage systems although all fuel is planned to be moved to dry storage before 2021. Tables A-5 and A-6 provide the storage systems (dry storage container, storage and transport cask) and the quantities of the fuel and GTCC waste casks at the current and future stranded sites.

Table A-5. Cask Systems Used at Currently Stranded Sites.

Reactor Site	Type	ISFSI Load Dates[a]	Storage System/Canisters	Transport Cask Status	Number of Canisters Fuel/GTCC
Big Rock Point	BWR	12/2002-03/2003	Fuel Solutions W150 Storage Overpack/W74 Canister	TS-125 (Docket No. 71-9276); Certificate expires 10/31/2017. None fabricated	7/1
Haddam Neck	PWR	05/2004-03/2005	NAC-MPC/MPC-26 and MPC-24 canisters	NAC-STC (Docket No. 71-9235); Certificate expires 5/31/2014. Foreign use versions fabricated.	40/3
Humboldt Bay 3	BWR	08/2008-12/2008	Holtec HI-STAR HB/MPC-HB canister	HI-STAR HB (Docket No. 71-9261); Certificate expires 3/31/2014. Fuel in canisters in fabricated casks. No impact limiters.	5/1[b]
LaCrosse	BWR	07/2012- 09/2012	NAC MPC-LACBWR/MPC-LACBWR canister	NAC-STC (Docket No. 71-9235); Certificate expires 5/31/2014. Foreign use versions fabricated.	5[c]
Maine Yankee	PWR	08/2002-03/2004	NAC-UMS/UMS-24 canister	NAC-UMS (Docket No. 71-9270); Certificate expires 10/31/2017. None fabricated	60/4
Rancho Seco	PWR	04/2001-08/2002	TN NUHOMS/FO-DSC, FC-DSC, and FF DSC	NUHOMS MP187 (Docket No. 71-9255); Certificate expires 11/30/2013. One cask fabricated. No impact limiters.	21/1
Trojan	PWR	12/2002-09/2003	TranStor Storage Overpack/Holtec MPC-24E and MPC-24EF canisters	HI-STAR 100 (Docket No. 71-9261) Certificate expires 3/31/2014. Units fabricated but dedicated to storage at other sites. No impact limiters	34/0
Yankee Rowe	PWR	06/2002-06/2003	NAC-MPC/MPC-36 canister	NAC-STC (Docket No. 71-9235); Certificate expires 05/31/2014. Foreign use versions fabricated	15/1
Zion 1 and 2	PWR	Planned 2013	NAC MAGNASTOR/TSC 37 canister	NAC MAGNATRAN (Docket No. 71-9356); License under review. None fabricated	61[c,d]

ISFSI = independent spent fuel storage installation, BWR= boiling water reactor, PWR= pressurized water reactor

a. Dates represent the dates that the used nuclear fuel was transferred to the ISFSI.

b. One canister of GTCC low-level radioactive is expected to be loaded and transferred to the Humboldt Bay ISFSI in Spring 2013 (NRC 2012b).

c. Additional canisters of GTCC low-level radioactive waste could be generated during decommissioning.

d. Estimated.

Except for Oyster Creek, all the stranded fuel sites have implemented a dry storage system. Oyster Creek is in the planning stages for dry fuel storage and is currently planning to use the TransNuclear system indicated, although this is subject to change.

Table A-6. Cask Systems Used at Future Stranded Sites.

Reactor Site	Type	ISFSI Load Dates[a]	Storage System/Canisters	Transport Cask Status	Number of Canisters Fuel/GTCC
Crystal River 3*	PWR	N/A	Does not have a licensed ISFSI, early selection TransNuclear, NUHOMS 32PTH1 storage canister, in a Horizontal Concrete Overpack	TN MP197HB (Docket No. 71-9302); This cask is not currently licensed for the 32PTH1 payload; One in fabrication	41/?[b,c] None loaded
Kewaunee	PWR	2009-??	TransNuclear, NUHOMS 32PT storage canister, in a Horizontal Concrete Overpack	TN MP197HB (Docket No. 71-9302); This cask is not currently licensed for the 32PT payload; One in fabrication	42/? [b,c] 8 DCS loaded
Oyster Creek	BWR	2002-??	TransNuclear, NUHOMS 61BT storage canister, in a Horizontal Concrete Overpack	TN MP197HB (Docket No. 71-9302); One in fabrication	77/? [b,c] 23 DCS loaded

ISFSI = independent spent fuel storage installation, BWR= boiling water reactor, PWR= pressurized water reactor

a. Dates represent the dates that the used nuclear fuel was transferred to the ISFSI.

b. Additional canisters of GTCC low-level radioactive waste could be generated during decommissioning.

c. Estimated.

d. Actual Canisters loaded as of 2/5/2013.

As this report was being finalized San Onofre announce that units 2 and 3 would not be restarted, these quantities have not been included here

Figure A-7 provides information on the dry cask storage systems used at current shutdown plants, with operating reactors on the same site.

Table A-7. Cask Systems Used at Shutdown Sites.

Reactor Site	Type	ISFSI Load Dates[a]	Storage System/Canisters	Transport Cask Status	Number of Canisters Fuel/GTCC
Dresden 1	BWR	2000-ongoing	HI-STAR 100 Vertical Metal Cask containing MPC-68 DSC	HI-STAR 100 (Docket No. 71-9261) Certificate expires 3/31/2014. No impact limiters	4/0
Dresden 1	BWR	2000-ongoing	HI-STORM Vertical Concrete Storage Cask containing MPC-68 DSC	HI-STAR 100 (Docket No. 71-9261) Certificate expires 3/31/2014. No impact limiters	49/0
Indian Point 1	PWR	2008	HI-STORM Vertical Concrete Storage Cask containing MPC-32 DSC	HI-STAR 100 (Docket No. 71-9261) Certificate expires 3/31/2014. No impact limiters	5
Millstone 1	PWR	2005	NUHOMS 32PT DSC in a horizontal concrete storage module	TN MP197HB (Docket No. 71-9302); This cask is not currently licensed for the 32PT payload; One in fabrication	18
San Onofre 1	PWR	2005	NUHOMS 24PT1 DSC in a horizontal concrete storage module.	TN MP197HB (Docket No. 71-9302); This cask is not currently licensed for the 24PT1 payload; One in fabrication. TN-187 (Certificate USA/9255/B(U)F-85) has the 24PT1 as a licensed payload. Only a single TN-187 has been fabricated and is has been replaced with the MP-197HB.	18/0

ISFSI = independent spent fuel storage installation, BWR= boiling water reactor, PWR= pressurized water reactor

a. Dates represent the dates that the used nuclear fuel was transferred to the ISFSI.

b. Additional canisters of GTCC low-level radioactive waste could be generated during decommissioning.

c. Estimated.

d. Actual Canisters loaded as of 2/5/2013.

As this report was being finalized San Onofre announce that units 2 and 3 would not be restartedthe SONGS 1 quantities wiil be moved to the future stranded category in later revisions

Table A-8 provides the total list of UNF discharges by site.

Table A-8. Total Fuel Discharges by Reactor Site.

	Fuel Discharged Prior to 12/31/2002		Forecast Discharges to 12/31/2012		Forecast Future Discharges		Forecast Discharged Fuel	
Reactor	Assy.	Initial Uranium (MT)	Assy.	Initial Uranium (MT)	Assy.	Initial Uranium (MT)	Assy.	Initial Uranium (MT)
Arkansas Nuclear 1	1,043	482.35	359	166.45	1,008	467.37	2,410	1,116.17
Arkansas Nuclear 2	1,026	425.78	589	252.02	1,320	564.79	2,935	1,242.58
Beaver Valley 1	876	404.67	480	221.62	1,221	563.74	2,577	1,190.03
Beaver Valley 2	580	268.22	438	202.26	1,618	747.17	2,636	1,217.64
Braidwood 1	726	307.58	606	254.09	2,131	893.49	3,463	1,455.16
Braidwood 2	759	321.15	602	252.44	2,243	940.58	3,604	1,514.17
Browns Ferry 1	1,584	294.77	1,082	190.90	3,682	649.63	6,348	1,135.30
Browns Ferry 2	2,952	541.77	1,815	307.80	4,308	730.58	9,075	1,580.15
Browns Ferry 3	2,160	393.67	1,634	277.36	4,422	750.60	8,216	1,421.63
Brunswick 1	2,360	427.58	1,264	225.80	3,380	603.79	7,004	1,257.17
Brunswick 2	2,356	428.62	1,245	222.14	3,006	536.35	6,607	1,187.11
Byron 1	932	394.65	594	249.68	1,972	828.89	3,498	1,473.21
Byron 2	854	361.76	512	214.94	2,159	906.37	3,525	1,483.07
Callaway	1,118	479.04	570	237.80	2,200	917.81	3,888	1,634.64
Calvert Cliffs 1	1,242	477.45	454	185.14	1,195	487.31	2,891	1,149.90
Calvert Cliffs 2	1,068	409.44	531	214.84	1,268	513.02	2,867	1,137.29
Catawba 1	944	416.26	586	266.79	1,790	814.95	3,320	1,498.01
Catawba 2	836	366.16	596	271.34	1,835	835.43	3,267	1,472.94
Clinton	1,580	288.79	1,548	276.61	5,922	1,058.18	9,050	1,623.58
Columbia Generating Station	2,244	394.68	1,423	250.78	5,146	906.89	8,813	1,552.35
Comanche Peak 1	744	319.60	535	222.87	2,641	1,100.16	3,920	1,642.63
Comanche Peak 2	529	221.11	618	256.33	2,619	1,086.28	3,766	1,563.73

	Fuel Discharged Prior to 12/31/2002		Forecast Discharges to 12/31/2012		Forecast Future Discharges		Forecast Discharged Fuel	
Reactor	Assy.	Initial Uranium (MT)	Assy.	Initial Uranium (MT)	Assy.	Initial Uranium (MT)	Assy.	Initial Uranium (MT)
Cooper	2,593	477.01	780	139.07	2,335	416.31	5,708	1,032.38
Crystal River 3	824	382.32	488	234.72	-	-	1,312	617.04
Davis-Besse	821	385.17	358	174.22	1,013	492.98	2,192	1,052.37
Diablo Canyon 1	908	397.20	541	228.05	1,904	802.60	3,353	1,427.86
Diablo Canyon 2	828	363.64	544	232.09	1,868	796.96	3,240	1,392.69
D.C.Cook 1	1,238	556.11	583	265.27	1,203	547.37	3,024	1,368.74
D.C.Cook 2	960	412.88	611	256.10	1,591	666.87	3,162	1,335.84
Dresden 2	3,741	678.72	1,237	213.55	2,755	475.62	7,733	1,367.89
Dresden 3	2,976	532.01	1,220	209.86	2,747	472.53	6,943	1,214.40
Duane Arnold	1,912	347.85	939	167.14	2,263	402.81	5,114	917.81
Hatch 1	3,079	560.00	1,152	205.30	2,942	524.31	7,173	1,289.61
Hatch 2	2,756	500.50	1,143	202.35	3,523	623.68	7,422	1,326.52
Fermi2	1,708	304.58	1,401	240.40	4,806	824.67	7,915	1,369.65
Fort Calhoun	839	304.95	301	112.28	779	290.59	1,919	707.81
Grand Gulf 1	3,160	560.16	1,472	261.22	5,643	1,001.40	10,275	1,822.79
Robinson 2	1,149	498.94	366	159.21	826	359.31	2,341	1,017.46
Hope Creek 1	2,376	431.47	1,522	271.19	5,770	1,028.10	9,668	1,730.77
Indian Point 2	1,078	491.16	440	197.73	1,152	517.70	2,670	1,206.60
Indian Point 3	833	381.87	511	230.62	1,180	532.54	2,524	1,145.02
FitzPatrick	2,664	483.71	988	177.34	2,644	474.57	6,296	1,135.62
Farley 1	1,050	473.60	496	209.92	1,255	531.16	2,801	1,214.68
Farley 2	961	430.15	406	171.76	1,468	621.05	2,835	1,222.96
Kewaunee	904	347.60	298	119.10	121	48.36	1,323	515.06
LaSalle 1	2,194	397.21	1,438	254.68	5,022	889.43	8,654	1,541.32
LaSalle 2	1,912	347.34	1,673	296.51	5,866	1,039.63	9,451	1,683.47

	Fuel Discharged Prior to 12/31/2002		Forecast Discharges to 12/31/2012		Forecast Future Discharges		Forecast Discharged Fuel	
Reactor	Assy.	Initial Uranium (MT)	Assy.	Initial Uranium (MT)	Assy.	Initial Uranium (MT)	Assy.	Initial Uranium (MT)
Limerick 1	2,335	419.87	1,342	238.36	5,315	944.04	8,992	1,602.28
Limerick 2	2,266	404.09	1,379	244.71	5,774	1,024.63	9,419	1,673.44
McGuire 1	1,072	476.90	519	236.26	1,738	791.18	3,329	1,504.34
McGuire 2	1,020	453.43	585	266.32	1,816	826.74	3,421	1,546.50
Millstone 2	1,020	401.42	472	188.06	1,206	480.52	2,698	1,070.01
Millstone 3	654	300.82	454	206.66	1,989	905.39	3,097	1,412.88
Monticello	2,400	434.25	730	124.49	2,030	346.18	5,160	904.92
Nine Mile Point 1	2,524	458.37	808	137.28	2,183	370.89	5,515	966.55
Nine Mile Point2	1,932	343.18	1,453	246.86	5,830	990.52	9,215	1,580.56
North Anna 1	926	427.76	449	208.67	1,232	572.56	2,607	1,208.99
North Anna 2	964	445.79	383	177.95	1,348	626.33	2,695	1,250.07
Oconee 1	1,186	553.04	431	200.18	880	408.72	2,497	1,161.94
Oconee 2	1,156	538.79	356	163.51	983	451.49	2,495	1,153.79
Oconee 3	1,103	513.70	430	203.12	1,050	496.00	2,583	1,212.82
Oyster Creek	2,800	503.51	862	148.26	978	168.22	4,640	819.99
Palisades	1,081	433.11	434	186.83	964	414.98	2,479	1,034.92
Palo Verde 1	948	399.46	594	259.44	2,368	1,034.28	3,910	1,693.19
Palo Verde 2	948	399.32	706	308.15	2,359	1,029.65	4,013	1,737.12
Palo Verde 3	851	358.99	718	313.53	2,531	1,105.23	4,100	1,777.76
Peach Bottom 2	3,594	648.16	1,444	258.57	3,447	617.23	8,485	1,523.96
Peach Bottom 3	3,333	605.13	1,415	251.54	3,804	676.23	8,552	1,532.90
Perry 1	2,088	378.36	1,496	268.32	5,566	998.32	9,150	1,645.01
Pilgrim 1	2,274	413.90	808	141.19	2,144	374.64	5,226	929.73
Point Beach1	920	350.69	224	88.47	562	221.96	1,706	661.11
Point Beach 2	802	304.41	273	107.81	612	241.68	1,687	653.89

	Fuel Discharged Prior to 12/31/2002		Forecast Discharges to 12/31/2012		Forecast Future Discharges		Forecast Discharged Fuel	
Reactor	**Assy.**	**Initial Uranium (MT)**	**Assy.**	**Initial Uranium (MT)**	**Assy.**	**Initial Uranium (MT)**	**Assy.**	**Initial Uranium (MT)**
Prairie Island 1	909	336.62	296	103.98	827	290.52	2,032	731.13
Prairie Island 2	906	336.04	294	103.11	850	298.09	2,050	737.24
Quad Cities 1	3,161	569.96	1,218	211.76	3,338	580.35	7,717	1,362.07
Quad Cities 2	2,955	536.56	1,236	213.25	3,101	535.02	7,292	1,284.82
River Bend 1	2,148	383.88	1,273	223.27	4,473	784.53	7,894	1,391.68
R. E. Ginna	1,007	372.66	322	111.39	679	234.90	2,008	718.95
Saint Lucie 1	1,369	524.37	454	181.15	1,295	516.71	3,118	1,222.22
Saint Lucie2	909	346.35	494	197.10	1,498	597.68	2,901	1,141.13
Salem 1	992	457.82	449	204.35	1,426	649.01	2,867	1,311.19
Salem 2	812	374.84	519	236.98	1,569	716.41	2,900	1,328.22
San Onofre 2	1,096	454.86	592	257.52	1,582	688.17	3,270	1,400.55
San Onofre 3	999	412.18	588	255.78	1,657	720.80	3,244	1,388.76
Seabrook 1	624	287.24	572	259.84	2,132	968.50	3,328	1,515.59
Sequoyah 1	815	375.22	542	246.07	1,567	711.42	2,924	1,332.70
Sequoyah 2	884	407.35	565	256.51	1,648	748.19	3,097	1,412.05
Shearon Harris 1	577	259.14	450	206.10	1,626	744.71	2,653	1,209.94
South Texas 1	627	339.21	532	282.49	1,808	960.05	2,967	1,581.75
South Texas2	627	338.56	433	229.92	1,952	1,036.51	3,012	1,604.99
Surry 1	1,015	464.27	437	201.81	974	449.79	2,426	1,115.87
Surry 2	998	456.86	441	203.54	1,009	465.70	2,448	1,126.09
Susquehanna 2	2,956	521.39	1,373	243.71	5,549	984.95	9,878	1,750.04
Susquehanna 1	2,584	455.50	1,368	242.82	6,129	1,087.90	10,081	1,786.21
Three Mile Island 1	898	416.08	351	170.61	933	453.49	2,182	1,040.17
Turkey Point 3	941	430.31	400	181.20	862	390.49	2,203	1,001.99
Turkey Point 4	939	429.57	382	173.05	967	438.05	2,288	1,040.67

	Fuel Discharged Prior to 12/31/2002		Forecast Discharges to 12/31/2012		Forecast Future Discharges		Forecast Discharged Fuel	
Reactor	**Assy.**	**Initial Uranium (MT)**	**Assy.**	**Initial Uranium (MT)**	**Assy.**	**Initial Uranium (MT)**	**Assy.**	**Initial Uranium (MT)**
Vermont Yankee	2,671	488.35	800	143.23	2,726	488.06	6,197	1,119.64
Summer	812	353.86	463	193.07	1,406	586.30	2,681	1,133.24
Vogtle 1	900	397.26	609	257.74	2,168	917.55	3,677	1,572.56
Vogtle 2	739	323.56	548	231.81	2,380	1,006.79	3,667	1,562.16
Waterford 3	960	396.35	644	274.65	2,195	936.10	3,799	1,607.10
WattsBar 1	297	136.55	562	258.52	2,091	961.86	2,950	1,356.93
Wolf Creek 1	925	427.26	584	266.48	1,925	878.38	3,434	1,572.12
Total	**151,226**	**43,247**	**77,545**	**22,447**	**240,813**	**69,228**	**469,584**	**134,923**

Table A-9 lists the UNF transferred from NPPS to INL. Table A-10 provides additional details on dry cask storage by NPPs.

Table A-9. UNF Transferred to Idaho National Laboratory.

		Discharges as of Dec. 2002		Transferred to INL	
Reactor	**Status**	**Assemblies**	**Initial Uranium (MT)**	**Assemblies**	**Initial Uranium (MT)**
Robinson 2	Operating	1,149	498.94	1	0.44
Peach Bottom 2	Operating	3,594	648	2	0.38
Peach Bottom 1	Operating	920	350.69	6	2.36
R. E. Ginna	Operating	1,007	372.66	40	15/29
Surry 1	Operating	1,015	464.27	1	0.45
Surry 2	Operating	998	456.86	68	31/03
Turkey Point 3	Operating	941	430.31	18	8.18
Dresden 1	Shutdown	892	90.86	3	0.26
Big Rock Point	Stranded	527	69.53	85	11.48
Total				**225**	**70.30**

Table A-10. Dry Storage Details.

U.S. Dry Storage Details (03/05/2013)

Utility	Reactor	Type	License Type	Year of First Load [14]	Vendor	Cask System	Canister or Cask Type	Total Canisters or Casks Loaded	Assemblies Stored	MTiHM (Based on Average Assembly)	Storage Configuration	Primary Canister Transportation Cask (License Num.)	Primary Transport Cask Fabricated?	Alternative Canister Transportation Cask	Alternate Transport Cask Fabricated?	Bare Fuel Cask Transportation License (License Number)	"Storage Only" Canisters or Casks	Minimum Lead Time for Shipment
AEP	D.C.Cook	PWR	GL	2012	Holtec	HI-STORM	MPC-32	12	384	167.2	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
APS	Palo Verde	PWR	GL	2003	NAC	NAC-UMS	UMS-24	98	2352	1,024.3	Canister in Vertical Concrete Overpack	NAC-UMS (71-9270)	No	NAC-MAGNASTOR	No			24 Months[8]
Constellation	Calvert Cliffs	PWR	SS	1992	TN	NUHOMS	24P	48	1152	501.7	Canister in Horizontal Concrete Overpack		No		No		24P	36 Months[10]
Constellation	Calvert Cliffs	PWR	SS	1992	TN	NUHOMS	32P	24	768	334.5	Canister in Horizontal Concrete Overpack		No		No		32P	36 Months[10]
Constellation	Ginna	PWR	GL	2010	TN	NUHOMS	32PT	6	192	83.6	Canister in Horizontal Concrete Overpack	MP197HB	No	MP197	No			24 Months[8]
Constellation	Nine Mile Point	BWR	GL	2012	TN	NUHOMS	61BT	6	366	159.4	Canister in Horizontal Concrete Overpack	MP197HB (71-9302)	No	MP197(71-9302)	No			24 Months8
Consumers	Big Rock Point[12]	BWR	GL	2002	BFS/ES	FuelSolutions	W150	8	441	78.8	Canister in Vertical Concrete Overpack	TS-125 (71-9276)	No		No			24 Months[8]
Ct.Yankee	Conn Yankee[12]	PWR	GL	2004	NAC	NAC-MPC	MPC-26	43	1019	443.8	Canister in Vertical Concrete Overpack	NAC-STC (71-9235)	No	NAC-MAGNASTOR	No			24 Months[8]
Dairyland Power	Lacrosse	BWR	GL	2012	NAC	NAC	LACBWR	5	333	59.5	Canister in Horizontal Concrete Overpack	NAC-STC (71-9235)	No	NAC-MAGNASTOR	No			24 Months[8]
DOE	INEEL	PWR	SS		TN	NUHOMS	12T	29	177	77.1	Canister in Horizontal Concrete Overpack		No		No		12T	36 Months[10]
Dominion	Kewaunee	PWR	GL	2009	TN	NUHOMS	32PT	8	256	111.5	Canister in Horizontal Concrete Overpack	MP197HB	No	MP197	No			24 Months[8]
Dominion	Millstone	PWR	GL	2005	TN	NUHOMS	32PT	18	576	250.8	Canister in Horizontal Concrete Overpack	MP197HB	No	MP197	No			24 Months[8]
Dominion	North Anna	PWR	SS	1998	TN	TN Metal Casks	TN-32	27	864	376.3	Bare Fuel	-	-	-	-	No[3]		24 Months[7]
Dominion	North Anna	PWR	GL	2008	TN	NUHOMS	32PTH	13	416	181.2	Canister in Horizontal Concrete Overpack	MP197HB	No	MP197	No			24 Months[8]
Dominion	Surry	PWR	SS	1986	GNB	Castor	V/21 and X33	26	558	243.0	Bare Fuel	-	-	-	-	No[4]		36 Months[10]
Dominion	Surry	PWR	SS	1986	NAC	NAC-I28	NAC-I28	2	56	24.4	Bare Fuel	-	-	-	-	No[5]		24 Months[7]
Dominion	Surry	PWR	GL	2007	TN	NUHOMS	32PTH	22	704	306.6	Canister in Horizontal Concrete Overpack	MP197HB	No	MP197	No			24 Months[8]
Dominion	Surry	PWR	SS	1986	TN	TN Metal Casks	TN-32	26	832	362.3	Bare Fuel	-	-	-	-	No[3]		24 Months[7]
Dominion	Surry	PWR	SS	1986	W	MC-10	MC-10	1	24	10.5	Bare Fuel	-	-	-	-	No[6]		24 Months[7]
Duke	Catawba	PWR	GL	2007	NAC	NAC-UMS	UMS-24	24	576	250.8	Canister in Vertical Concrete Overpack	NAC-UMS (71-9270)	No	NAC-MAGNASTOR	No			24 Months[8]
Duke	McGuire	PWR	GL	2001	NAC	NAC-UMS	UMS-24	28	672	292.7	Canister in Vertical Concrete Overpack	NAC-UMS (71-9270)	No	NAC-MAGNASTOR	No			24 Months[8]
Duke	McGuire	PWR	GL	2001	TN	TN Metal Casks	TN-32	10	320	139.4	Bare Fuel	-	-	-	-	No[3]		24 Months[7]
Duke	Oconee	PWR	GL/SS	1990	TN	NUHOMS	24P	84	2016	878.0	Canister in Horizontal Concrete Overpack		No		No		24P	36 Months[10]
Duke	Oconee	PWR	GL	2000	TN	NUHOMS	24PHB	40	960	418.1	Canister in Horizontal Concrete Overpack		No		No		24PHB	36 Months[10]
Energy Northwest	Columbia	BWR	GL	2002	Holtec	HI-STORM	MPC-68	27	1836	327.9	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Entergy	ANO	PWR	GL	1996	BFS/ES	FuelSolutions	VSC-24	24	576	250.8	Canister in Vertical Concrete Overpack		No		No		VSC-24	36 Months[10]
Entergy	ANO	PWR	GL	1996	Holtec	HI-STORM	MPC-24	22	528	229.9	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Entergy	ANO	PWR	GL	1996	Holtec	HI-STORM	MPC-32	16	512	223.0	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Entergy	Fitzpatrick	BWR	GL	2002	Holtec	HI-STORM	MPC-68	15	1020	182.2	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Entergy	Grand Gulf	BWR	GL	2006	Holtec	HI-STORM	MPC-68	17	1156	206.5	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Entergy	Indian Point 1	PWR	GL	2008	Holtec	HI-STORM	MPC-32	5	160	69.7	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Entergy	Indian Point 2	PWR	GL	2008	Holtec	HI-STORM	MPC-32	17	544	236.9	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Entergy	Palisades	PWR	GL	1993	BFS/ES	FuelSolutions	VSC-24	18	432	188.1	Canister in Vertical Concrete Overpack		No		No		VSC-24	36 Months[10]
Entergy	Palisades	PWR	GL	1993	TN	NUHOMS	24PTH	13	312	135.9	Canister in Horizontal Concrete Overpack	MP197HB	No	MP197	No			24 Months[8]
Entergy	Palisades	PWR	GL	1993	TN	NUHOMS	32PT	11	352	153.3	Canister in Horizontal Concrete Overpack	MP197HB	No	MP197	No			24 Months[8]
Entergy	River Bend	BWR	GL	2005	Holtec	HI-STORM	MPC-68	19	1292	230.8	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Entergy	Vermont Yankee	BWR	GL	2008	Holtec	HI-STORM	MPC-68	14	952	170.0	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Exelon	Waterford	PWR	GL	2011	Holtec	HI-STORM	MPC-32	9	288	125.4	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Exelon	Braidwood	PWR	GL	2011	Holtec	HI-STORM	MPC-32	3	96	41.8	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Exelon	Byron	PWR	GL	2010	Holtec	HI-STORM	MPC-32	14	448	195.1	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Exelon	Dresden	BWR	GL	2000	Holtec	HI-STORM	MPC-68	49	3332	595.1	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Exelon	Dresden	BWR	GL	2000	Holtec	HI-STAR	MPC-68	4	272	48.6	Canister in Metal Cask	HI-STAR100 (71-9261)	Yes[1]		No			12 Months[11]
Exelon	LaSalle	BWR	GL	2010	Holtec	HI-STORM	MPC-68	6	408	72.9	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Exelon	Limerick	BWR	GL	2008	TN	NUHOMS	61BT	19	1159	207.0	Canister in Horizontal Concrete Overpack	MP197HB (71-9302)	No	MP197 (71-9302)	No			24 Months[8]
Exelon	Oyster Creek	BWR	GL	2002	TN	NUHOMS	61BT	23	1403	250.6	Canister in Horizontal Concrete Overpack	MP197HB (71-9302)	No	MP197 (71-9302)	No			24 Months[8]
Exelon	Peach Bottom	BWR	GL	2000	TN	TN Metal Casks	TN-68	59	4012	716.5	Bare Fuel	-	-	-	-	Yes (71-9293)		12 Months[11]
Exelon	Quad Cities	BWR	GL	2005	Holtec	HI-STORM	MPC-68	35	2380	425.1	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
FirstEnergy	Davis-Besse	PWR	GL	1995	TN	NUHOMS	24P	3	72	31.4	Canister in Horizontal Concrete Overpack		No		No		24P	36 Months[10]
FirstEnergy	Perry	BWR	GL	2012	Holtec	HI-STORM	MPC-68	6	408	72.9	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes					
FPL	Duane Arnold	BWR	GL	2003	TN	NUHOMS	61BT	20	1220	217.9	Canister in Horizontal Concrete Overpack	MP197HB (71-9302)	No	MP197 (71-9302)	No			24 Months[8]
FPL	Point Beach	PWR	GL	1995	BFS/ES	FuelSolutions	VSC-24	16	384	167.2	Canister in Vertical Concrete Overpack		No		No		VSC-24	36 Months[10]
FPL	Point Beach	PWR	GL	1995	TN	NUHOMS	32PT	32	1024	446.0	Canister in Horizontal Concrete Overpack	MP197HB	No	MP197	No			24 Months[8]
FPL	St.Lucie	PWR	GL	2008	TN	NUHOMS	32PTH	14	448	195.1	Canister in Horizontal Concrete Overpack	MP197HB	No	MP197	No			24 Months[8]
FPL	Seabrook	PWR	GL	2008	TN	NUHOMS	32PTH	6	192	83.6	Canister in Horizontal Concrete Overpack	MP197HB	No	MP197	No			24 Months[8]
FPL	Turkey Point	PWR	GL	2011	TN	NUHOMS	32PTH	18	576	250.8	Canister in Horizontal Concrete Overpack	MP197HB	No	MP197	No			24 Months[8]
Luminant	Comanche Peak	PWR	GL	2012	Holtec	HI-STORM	MPC-32	9	288	125.4	Canister in Vertical Concrete Overpack	HISTAR 100 (71-9261)	Yes[1]		No			14 Months[8]
Maine Yankee	Maine Yankee[12]	PWR	GL	2002	NAC	NAC-UMS	UMS-24	64	1434	624.5	Canister in Vertical Concrete Overpack	NAC-UMS (71-9270)	No	NAC-MAGNASTOR	No			24 Months[8]
NPPD	Cooper	BWR	GL	2010	TN	NUHOMS	61BT	8	488	87.2	Canister in Horizontal Concrete Overpack	MP197 (71-9302)	No	MP197HB (71-9302)	No			24 Months[8]
OPPD	Fort Calhoun	PWR	GL	2006	TN	NUHOMS	32PT	10	320	139.4	Canister in Horizontal Concrete Overpack	MP197HB	No	MP197	No			24 Months[8]
Portland	GE Trojan	PWR	GL	2002	Holtec	TranStor Cask	MPC-24E/EF	34	780	339.7	Canister in Vertical Concrete Overpack	HISTAR 100 (71-9261)	Yes[1]		No			14 Months[8]
PPL	Susquehanna	BWR	GL	1999	TN	NUHOMS	52B	27	1404	250.8	Canister in Horizontal Concrete Overpack		No		No		52B	36 Months[10]
PPL	Susquehanna	BWR	GL	1999	TN	NUHOMS	61BT	44	2684	479.4	Canister in Horizontal Concrete Overpack	MP197 (71-9302)	No	MP197HB(71-9302)	No			24 Months[8]
Progress	Brunswick	BWR		2010	TN	NUHOMS	61BTH	8	488	87.2	Canister in Horizontal Concrete Overpack	MP197HB (71-9302)	No	MP197HB(71-9302)	No			24 Months[8]
Progress	Robinson	PWR	SS	1989	TN	NUHOMS	7P	8	56	24.4	Canister in Horizontal Concrete Overpack		No		No		7P	36 Months[10]
Progress	Robinson	PWR	GL	2007	TN	NUHOMS	24PTH	14	336	146.3	Canister in Horizontal Concrete Overpack	MP197HB	No	MP197	No			24 Months[8]
PS Colorado	Ft. St. Vrain[15]	HTGR	SS	1991	DOE	Foster Wheeler	MVDS		1464	1,023.3	Canister in Vault	TN-FSV (71-9253)	Yes[2]		No			12 Months[2]
PSE&G	Hope Creek	BWR	GL	2006	Holtec	HI-STORM	MPC-68	16	1088	194.3	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
PSE&G	Salem	PWR	GL	2010	Holtec	HI-STORM	MPC-32	16	512	223.0	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
PG&E	Diablo Canyon	PWR	SS	2009	Holtec	HI-STORM	MPC-32	23	736	320.5	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
PG&E	Humboldt Bay[12]	BWR	SS	2008	Holtec	HI-STAR	MPC-80	5	390	69.7	Canister in Metal Cask	HI-STAR100 (71-9261)	Yes[1]		No			12 Months[11]
SMUD	Rancho Seco[12]	PWR	SS	2001	TN	NUHOMS	24PT	22	493	214.7	Canister in Horizontal Concrete Overpack	MP187 (71-9255)	Yes[2]	MP197HB	No			12 Months[2]
Southern Cal Edison	SONGS 1[12,13]	PWR	GL	2003	TN	NUHOMS	24PT1	18	395	172.0	Canister in Horizontal Concrete Overpack	MP187 (71-9255)	Yes	MP197HB	No			24 Months[8]
Southern Cal Edison	SONGS 2	PWR	GL	2003	TN	NUHOMS	24PT4	33	792	344.9	Canister in Horizontal Concrete Overpack	MP197HB (71-9302)	No	MP197	No			24 Months[8]
Southern Nuclear	Farley	PWR	GL	2005	Holtec	HI-STORM	MPC-32	21	672	292.7	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			24 Months[8]
Southern Nuclear	Hatch	BWR	GL	2000	Holtec	HI-STORM	MPC-68	48	3264	583.0	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			24 Months[8]
Southern Nuclear	Hatch	BWR	GL	2000	Holtec	HI-STAR	MPC-68	3	204	36.4	Canister in Metal Cask	HI-STAR100 (71-9261)	Yes[1]		No			12 Months[11]
TVA	Browns Ferry	BWR	GL	2005	Holtec	HI-STORM	MPC-68	40	2720	485.8	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
TVA	Sequoyah	PWR	GL	2004	Holtec	HI-STORM	MPC-32	32	1024	446.0	Canister in Vertical Concrete Overpack	HI-STAR100 (71-9261)	Yes[1]		No			14 Months[8]
Xcel Energy	Prairie Island	PWR	SS	1993	TN	TN Metal Casks	TN-40	29	1160	505.2	Bare Fuel	-	-	-	-	Yes (71-9313)		12 Months[9]
Xcel Energy	Monticello	BWR	GL	2008	TN	NUHOMS	61BT	10	610	108.9	Canister in Horizontal Concrete Overpack	MP197 (71-9302)	No	MP197	No			24 Months[8]
YAEC	Yankee Rowe[13]	PWR	GL	2002	NAC	NAC-MPC	MPC-36	16	533	232.1	Canister in Vertical Concrete Overpack	NAC-STC (71-9235)	No	NAC-MAGNASTOR				24 Months[8]
							Totals:	1720	68143	21,079.8								

Appendix B

Used Nuclear Fuel Characteristics

Table B-1. PWR 40 GWd/MT Used Fuel Decay Heat.

Elements	Decay Heat (Watts/MT)							
	Time (years)							
	1	10	30	50	70	100	300	500
Gases H, C, Xe, Kr, I	0	0	0	0	0	0	0	0
Cs/Sr/Ba/Rb/Y	2765	1054	566	354	222	110	1	0
Noble Metals Ag, Pd, Ru, Rh	2752	11	0	0	0	0	0	0
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	3,593	64	10	2	0	0	0	0
Actinides Ac, Th, Pa, U	0	0	0	0	0	0	0	0
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	819	348	332	309	287	258	159	116
Others	515	15	2	1	0	0	0	0
Total	**10,444**	**1,492**	**910**	**666**	**509**	**368**	**160**	**116**

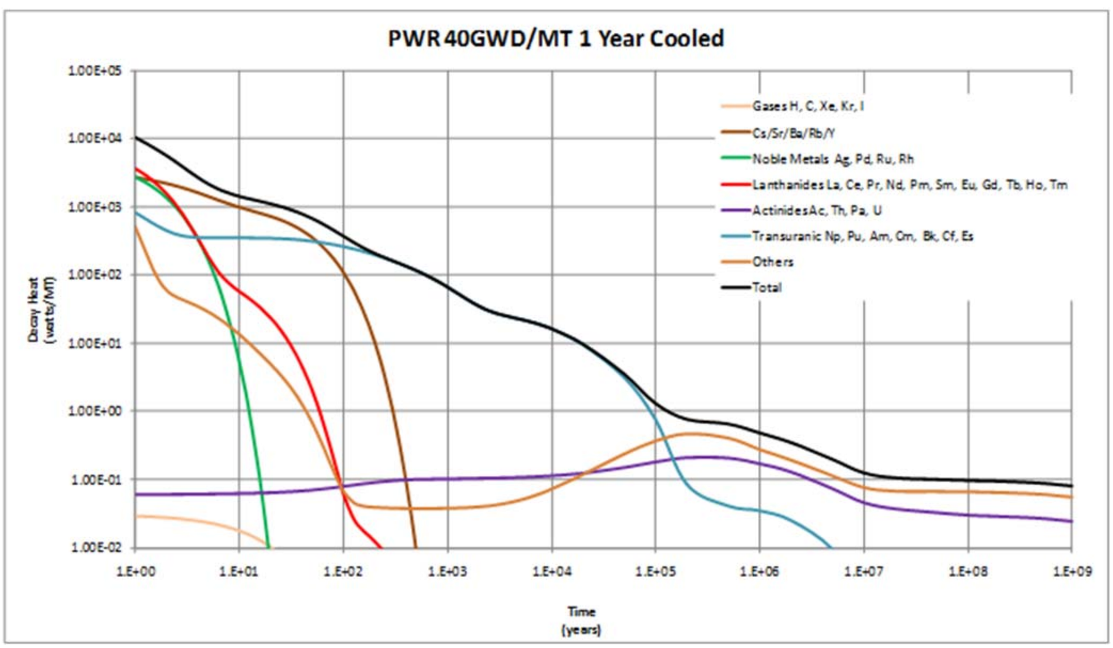

Figure B-1. PWR 40 GWd/MT Used Fuel Decay Heat.

Table B-2. PWR 60. GWd/MT Used Fuel Decay Heat.

Elements	Decay Heat (Watts/MT)							
	Time (years)							
	1	10	30	50	70	100	300	500
Gases H, C, Xe, Kr, I	0	0	0	0	0	0	0	0
Cs/Sr/Ba/Rb/Y	4,608	1,576	824	516	323	160	1	0
Noble Metals Ag, Pd, Ru, Rh	3,447	14	0	0	0	0	0	0
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	3,843	109	17	3	1	0	0	0
Actinides Ac, Th, Pa, U	0	0	0	0	0	0	0	0
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	1,515	785	613	516	449	381	199	139
Others	522	21	3	1	0	0	0	0
Total	**13,936**	**2,505**	**1,458**	**1,036**	**773**	**541**	**201**	**139**

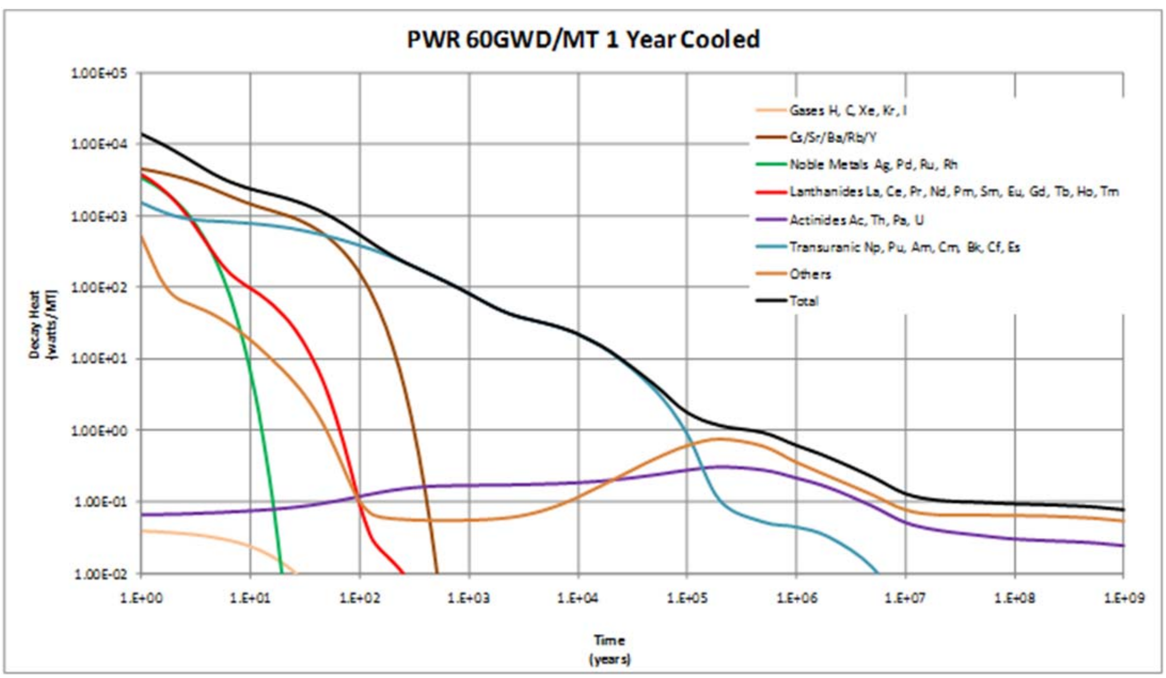

Figure B-2. PWR 60 GWd/MT Used Fuel Decay Heat.

Table B-3. BWR 30 GWd/MT Used Fuel Decay Heat.

Elements	Decay Heat (Watts/MT)							
	Time (years)							
	1	10	30	50	70	100	300	500
Gases H, C, Xe, Kr, I	0	0	0	0	0	0	0	0
Cs/Sr/Ba/Rb/Y	1,895	778	425	266	166	82	1	0
Noble Metals Ag, Pd, Ru, Rh	2,042	8	0	0	0	0	0	0
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	2,675	43	6	1	0	0	0	0
Actinides Ac, Th, Pa, U	0	0	0	0	0	0	0	0
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	588	225	234	225	213	196	127	94
Others	403	12	2	0	0	0	0	0
Total	7,603	1,067	667	493	380	278	128	94

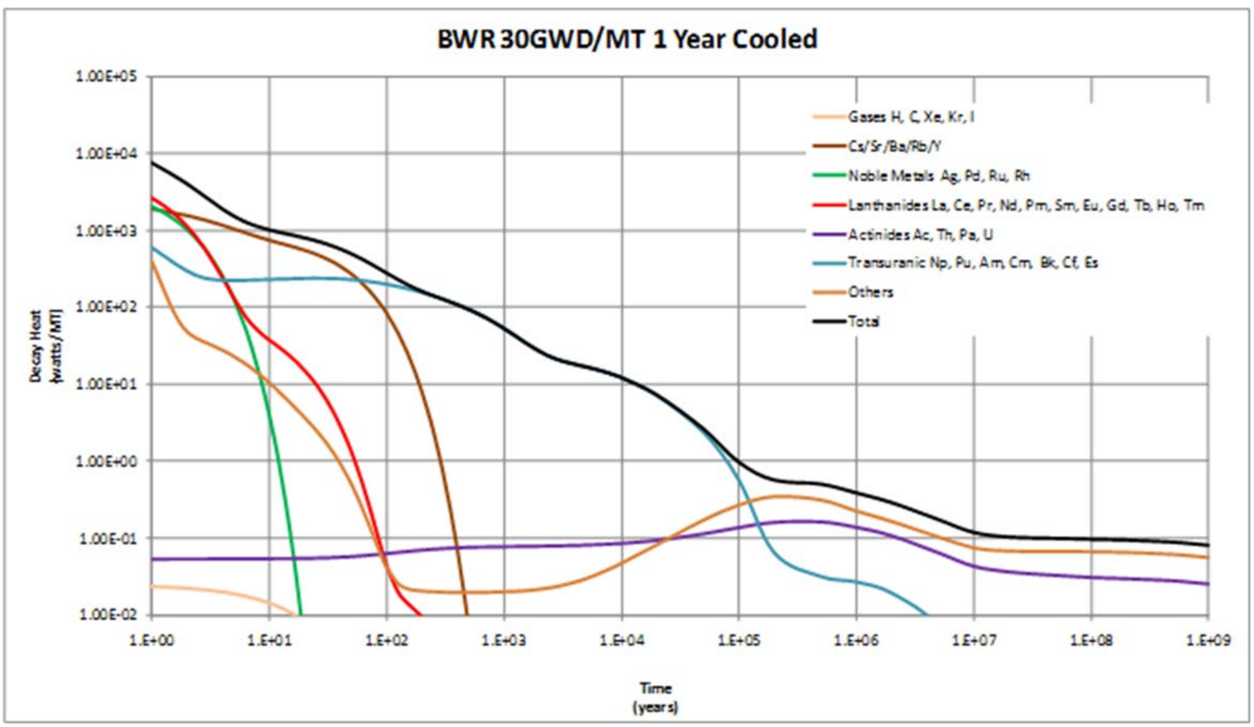

Figure B-3. BWR 30 GWd/MT Used Fuel Decay Heat.

Table B-4. BWR 50 GWd/MT Used Fuel Decay Heat.

Elements	Decay Heat (Watts/MT)							
	Time (years)							
	1	10	30	50	70	100	300	500
Gases H, C, Xe, Kr, I	0	0	0	0	0	0	0	0
Cs/Sr/Ba/Rb/Y	3,558	1,257	662	414	259	128	1	0
Noble Metals Ag, Pd, Ru, Rh	2,669	11	0	0	0	0	0	0
Lanthanides La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Ho, Tm	2,734	92	14	3	1	0	0	0
Actinides Ac, Th, Pa, U	0	0	0	0	0	0	0	0
Transuranic Np, Pu, Am, Cm, Bk, Cf, Es	1,627	760	591	496	433	369	199	139
Others	420	17	2	1	0	0	0	0
Total	11,008	2,137	1,271	914	693	498	200	139

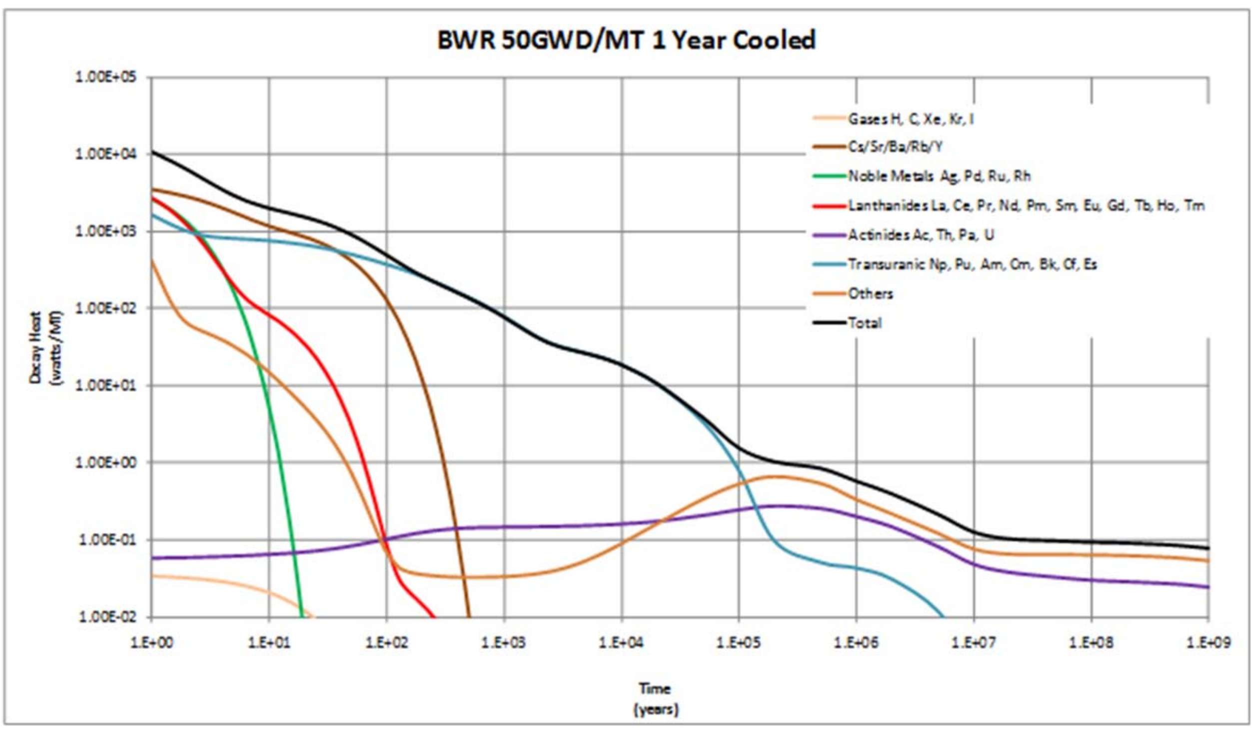

Figure B-4. BWR 50 GWd/MT Used Fuel Decay Heat.

Appendix C
Government-Owned Used Fuel and HLW Inventory

Since the inception of nuclear reactors, the DOE and its predecessor agencies operated or sponsored a variety of research, test, training, and other experimental reactors both domestically and overseas. The Naval Nuclear Propulsion Program (NNPP) has generated UNF from operation of nuclear powered submarines and surface ships, operation of land-based prototype reactor plants, operation of moored training ship reactor plants, early development of commercial nuclear power, and irradiation test programs.

Aqueous reprocessing of DOE UNF has occurred at the Hanford Site, the Idaho National Laboratory (INL), and the Savannah River Site (SRS). The INL is pursuing the use of electro-chemical processing to treat 60 MTHM of sodium bonded UNF. DOE is also responsible for clean-up of the commercial UNF reprocessing site at West Valley, New York.

The waste requiring disposition from these DOE activities are fairly well understood and documented. This section summarizes these radioactive materials.

DOE Used Nuclear Fuel

DOE UNF is primarily generated by DOE production reactors, demonstration commercial power reactors, and domestic and foreign research and training reactors. DOE UNF includes some commercial UNF not in the possession of NRC-licensed commercial utilities.

Since the inception of nuclear reactors, the DOE and its predecessor agencies operated or sponsored a variety of research, test, training, and other experimental reactors with different characteristics from the commercial power reactors of today. DOE UNF generated in production reactors supported weapons and other isotope production programs. An example of UNF existing today from production reactors is the N Reactor UNF stored at Hanford. Some UNF from commercial power reactors, such as Shippingport, Peach Bottom, and Fort St. Vrain, is stored within the DOE complex. This UNF was generated for commercial power demonstration purposes or as part of research projects. Also, the Three Mile Island Unit 2 UNF debris is stored at the INL.

DOE has sponsored nuclear research activities in the U. S. and overseas. There are numerous university and government research reactor sites within the United States. UNF from research reactors is stored primarily at the INL and SRS. Examples of research reactor UNF being stored within the DOE complex include the High-Flux Beam Reactor UNF stored at the SRS; the Fast Flux Test Facility UNF stored at Hanford and the INL; training, research, and isotope reactors (built by GA) (TRIGA) UNF stored at Hanford and the INL; and the Advanced Test Reactor UNF stored at the Idaho National Laboratory. Additional research reactor UNF is being returned to the U. S. from foreign research reactors as part of the DOE Foreign Research Reactor Spent Nuclear Fuel Return Program.

DOE UNF Inventory

The source of current inventory data for this study is information collected in support of the OCRWM efforts for licensing the Yucca Mountain Repository. [DOE, 2008] Complex wide DOE UNF data have been collected and is maintained in the Spent Fuel Database.

The majority of DOE UNF (about 2500 metric tons of heavy metal (MTHM) that has been generated is in storage. DOE continues to operate several research reactors and will be receiving UNF from universities and the foreign research reactor return program. Projected material amounts are relatively small (about 50 MTHM) and there is some uncertainty as to the total amount that will be generated or received. The inventory discussed below covers all DOE UNF, UNF which is currently in DOE storage and projected UNF generation or receipts.

DOE UNF comes from a wide range of reactor types, such as light- and heavy-water-moderated reactors, graphite-moderated reactors, and breeder reactors, with various cladding materials and enrichments, varying from depleted uranium to over 93% enriched U235. Many of these reactors, now decommissioned, had unique design features, such as core configuration, fuel element and assembly geometry, moderator and coolant materials, operational characteristics, and neutron spatial and spectral properties.

As described below, there is a large diversity of reactor and fuel designs. In addition, there is a relatively large number (over 200,000) of fuel pieces or assemblies, which range from a large number of pieces for some reactors (N Reactor) to a few individual pieces for other unique reactors (Chicago Pile-5 converter cylinders).

There are several hundred distinct types of DOE UNF, and it is not practical to attempt to determine the impact of each individual type when performing analyses covering all of this material such as considering repository performance. To support these types of analyses, the DOE UNF inventory was reduced to 34 DOE UNF groups based on fuel matrix, cladding, cladding condition, and enrichment. These parameters are the fuel characteristics that were determined to have major impacts on the release of radionuclides from the DOE UNF and contributed to nuclear criticality scenarios.

A discussion of each of the 34 groupings is presented in Appendix D of UFD Inventory [Carter 2012]. The discussions of each of the 34 groups provide a description of the fuel group and an example of fuel that makes up the group. When appropriate, a more detailed description of a fuel with the largest percentage of MTHM within each group is provided. This discussion is not intended to address each fuel in the group.

Appendix D Table D-1 of UFDC Inventory [Carter 2012] describes the typical ranges of the nominal properties for DOE UNF in the 34 groups.

DOE UNF Radionuclide Inventory

Process knowledge and the best available information regarding fuel fabrication, operations, and storage for DOE UNF are used to develop a conservative source-term estimate. The DOE UNF characterization process relies on precalculated results that provide radionuclide inventories for typical UNF at a range of decay times. These results are used as templates that are scaled to estimate radionuclide inventories for other similar fuels.

To estimate an UNF source term, the appropriate template is selected to model the production of activation products and transuranics by matching the reactor moderator and fuel cladding, constituents, and beginning-of-life enrichment. Precalculated radionuclide inventories are extracted from the appropriate template at the desired decay period and then scaled to account for differences in fuel mass and specific burn-up. Appendix D, Table D-2 of UFD Inventory lists the projected radionuclide inventory of DOE UNF for the nominal and bounding cases as of 2010. The nominal case is the expected or average inventory. The bounding case represents the highest burn-up assembly or accounts for uncertainties if fuel burn-up is not known.

DOE UNF Storage/Canisters

Although DOE UNF is stored throughout the U. S. at numerous facilities, a decision was made in 1995 to consolidate DOE UNF at three existing DOE sites; Hanford Site in Washington, the INL in Idaho, and the SRS in South Carolina. The vast majority of DOE UNF is currently stored at these three sites. The storage configurations vary for each of the sites and include both dry and wet storage. On a MTHM basis, a large portion of the UNF (about 2100 MTHM) is contained in about 400 sealed canisters. The majority of the remaining UNF will most likely be placed in canisters.

In support of the Yucca Mountain project it was anticipated that all DOE UNF, except a very small amount of DOE UNF of commercial origin, would be placed in sealed disposal canisters. At the Hanford Site, about 400 Multicanister Overpacks (MCO) were used to package and store UNF. The MCO is a sealed stainless steel canister which is about 24 inches in diameter and about 14 feet long. For the remaining DOE UNF, a standardized disposal canister design was developed which included canisters of 18 and 24 inch diameter and 10 and 15 feet length. Because of uncertainty in disposal and packaging efficiencies the total number of canisters to be generated ranged from 2,500 to 5,000 with a point estimate of 3,542. Currently no UNF has been packaged into the standardized disposal canister design.

Decay heat of DOE UNF is based on the estimated radionuclide inventory. In support of the Yucca Mountain License Application, an analytical process using process knowledge and the best available information regarding fuel fabrication, operations, and storage for DOE UNF was used to develop a conservative radionuclide inventory estimate. This methodology was applied to each fuel in the DOE SNF inventory to develop a radionuclide estimate. Also in support of the Yucca Mountain License Application, a packaging plan was developed using the DOE standardized canisters. These two data sources are used to estimate the decay heat per canister for DOE UNF.

The radionuclide and resulting decay heat was calculated for the year 2010 and 2030 to support the Yucca Mountain repository. Considering the time required before a repository for DOE UNF would be open to accept waste, these values are considered adequate for this scoping evaluation.

Table 3-8 provides the distribution of DOE UNF canisters based on the 2010 and 2030 nominal decay heat using the 2035 total canister count. The 2010 data indicate approximately 35% of the DOE UNF canisters will be generating decay heat of less than 50 watts. Approximately 90% of the DOE UNF canisters will be generating decay heat less than 300 watts. Nearly all the DOE UNF canisters (>99%) will be generating less than 1 kW. Since the methodology used to calculate the radionuclide inventory is very conservative, some fuels have radionuclide amounts based on bounding assumptions resulting in extreme decay heat values.

Table C-1. DOE Spent Nuclear Fuel Canister Decay Heat.

	2010		**2030**	
Decay heat per canister (watts)	**Number of canisters**	**Cumulative %**	**Number of canisters**	**Cumulative %**
<50	1228	34.7%	1670	47.1%
50-100	565	50.6%	392	58.2%
100-220	789	72.9%	690	77.7%
220-300	633	90.8%	586	94.2%
300-500	241	97.6%	140	98.2%
500-1000	55	99.1%	41	99.4%
1000-1500	10	99.4%	4	99.5%

	2010		**2030**	
Decay heat per canister (watts)	**Number of canisters**	**Cumulative %**	**Number of canisters**	**Cumulative %**
1500 - 2000	1	99.4%	5	99.6%
>2000	20	100.0%	13	100.0%
Total	**3542**		**3542**	
Does not include the Savannah River Site SRE fuel				

Naval UNF

The NNPP has generated UNF from operation of nuclear powered submarines and surface ships, operation of land-based prototype reactor plants, operation of moored training ship reactor plants, early development of commercial nuclear power, and irradiation test programs. The source of naval UNF information for this report is the unclassified portion of the Yucca Mountain Repository License Application. [DOE, 2008] Since most details regarding naval UNF are classified, only limited information is presented herein.[c]

Naval UNF Inventory

Naval UNF consists of solid metal and metallic components that are nonflammable, highly corrosion-resistant, and neither pyrophoric, explosive, combustible, chemically reactive, nor subject to gas generation by chemical reaction or off-gassing. Approximately 27 MTHM of Naval UNF currently exists with a projected inventory of less than 65 MTHM in 2035.

New naval nuclear fuel is highly enriched uranium. As a result of the high uranium enrichment, very small amounts of transuranics (TRU) are generated by end of life when compared to commercial UNF.

Naval UNF Radionuclide Inventory

In support of the Yucca Mountain repository, three different methods for packaging naval UNF into naval UNF canisters were developed; however, the design of the naval UNF canister is the same irrespective of packaging method. These packaging methods are based on the type of naval UNF assemblies and whether the naval UNF cladding is intact or non-intact. Each naval UNF canister would be loaded such that thermal, shielding, criticality, and other characteristics of the received waste would be within the proposed repository waste acceptance requirement limits. As a result, a radionuclide inventory for a representative naval UNF canister, five years after reactor shutdown, was developed for use in the

[c] Before using the information in this section for studies involving naval UNF, contact the NNPP Program Manager, Navy Spent Nuclear Fuel at (202) 781-6214.

repository source term analyses (UFD Inventory Appendix E, Table E-1 [Carter 2012]). Different packaging designs may be needed dependent upon the future disposal options.

Naval UNF Storage/Canisters

UNF from the NNPP is temporarily stored at the INL. To accommodate different naval fuel assembly designs, naval UNF is loaded in either a naval short UNF canister or a naval long UNF canister. Both were sized to fit within the proposed design for the Yucca Mountain repository waste package.

The outer diameter of the naval UNF canister is 66 in. nominal (66.5 inches maximum). The maximum external dimensions ensure naval UNF canisters fit into the waste packages. The naval short UNF canister is 185.5 inches (nominal) in length (187 inches maximum), and the naval long UNF canister is 210.5 inches (nominal) in length (212 inches maximum). With the exception of length, the other characteristics of naval UNF canisters are identical.

Approximately 400 naval UNF canisters (310 long and 90 short) are currently planned to be packaged and temporarily stored pending shipment. The average thermal load is 4,250 watts/container. Maximum is 11,800 watts/container. The NNPP is responsible for preparing and loading naval UNF canisters and began canister loading operations in 2002. As of February 2010, 27 naval UNF canisters have been loaded and are being temporarily stored at INL.

DOE HIGH LEVEL WASTE

High-level radioactive waste is the highly radioactive material resulting from the reprocessing of UNF. Following aqueous reprocessing, HLW is in a liquid form and initially stored in underground metal storage tanks. Long term storage of HLW requires stabilization of the wastes into a form that will not react, nor degrade, for an extended period of time. Two treatment methods used for stabilization of the waste are vitrification or calcination. Vitrification is the transition of the HLW into a glass by mixing with a combination of silica sand and other constituents or glass forming chemicals that are melted together and poured into stainless steel canisters. HLW canisters have a nominal diameter of 2 feet and have heights of 10 or 15 feet. Calcination of HLW is accomplished by injecting the waste with calcining additives into a fluidized bed to evaporate the water and decompose the remaining constituents into a granular solid material.

Aqueous reprocessing of DOE UNF has occurred at the Hanford Site, the INL, and the SRS. Commercial UNF was reprocessed at West Valley, New York.

In addition to aqueous reprocessing, the INL is pursuing the use of electro-chemical processing to treat 60 MTHM of sodium bonded UNF. The process converts the bond sodium into sodium chloride and separates the UNF into a uranium product and HLW. The HLW is produced in two forms, ceramic and metal. The ceramic waste form primarily contains the salt electrolyte with active metal fission products and the metal waste is primarily the cladding hulls and undissolved noble metals. The process has been demonstrated and used to treat about 4 MTHM of sodium bonded UNF to date.

Current DOE HLW Inventory

The source of inventory data for this study is information collected in support of the OCRWM efforts for licensing the Yucca Mountain Repository. [DOE, 2008] In addition, site treatment plans were also used. [DOE, 2009; SRS, 2007]

A commercial fuel reprocessing plant located at West Valley, New York operated from 1966 through 1972 and reprocessed approximately 640 metric tons of UNF to recover the unused uranium. Of the UNF reprocessed at West Valley, about 260 metric tons were commercial used fuel and about 380 metric tons were DOE N Reactor used fuel. During operations about 2,500 m3 of liquid HLW was generated. The liquid HLW was vitrified between 1996 and 2001 producing 275 HLW canisters that are stored at West Valley. [DOE, 1996]

The INL reprocessed UNF from naval propulsion reactors, test reactors, and research reactors to recover uranium and generated approximately 30,000 m3 of liquid HLW. Between 1960 and 1997, the INL converted all of their liquid HLW into about 4,400 m3 of a solid waste form called calcine (a granular solid with the consistency of powder laundry soap). These solids are stored retrievably on-site in stainless steel bins (like grain silos but smaller) within concrete vaults.

The SRS has reprocessed defense reactor UNF and nuclear targets to recover valuable isotopes since 1954 producing more than 530,000 m3 of liquid HLW. Through evaporation and vitrification of the waste, SRS has reduced this inventory to the current level about 136,000 m3 of liquid HLW. [Chew, 2010] SRS began vitrifying liquid HLW in 1996 and through June 2012 has produced 3,496 HLW canisters (2 feet × 10 feet). [Chew, 2010]

The Hanford Site reprocessed defense reactor UNF since the 1940s and has generated about 220,000 m3 of liquid HLW to recover the plutonium, uranium, and other elements for defense and other federal programs. Construction of a vitrification facility is currently underway with startup scheduled for 2019. Table C-2 summarizes the current HLW inventory.

Table C-2. Current High-Level Waste Inventory.

	HLW Canisters[1]	**Liquid HLW[2] (m^3)**	**Dry HLW[3] (m^3)**
West Valley	275	N/A	N/A
Hanford	N/A	220,000	N/A
INL	N/A	N/A	4,400
SRS	3,496	136,000	N/A

1. Vitrified HLW in stainless steel canisters
2. HLW stored in tanks
3. Calcined HLW stored in bins.

The Hanford Site encapsulated Cs and Sr separated from the HLW between 1974 and 1985. Some of these capsules were leased to companies as radiation sources. After one of the capsules developed a microscopic leak, the capsules were recalled. Hanford is storing 1,335 Cs capsules and 601 Sr capsules, approximately 109 million curies (as of 8/8/06). [Fact Sheet, 2006]

Projected DOE HLW Inventory

SRS currently has the only operating reprocessing facility, H Canyon. It is estimated that an additional 17,000 m3 of liquid HLW may be generated with continued canyon operations (approximately 2019).

The projected number of HLW canisters to be generated at each site will be dependent on actual loading and final waste form. Because of this uncertainty, the actual number of HLW canisters produced may vary significantly from what is anticipated today.

SRS began conversion of the liquid defense waste into borosilicate glass in 1996 and is the only DOE site with HLW in a packaged configuration. A total of 3496 canisters have been produced through June, 2012. Therefore, the SRS inventory can be described as those canisters in the current inventory and those projected from future operations. Decay heat of the current inventory is based on radiological inventories contained in the production records for those canisters. The decay heat of future canisters is estimated based the on radionuclide composition of the HLW inventory remaining in the liquid waste storage tanks. The radionuclide and resulting decay heat was calculated based on the year the canister is/will be produced. The total Savannah River canister count is based on information supporting Savannah River Liquid Waste Disposition Plan revision. [Gombert, 2007]

Table C-3 provides the canister distribution of SRS canisters based on the nominal decay heat at the time of production. The data indicate: 39% of the Savannah River canisters will be generating less than 50 watts; 96% of the Savannah River canisters will be generating less than 300 watts; all the SRS canisters will be generating less than 500 watts.

Table C-3. Savannah River Canister Decay Heat Distribution.

Savannah River		
Decay heat per canister (watts)	**Number of canisters**	**Cumulative %**
<50	2948	39.0%
50-100	459	45.1%
100-220	3891	96.5%
220-300	0	96.5%
300-500	264	100.0%
500-1000	0	100.0%
1000-1500	0	100.0%
1500 - 2000	0	100.0%
>2000	0	100.0%
Total	**7,562**	
Total Decay Heat (watts)	**805,500**	

The Hanford Waste Treatment Project (WTP) is currently under construction and therefore the Hanford borosilicate glass canisters are based on a projected inventory for their future production taken from the January 2011 Waste Treatment Plant document titled "2010 Tank Utilization Assessment". The data in Table 3-11 indicate: 83% of the Hanford canisters will be generating less than 50 watts; and 100% of the Hanford canisters will be generating less than 300 watts.

At INL several options were considered for ultimate disposal of the calcine. Alternatives included direct disposal, vitrification, or hot isostatic pressing (HIP) to compress the calcine into a volume reduced monolithic waste form. A Record of Decision issued December 2009 determined that DOE will use the HIP technology to treat the calcine.

Decay heat of DOE HLW that has been calcined and is currently stored at the Idaho site is taken from the October 2005 Idaho Cleanup Project document titled "Decay Heat and Radiation from Direct Disposed Calcine", EDF-6258 revision 0. Report EDF-6258 provides this data for direct disposal of the calcine waste. The current Record of Decision for disposal of the calcine is for it to be treated using HIP, which will result in an approximate 50% increase in the volume of material in each disposal canister and a 50% increase in the decay heat per canister.

Table C-4 provides the distribution of DOE calcine canisters based on the nominal decay heat in the year 2016. The data indicates that 100% of calcine canisters will be less than 50 watts.

Table C-4. Hanford and Idaho Waste Inventory.

	Hanford Borosilicate Glass		**Idaho Calcine**	
Decay heat per canister (watts)	**Number of canisters**	**Cumulative %**	**Number of canisters**	**Cumulative %**
<50	9291	83.9%	4391	100.0%
50-100	1237	95.0%		
100-220	523	99.7%		
220-300	28	100.0%		
300-500	0	100.0%		
500-1000	0	100.0%		
1000-1500	0	100.0%		
1500 - 2000	0	100.0%		
>2000	0	100.0%		
Total	**11,079**		**4391**	

Table C-5 shows the estimated number of HLW canisters to be produced. The current best estimate and a potential range are provided. [Marcinowski memo to Kouts, 2008; EIS, 2002; see also Chew, 2010]

Table C-5. Projected Total Number of DOE High-Level Waste Canisters.

	HLW Canisters[1] Best Estimate	**Potential Additional HLW Canister Range**
West Valley	2752	NA[2]
Hanford	11,079	9,667-14,111
INL (Calcine)	4,391	1,190-11,200
INL (Electro-chemical processing)	102	82-135
SRS	7,562	5,862-7,900
Total	98,759	17,100-336,003
1. With the exception of Hanford, all HLW canisters are 2 feet × 10 feet, Hanford HLW canisters		

	HLW Canisters[1] Best Estimate	Potential Additional HLW Canister Range
are 2 feet × 15 feet		
2. All the West Valley HLW canisters currently exist		
3. Rounded to nearest 100 canister		

The combined inventory from all three sites, which is used in Cases 2 and 3 is presented in Table C-6. The data indicate: 72% of the HLW canisters will be generating less than 50 watts; ~80% of the canisters will be generating less than 100 watts; almost 99% will be generating less than 300 watts and all the canisters will be less than 500 watts. The total decay heat to be emplaced in these cases is 1.2 million watts.

Table C-6. Decay Heat for All DOE HLW.

All DOE HLW Canisters		
Decay heat generation per canister (watts)	**Number of canisters**	**Cumulative %**
<50	16630	72.2%
50-100	1696	79.6%
100-220	4414	98.7%
220-300	28	98.9%
300-500	264	100.0%
500-1000	0	100.0%
1000-1500	0	100.0%
1500 - 2000	0	100.0%
>2000	0	100.0%
Total	23,032	
Total Decay Heat (watts)	1,203,103	
Not included in Table 3-3 are a) 275 HLW canisters from West Valley which have low heat values, and b) the Idaho HLW to be processed through the Integrated Waste Treatment Unit and then per the associated Record of Decision will be disposed of as RH-TRU.		

DOE HLW Radionuclide Inventory

UFD Inventory Appendix F, Table F-1 lists the total HLW radionuclide inventory for each of the generating sites decayed to 2017. Although, there may be some variation in the number of canisters produced for the sites that have not completed waste treatment, the total amount of radionuclide will not change.

OCRWM used the "projected maximum" inventory on a per canister basis for the HLW curie content supplied by SRS. The use of the "projected maximum" on a per canister basis resulted in a conservative total curie content for SRS that is approximately twice the actual SRS tank farm inventory. The expected curie content of SRS HLW is presented in UFD Inventory Table F2.

SRS is also the only site continuing reprocessing and the DOE-EM program periodically requires disposal of special isotopes via the reprocessing facility and the vitrification process. For example excess weapons plutonium has been disposed which results in the Pu concentration of some SRS canisters to be above the projected maximum inventory used in the licensing of Yucca Mountain. The potential for future EM special isotope disposal campaigns has not been assessed in this study.

The total radionuclide inventory for treatment of sodium bonded UNF is shown in UFD Inventory Table F-3. [Carter, 2012]

DOE HLW Storage

The HLW vitrified glass at SRS is stored in below grade concrete vaults, called Glass Waste Storage Buildings (GWSB), containing support frames for vertical storage of 2,262 HLW canisters. SRS currently has two GWSB constructed and a third planned. The HLW canisters at West Valley are currently stored in a shielded cell in the former reprocessing plant. Alternate interim storage options are being considered at West Valley to allow decommissioning of the reprocessing facility.

Appendix D
Work Breakdown Structure and WBS Element Descriptions

Note: Level 4 and below shown as "typical" for all WBS elements; lower levels added as needed.

WBS Level					Description
1	**2**	**3**	**4**	**5**	
1					Interim Storage and Transportation Project
	01.01				Pilot ISF
		01.01.01			Storage Pad
			01.01.01.01		Excavation
				01.01.01.01.01	Engineering & Design
				01.01.01.01.02	Construction
				01.01.01.01.03	Startup and Testing
			1.01.01.0x		(Add further Breakdowns as needed)
		01.01.02			Transfer (Cask Handling) Facility
		01.01.03			Horizontal Dry Storage Modules
		01.01.04			Vertical Dry Storage Casks
		01.01.05			Storage Cask Fabrication Facility
		01.01.06			Cask Maintenance Facility
		01.01.07			Concrete Batch Plant
		01.01.08			Visitor's Center / Auditorium
		01.01.09			Admin Building
		01.01.10			Security
			01.01.10.01		Lighting
			01.01.10.02		PIDAS
			01.01.10.03		Site Fencing
			01.01.10.04		CAS
			01.01.10.05		SAS

WBS Level					Description
1	2	3	4	5	
			01.01.10.06		Emergency Response
			01.01.10.07		Communications
			01.01.10.08		Entry Control Facility
			01.01.10.09		Training Facility/Armory
		01.01.11			Rail Spur / Receiving Yard
		01.01.12			Utilities
			01.01.12.01		Substation
			01.01.12.02		Backup Power
		01.01.13			Roads
		01.01.14			Parking
		01.01.15			Site Work
			01.01.15.01		Clearing and Grubbing
			01.01.15.02		Grading
			01.01.15.03		Drainage
			01.01.15.04		Landscaping
			01.01.15.05		Geotechnical
		01.01.16			Warehouse
		01.01.17			Maintenance Facility
		01.01.18			Waste Management Facility
	1.02				Larger ISF
		01.02.01			Expanded Storage Pad and Dry Cask Storage Systems
		01.02.03			Horizontal Dry Storage Modules
		01.02.04			Vertical Dry Storage Casks
		01.02.05			Storage Cask Fabrication Facility (expanded)
		01.02.06			Cask Maintenance Facility (expanded)

WBS Level					Description
1	2	3	4	5	
		01.02.07			Concrete Batch Plant (expanded)
		01.02.08			Visitor's Center / Auditorium (expanded)
		01.02.09			Admin Building (expanded)
		01.02.10			Security (expanded)
		01.02.11			Rail Spur / Receiving Yard (expanded)
		01.02.12			Utilities (expanded)
		01.02.13			Roads (expanded)
		01.02.14			Parking (expanded)
		01.02.15			Site Work (expanded)
		01.02.16			Warehouse (expanded)
		01.02.17			Maintenance Facility (expanded)
		01.02.18			Waste Management Facility (expanded)
		01.02.19			Laboratory/Hot Cell
			01.02.19.01		Structure
			01.02.19.02		Ports/Manipulators
			01.02.19.03		Lab
			01.02.19.04		Equipment
		01.02.20			Fuel Remediation Facility
			01.02.20.01		Structure
			01.02.20.02		Equipment
			01.02.20.03		Pool Liners
			01.02.20.04		Racking Systems
			01.02.20.05		Cooling/Filtering Systems
		01.02.21			Bare Fuel Receipt Facility
		01.02.22			Standardized Storage System
		01.02.23			Standardized Disposal Canister

WBS Level					Description
1	2	3	4	5	
		01.02.24			Canister Repackaging Facility (for Repository)
	1.03				Transportation Equipment
		01.03.01			Transportation Casks
		01.03.02			Rail Equipment
			01.03.02.01		Cask Cars
			01.03.02.02		Escort Cars
			01.03.02.03		Buffer Cars
			01.03.02.04		Road Locomotives
			01.03.02.05		Yard Locomotives
		01.03.03			Rail Maintenance Facility
		01.03.04			Transportation System Services
		01.03.05			Truck Equipment
	1.04				System Engineering
	1.05				Project Management and Support
		1.05.01			Project Management
		1.05.02			Construction Management
		1.05.03			Project Support
		1.05.04			QA
		1.05.05			ES&H
		1.05.06			Regulatory Services
	1.06				Site Selection
		01.06.01			Public Outreach and Communications
		01.06.02			Hearings
		01.06.03			Proposals & Evaluations
		01.06.04			NEPA
	1.07				D&D (Post operating phase)

WBS Element Descriptions

WBS Code	**WBS Element**
1.01.01	Pilot Storage Pad
WBS Element Description	
The storage pad constitutes the reinforced concrete pad that will be used for the initial storage of the casks via horizontal and vertical storage modules. The pad is built to withstand all environmental impacts, safety concerns, and seismic events. Final shape and size of the pad will be dependent upon the selected site and preferred method of storage of the canisters. This element does not include the roadwork, fencing or security but does include and concrete ramping to allow for ingress and egress of the pad. The pad does not include the storage cask systems; please see WBS 01.01.03 and 01.01.04 for details on those elements.	
WBS Code	**WBS Element**
1.01.02	Pilot Transfer Facility (Cask Handling Building)
WBS Element Description	
The Transfer Facility (or "Cask Handling Building") will incorporate a building sufficiently sized for incoming rail cars and OTR trucks to enter. The CHB will include the necessary crane(s) to offload the casks, a temporary storage facility for the casks and a load area for the casks to be transferred to the transfer trailers for transport to storage pads. This includes the design and construction of not only the structure but also the equipment contained therein.	
WBS Code	**WBS Element**
1.01.03	Pilot Horizontal Dry Storage Module
WBS Element Description	
Concrete and steel reinforced vessels to hold casks that will be stored horizontally on the dry storage pad.	
WBS Code	WBS Element
1.01.04	Pilot Vertical Dry Storage Module
WBS Element Description	
Concrete and steel reinforced vessels to hold casks that will be stored vertically on the dry storage pad.	
WBS Code	**WBS Element**
1.01.08	Visitor's Center & Auditorium
WBS Element Description	
The Visitors Center element incorporates all receiving functions including badging, informational displays on site operations and facilities spaces for public events including a large auditorium. The Center will be located outside of the secure area. This element does not include administrative offices; please see WBS 01.01.6 for this element.	
WBS Code	**WBS Element**
1.01.09	Administration Building
WBS Element Description	

Includes a commercial office building housing administrative offices including management, administration, engineering, licensing, records management, large conference room, kitchen, break rooms and conference rooms as necessary to support the ongoing operation of the CSF.	
WBS Code	**WBS Element**
1.01.10	Security Facilities
WBS Element Description	
This element includes all outputs directly related to site security within and external to the Protected Area including: • Security Building providing access to the protected area and housing offices for security personnel, security equipment including communications and electrical equipment. • Site Lighting • Vehicles • Inspection equipment for vehicles, rail and personal • Hardened sites • PIDAS (Perimeter Intrusion Detection and Assessment System) including Lighting, Cameras, Vehicle and Personnel portals, etc.) • Fencing • Central and Secondary Alarm Systems • Training Facility and Armory	
WBS Code	**WBS Element**
1.01.11	Rail Spur, Receiving Yard, Maintenance Facility
WBS Element Description	
A secure rail yard spur and yard, located in the OCA, will be constructed inside the security fence of the facility to receive casks and other supplies. Included are all railway bed preparations, signaling, switches, etc. This will be integrated into existing local rail lines and will include an area for the staging of cars and a termination in the transfer facility	
WBS Code	**WBS Element**
1.01.12	Utilities
WBS Element Description	
Includes all tie-ins to local utility provider(s), backup generators, interconnectivity to individual buildings, duct banks, a substation and switching station, any on-site power generation facilities, etc. Includes water and potentially sewer if connected to off-site sewage treatment.	
WBS Code	**WBS Element**
1.01.13	Roads
WBS Element Description	
Includes the engineering and construction of all roads on the site including curbing, striping and directional signage, but excluding parking lots (see WBS 01.01.11). This element also includes the construction of all roads necessary to connect the site to public roadways and will be of sufficient design and construction to accommodate OTR trucks accessing the site, construction equipment, etc.	
WBS Code	**WBS Element**
1.01.14	Parking
WBS Element Description	

The Parking element includes all necessary surface parking facilities at all buildings both for civilian vehicles as well as site vehicles. Element includes concrete or asphalt deck, curbing, striping and directional signage. This element also includes any necessary staging area for OTR trailer deliveries.	
WBS Code	**WBS Element**
1.01.15	Site Work
WBS Element Description	
Siting includes all necessary site preparations including clearing and grubbing, grading, drainage, landscaping and geotechnical work.	
WBS Code	**WBS Element**
1.01. 16	Warehouse
WBS Element Description	
The warehouse will be a secure facility used for the housing of all supplies and equipment necessary for operations of the facility. It will include a loading dock, necessary loading equipment and office space.	
WBS Code	**WBS Element**
1.01. 17	Maintenance Facility
WBS Element Description	
Comprised of a building housing all necessary supplies and equipment to provide for the maintenance and upkeep of the physical plant and equipment. This does not include any maintenance necessary inside the radioactive areas.	
WBS Code	**WBS Element**
1.01. 18	Waste Management Facility
WBS Element Description	
This facility allows for the handling, decontamination and disposition of bare UNF casks, Solid and liquid LLW, pool filters and ventilation exhaust filters. Additionally, this facility will dispose of hazardous materials than is non-radiological.	
WBS Code	**WBS Element**
1.02. 01	Larger ISF Expanded Storage Pad
WBS Element Description	
This incorporates any necessary expansion of the storage pad for the ISF and dry cask storage systems.	
WBS Code	**WBS Element**
1.02.05	ISF Storage Cask Fabrication Facility (expanded)
WBS Element Description	
This area will manufacture storage casks for on-site use.	
WBS Code	**WBS Element**
1.02.06	ISF Cask Maintenance Facility (expanded)

WBS Code	WBS Element
WBS Element Description	
The cask maintenance facility will repair damaged casks and associated equipment. The facility will also prepare casks for future use. Spare parts, handling equipment and necessary office space will be included in this element.	
WBS Code	**WBS Element**
1.02.07	Concrete Batch Plant (expanded)
WBS Element Description	
Consists of a concrete manufacturing facility for the supply of concrete for the pad and cask storage modules and other buildings as needed. It will be located adjacent to the rail spur for delivery of supplies. This element includes the storage yard for the materials needed to make concrete.	
WBS Code	**WBS Element**
1.02.18	Waste Management Facility (expanded)
WBS Element Description	
This element reflects the expansion of the waste management facility from being only a storage pad to the use of a hot cell and transfer pool.	
WBS Code	**WBS Element**
1.02.19	Laboratory/Hot Cell
WBS Element Description	
The laboratory/hot cell will provide for the unloading and opening of select canisters, unloading of UNF assemblies and analyses of the UNF and select canisters, re-packaging of canisters, rods and assemblies and testing of rods and assemblies along with necessary laboratory facilities and offices.	
WBS Code	**WBS Element**
1.02.20	Fuel Remediation Facility
WBS Element Description	
The Fuel Remediation facility will be a pool sized to simultaneously accommodate two shipping or transfer casks enclosed by a building. The building will also contain a service crane to transport the casks. The pool building will also contain all necessary offices, central systems, utilities, filtering, fuel repair/canning area, accident mitigation equipment and laboratory facilities. The facility will also have sufficient space for temporary storage of one DSC's complement of UNF.	
WBS Code	**WBS Element**
1.02.21	Bare Fuel Receipt Facility
WBS Element Description	
The bare fuel receipt facility provides a production scale capability to receive and process bare fuel transportation casks. The fuel storage method is being investigated but for this study a pool is assumed to load dry storage canisters.	
WBS Code	**WBS Element**
1.02.22	Standardized Canisters/Storage Systems
WBS Element Description	

Development and provision of a standardized canister which may be used for ISF. (Not part of the report baseline)	
WBS Code	**WBS Element**
1.02..23	Standardized Disposal Canister
WBS Element Description	
Development and provision of a standardized canister for a future repository. (Not part of the report baseline)	
WBS Code	**WBS Element**
1.02.24	Canister Repackaging Facility
WBS Element Description	
The canister repackaging facility (CRF) will be a shielded facility (pool or hot cell) and support equipment to open storage canisters and repackage the used fuel assemblies into a standard disposal canister for use in the repository. The CRF may include storage of canisters prior to shipment and loading of shipping casks. This facility will be developed later in the ISF life as the canister design is completed to meet repository requirements.	
WBS Code	**WBS Element**
1.03.01	Transportation Casks
WBS Element Description	
Transportation casks will need to be sourced for all plants and US NRC approval will be required. These casks may be either Dual Purpose Casks or Transportable Storage casks. Additionally, cradles to attach the cask to the rail cars and impact limiters as well as handling equipment to load and unload the casks will be required.	
WBS Code	**WBS Element**
1.03.02	Rail Cars
WBS Element Description	
Rolling stock required for the transportation of the fuel both to the CSF as well as at the CSF inside the secure perimeter including Cask Cars, Buffer Cars, Escort Cars and Yard Locomotives. (Road Locomotives are assumed to be provided under contract with railroads.)	
WBS Code	**WBS Element**
1.03.03	Railcar Maintenance Facility
WBS Element Description	
Maintenance facility and equipment for preventive maintenance for all rolling stock and corrective maintenance/repairs for cars and associated equipment.	
WBS Code	**WBS Element**
1.03.04	Transportation System Services
WBS Element Description	
Systems analysis and training required for transportation system planning and analysis.	
WBS Code	**WBS Element**
1.03.05	Truck Equipment

WBS Element Description	
Truck equipment needed for heavy haul of transportation casks to the rail head. Assume truck tractors and trailers are leased. This is specialty equipment needed, owned by the government.	
WBS Code	**WBS Element**
1.04	System Engineering
WBS Element Description	
Includes the creation of an interdisciplinary process to define, evaluate and create the systems necessary for the development and construction of the CSF. The element includes the functional analysis and evaluation of the CSF concept, the requirements analysis and the alternatives to the CSF.	
WBS Code	**WBS Element**
1.05	Project Management and Support
WBS Element Description	
Includes all necessary project management and construction management staff, equipment, office space, and the planning, organization and management of all resources related to the management of the construction and development of the ISF. Includes project support/project controls, QA, ES&H, and Regulatory Services.	
WBS Code	**WBS Element**
1.05.01	Project Management
WBS Element Description	
Includes all necessary project management staff, equipment, office space, and the planning, organization and management of all resources related to the management of the construction and development of the ISF	
WBS Code	**WBS Element**
1.05.02	Construction Management
WBS Element Description	
Includes all necessary project management and construction management staff, equipment, office space, and the planning, organization and management of all resources related to the management of the construction and development of the ISF. Includes Regulatory Activities.	
WBS Code	**WBS Element**
1.05.03	Project Support/Controls
WBS Element Description	
Includes all necessary project support and project controls for project.	
WBS Code	**WBS Element**
1.05.04	Quality Assurance
WBS Element Description	

Includes all necessary quality assurance staff, equipment, office space, and actions required to monitor and maintain the stated standards, benchmarks and milestones of the construction and operation of the facility and systems therein.	
WBS Code	**WBS Element**
1.05.05	ES&H
WBS Element Description	
Includes all necessary environmental, safety, and health staff, equipment, office space, and actions required to monitor and maintain the stated standards, benchmarks and milestones of the construction and operation of the facility and systems therein.	
WBS Code	**WBS Element**
01.05.06	Regulatory Services
WBS Element Description	
Includes all necessary Licenses, Permits, Data Management systems and expenses associated with the procurement of, but not limited to: • Nuclear Regulatory Commission site licensing activities • Environmental • Clean Air • Clean Water • Hazardous and Solid waste Special Use Permits • DOT • EPA • SWPP • BLM • Building • Grading and Drainage • Utility • State and local permits.	
WBS Code	**WBS Element**
1.06	Site Selection
WBS Element Description	
All activities required to acquire the ISF site(s) including public outreach and communications, hearings, proposals and evaluations, and NEPA activities.	
WBS Code	**WBS Element**
1.07	Decontamination and Decommissioning (D&D)
WBS Element Description	
All activities to support decontamination and decommissioning of the ISF(s) at the end of useful life.	

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Appendix E

Capital Cost Estimate

Basis of Estimate, Assumptions and Exclusions for Capital Cost Estimates

The following BOE, key assumptions, and cost exclusions are listed here.

Basis of Estimate

- Costs are in 2012 constant dollars.
- Funding is unconstrained.
- The costs represent Total Project Cost, which includes Total Estimated Costs and Other Project Costs.
- Owner's costs such as siting, permitting, and NRC licensing are included.
- The costs include facilities for administration, operations, and maintenance.
- Infrastructure improvements are part of the cost estimate.
- The costs include a Physical Protection System, including all systems and structures required for site security.
- The project will provide all equipment necessary to retrieve, load and transport UNF from shutdown reactor sites, if the site does not already have adequate transfer equipment.
- Land acquisition costs are included.
- Parametric cost factors are as follows:
    - Project Management – 10% of direct and indirect construction costs + 5% construction management on direct construction costs
    - Engineering and Design costs are estimated at 20% of direct and indirect construction costs.
    - Contractor fees and overhead markups – 20% of direct construction costs
    - Contingency - 30% of direct and indirect construction, engineering and design costs
- Engineering and Design costs include all conceptual, preliminary, and final design costs and Title III engineering (including testing and inspection).
- The costs include all contingency and management reserve.
- The cost estimate is a Class 4 cost estimate with an accuracy of -30% +50%.

Key Assumptions

- The site is located within the 48 contiguous United States.
- The Pilot will be sized to handle approximately 5000 MTHM of UNF and GTCC waste stored in dry storage casks. Two years of VSCs and HSMs are included in the Pilot capital cost estimate. The remaining storage modules are part of the operating cost estimate.
- The Pilot will be operational by 2021.
- The larger ISF is an extension of the Pilot and will be nominally sized for 20,000 MTHM initially (growing to 70,000 MTHM later in the facility's life). Costs are based on 20,000 MTHM for this report. Two years of VSCs and HSMs are included in the capital costs. (The remaining storage modules are operating costs.)
- The larger ISF will be operational by 2025.
- A waste management facility
- A hot cell laboratory facility to allow examination of stored fuel

- A fuel remediation facility for handling small amounts of bare and damaged fuel and packaging canisters for storage. These capabilities are co-located with a larger interim storage facility. The packaging facility is sized to handle only two canisters at a time.
- A bare fuel receipt facility to handle quantities of bare fuel received in reusable transport casks and repackaged into dry storage canisters.
- The laboratory and fuel handling (bare fuel and fuel remediation)
- The facilities will be licensed by the NRC.
- Transportation equipment will be licensed by the NRC and meet NRC and DOT requirements.
- The facilities will be capable of handling and storing all types of casks and canisters that may be encountered at commercial reactor sites.
- Existing roads, railroads, and waterways will be utilized to the maximum extent possible for transportation of UNF and HLW.
- Utilities (power, water, etc.) are available within a reasonable distance from the site.
- An Environmental Impact Statement will be required.
- No unproven, first-of-a-kind technology is required.
- The project will comply with the requirements of DOE O 413.3B.
- Transportation and storage equipment will include containers, over-packs, casks, trailers, railcars and other required equipment. Transportation equipment is procured in phases, as needed for the Pilot and larger ISF. Road locomotives are provided by the transporting railroad.

Cost Exclusions

- Escalation
- All equipment and transportation costs necessary to transport UNF and HLW from Pilot or larger ISF to a final monitored geologic repository.
- A repackaging facility for repository canisters.
- The retrieval, transportation, and storage costs of Defense nuclear waste, DOE used nuclear fuel, and Naval Nuclear Power Propulsion used nuclear fuels
- All costs for federal personnel
- Pre-conceptual design costs

Table E-1. Capital Cost Estimate by WBS ($M).

WBS	Description	Pilot	Larger ISF	Laboratory	Fuel Remediation	Bare Fuel Receipt
1.	**Interim Storage and Transportation Project (TPC)**	**1007.5**	**2290.2**	**1069.6**	**647.8**	**1533.6**
01.01	**Pilot**	**568.3**				
01.01.01	Storage Pad (for 5000 MTHM)	10				
01.01.02	Transfer (Cask Handling) Facility	40				
01.01.03	Horizontal Storage	40				

WBS	Description	Pilot	Larger ISF	Laboratory	Fuel Remediation	Bare Fuel Receipt
	Modules[1]					
01.01.04	Vertical Storage Casks[1]	60				
01.01.05	Storage Cask Fabrication Facility	5				
01.01.06	Cask Maintenance Facility	8				
01.01.07	Concrete Batch Plant	2				
01.01.08	Visitor's Center / Auditorium	0.6				
01.01.09	Admin. Building	3				
01.01.10	Security	16				
01.01.11	Rail Spur / Receiving Yard	20				
01.01.12	Utilities	21				
01.01.13	Roads	18				
01.01.14	Parking (costs included in Roads)					
01.01.15	Site Work	18				
01.01.16	Warehouse	2				
01.01.17	Maintenance Facility	10				
01.01.18	Waste Management Facility	30				
01.01.xx.cf.	Contractor O/H & Fees	60.7				
01.01.xx.EDT .	Engineering, Design, Testing	72.9				

WBS	Description	Pilot	Larger ISF	Laboratory	Fuel Remediation	Bare Fuel Receipt
01.01.Cont.	Contingency (@ 30%)	131.2				
01.02	**ISF**		**1960.0**	**936.0**	**561.6**	**1347.8**
01.02.01	Expanded Storage Pad (for an additional 20,000 MTHM)		30			
01.02.02	Transfer (Cask Handling) Facility (expanded)		20			
01.02.03	Horizontal Storage Modules*		80			
01.02.04	Vertical Storage Casks*		120			
01.02.05	Storage Cask Fabrication Facility (expanded)		5			
01.02.06	Cask Maintenance Facility (expanded)		4			
01.02.07	Concrete Batch Plant (expanded)		2			
01.02.08	Visitor's Center / Auditorium (no change)					
01.02.09	Admin. Building (no change)					
01.02.10	Security (expanded PIDAS)		26			
01.02.11	Rail Spur / Receiving Yard (expanded)		40			
01.02.12	Utilities– no					

WBS	Description	Pilot	Larger ISF	Laboratory	Fuel Remediation	Bare Fuel Receipt
	change					
01.02.13	Roads – no change					
01.02.14	Parking (costs included in Roads) (no change)					
01.02.15	Site Work (no change)					
01.02.16	Warehouse (no change)					
01.02.17	Maintenance Facility (no change)					
01.02.18	Waste Management Facility (no change)					
01.02.19	Laboratory/ Hot Cell			500		
01.02.20	Fuel Remediation Facility				300	
01.02.20.01	Handling Pool Facility				110	
01.02.20.02	Pool Handling Equipment				150	
01.02.20.03	Heat Rejection Equipment				40	
01.02.21.01	Bare Fuel Handling Facility					720
01.02.xx.cf.	Contractor O/H & Fees		65.4	100	60	144
01.02.xx.EDT.	Engineering, Design, Testing		78.5	120	72	172.8
01.02.Cont.	Contingency (@30%)		141.3	216	129.6	311

WBS	Description	Pilot	Larger ISF	Laboratory	Fuel Remediation	Bare Fuel Receipt
01.03	**Transportation Equipment**	**301.9**	**1430.0**			
01.03.01	Transportation Casks	122.0	573.0			
01.03.02	Rail Equipment	59.0	268.0			
01.03.03	Rail Car Maintenance Facility		20.0			
01.03.04	Transportation System Services	9.1	43.1			
01.03.05	Truck Equipment	1.6				
01.03.xx.cf.	Contractor O/H & Fees	1.8	12.6			
01.03.xx.EDT	Engineering, Design, Testing	38.7	183.3			
01,03.Cont.	Contingency	69.7	330.0			
1.04	System Engineering	10.0	20.0	5.0	5.0	5.0
1.05	Project Management and Support[2]	114.7	228.1	128.6	111.2	180.8
1.06	Site Selection[3]	12.5				

Notes:
[1]Storage Casks included for first 2 years of operations, remainder are part of Operating Costs and not included in capital cost estimate.
[2]Includes project management, construction management, quality assurance, environmental safety and health, and regulatory/licensing/permitting.
[3]Includes land and land rights, and site selection, NEPA compliance, etc. Assumes ISF co-located with Pilot.

Table E-2. Rolling Stock Direct Costs

	Unit Cost ($M)	Pilot		ISF	
		Units	Cost ($M)	Additional Units	Cost ($M)
Road Locomotive	*	10		25	
Yard Locomotive	0.75	1	0,75	3	2.25
Cask Car	1.0	25	25	100	100
Buffer Car	0.765	10	7.65	50	38.25
Escort Car	5.1	5	25.5	25	127.5
Total			**58.9**		**268**
*Road Locomotives to be provided by railroads – included in Operating Costs					

Table E-3. Capital Cost Estimate Summary ($M).

	Low	Point Estimate	High
Pilot with Transportation Equipment	705.2	1007.5	1511.2
Larger ISF with Transportation Equipment	1603.1	2290.2	3435.3
Laboratory Facility	748.7	1069.6	1604.4
Fuel Remediation Facility	453.4	647.8	971.6
Bare Fuel Receipt Facility	1073.5	1533.6	2300.4.0

Appendix F

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