UNITED STATES OF AMERICA

A. National Framework for Management of Radioactive Waste and Spent Fuel

The United States of America (U.S.) has 100 operating nuclear power plants generating about 20 percent of its electricity. In addition, there are numerous test, training, and research reactors. Nuclear reactors generate spent fuel and radioactive waste. The U.S. has thousands of users of materials that generate radioactive waste, including nuclear fuel cycle facilities, research and development facilities, medical facilities, industries, universities, and defense facilities.

U.S. radioactive waste management policy focuses on disposal of waste in a manner that is protective of human health and the environment. Radioactive wastes in the U.S. have many designations depending on their hazards and the circumstances and processes creating them. High-level waste (HLW) and transuranic (TRU) waste are managed for disposal in a geologic repository. Other waste, such as low-level radioactive waste (LLW) and uranium and thorium mill tailings are managed through land disposal in either above ground, near surface (first 30 meters) or intermediate depth disposal facilities. A significant volume of waste in the U.S. results from decommissioning and cleanup of nuclear and radiological facilities. Waste with both radioactive and hazardous constituents in the U.S. is called "mixed" waste (mixed LLW or mixed TRU waste).

Owners and operators of nuclear power plants and other types of facilities manage radioactive waste generated by their facilities prior to disposal. There is a commercial market for radioactive waste management services. U.S. Federal or state governments, however, will ultimately administer waste disposal sites after closure. The 50 U.S. States have the responsibility to provide for disposal of Class A, B, and C LLW, and may join together as compacts for this purpose.

The U.S. Department of Energy (DOE) is responsible for and has regulatory authority over most of the spent fuel and radioactive waste management activities for DOE-owned and generated waste and materials, mostly located on Government-owned sites. DOE is also responsible for disposition of HLW and spent fuel, and Greater-than-Class C (GTCC) LLW. DOE operates the Waste Isolation Pilot Plant (WIPP), a geologic repository for defense TRU waste.

The U.S. Nuclear Regulatory Commission (NRC) is an independent authority regulating commercial spent fuel and radioactive waste management activities, including the possession and use of radioactive materials as well as the siting, construction, and operation of nuclear facilities. NRC regulates commercial nuclear fuel cycle materials and facilities, commercial sealed sources, including disused sealed sources. NRC also oversees certain state programs where NRC has relinquished limited regulatory authority to the individual states. "NRC Agreement States" can regulate commercial LLW disposal sites and uranium mill tailings sites. These Agreement States do not have

regulatory authority for spent fuel, special nuclear material sufficient to form a critical mass, and HLW.

The U.S. Environmental Protection Agency (EPA) establishes generally applicable environmental standards to protect the environment from hazardous materials and certain radioactive materials. EPA establishes standards for remediating active and inactive uranium mill tailing sites, environmental standards for the uranium fuel cycle, and environmental radiation protection standards. EPA promulgates standards for and certifies compliance at WIPP. Some "EPA Authorized" states also have regulatory authority delegated to them by EPA, such as for discharges from some industrial or mining practices. The separation between EPA's standard-setting function and NRC's implementing function reflects a policy of centralizing environmental standard setting in a single agency.

B. National Legal and Regulatory Framework

The national legal and regulatory framework for spent fuel and radioactive waste management in the U.S. has evolved through a series of laws establishing Federal Government agencies responsible for the safety of radioactive materials. Federal Legislation is enacted by Congress and signed into law by the President. The regulatory system for spent fuel and radioactive waste management in the U.S. involves several agencies such as DOE, NRC and the EPA.

C. Waste Management, Decommissioning, and Spent Fuel Strategy and Current Practices and Technologies

C.1 Strategies and Current Practices

C.1.1 Radioactive Waste

Radioactive wastes are treated primarily to produce a structurally stable, final waste form and minimize the release of radioactive and hazardous components.

HLW from commercial reprocessing activities is vitrified and is stored at the former reprocessing plant in West Valley, New York. Defense HLW is stored, managed and processed at three DOE sites. HLW disposal strategy is discussed in C.2.

Class A, B and C LLW are generally disposed of in near surface facilities. GTCC LLW is stored until an adequate method of disposal is established. DOE is responsible for the ultimate disposal of GTCC LLW and is considering strategies in its Environmental Impact Statement that is currently in preparation. Generators of LLW waste must treat these wastes to remove free liquids, and stabilize or destroy other hazardous components contained in the waste. Private companies in the U.S. provide processing (e.g. packaging

and treatment) and brokerage services to facilitate safe storage, transportation and, ultimately, disposal of LLW at one of four commercial disposal facilities.

TRU waste is radioactive waste contaminated with long-lived radioisotopes beyond or "heavier" than uranium on the periodic table of the elements. TRU waste is produced during nuclear fuel research and development; and during nuclear weapons research, production, and cleanup. TRU waste from the government's defense activities is disposed in a deep geologic repository at WIPP.

Uranium recovery is the extraction or concentration of uranium from any ore processed primarily for its source material content. These wastes usually have relatively low concentrations of radioactive materials with long half-lives and were disposed of in mill tailings impoundments. Most conventional mill uranium recovery facilities shut down or scaled back operations in the early 1980s. Many of the previously operating conventional uranium mills were reclaimed or are in the process of decommissioning and reclamation. Most uranium recovery facilities in the U.S. today use in situ recovery technology to extract uranium from underground ore bodies. Since 2010, NRC has approved licenses for five new in situ recovery sites. NRC is expecting applications for several more in situ recovery facilities in the next few years. Solid wastes generated at in situ recovery facilities are typically disposed of in mill tailings impoundments at conventional uranium mills. Liquid wastes generated at in situ recovery facilities are typically injected into deep geologic formations through a series of injection wells located at each facility

C.1.2 Spent fuel

Spent fuel is stored in government and licensed non-government facilities pending disposal. The overwhelming majority is located in spent fuel pools within nuclear power plants or independent spent fuel storage facilities (ISFSIs), many of which are located at decommissioned or operating nuclear power plant sites.

C.2 Overview of Main Waste and Spent Fuel Issues:

Disposition of HLW and Spent Fuel: By law DOE was required to characterize a site at Yucca Mountain, Nevada, for its potential use as a deep geologic repository. However, in 2009, it was determined that developing a repository at Yucca Mountain was not a workable option and the U.S. needed a different solution for spent fuel and HLW disposal. A Blue Ribbon Commission (BRC) on America's Nuclear Future evaluated alternative approaches for managing spent fuel and HLW from commercial and defense activities. The BRC report contained recommendations for legislative and administrative action to develop a new strategy to manage nuclear waste. Subsequently a Strategy for the Management and Disposal of Used Nuclear Fuel and High-Level Radioactive Waste, was issued containing policy on addressing the disposition of used nuclear fuel and HLW. The document outlines plans that:

- Sites, designs, 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 toward 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.

The execution of these plans is dependent on passage of enabling legislation, legal approvals, and policy decisions.

In the meantime, the U.S Court of Appeals directed NRC to resume the Yucca Mountain licensing process. NRC is proceeding to complete the Safety Evaluation Report of DOE's Application to construct the Yucca Mountain repository, which is the next step in the licensing process. Licensing activities continue within the constraints of funding appropriated by the U.S. Congress.

The lack of a repository for Greater-than-Class-C LLW: DOE began to prepare in 2007 an Environmental Impact Statement (EIS) to dispose of GTCC LLW and other DOE GTCC-like waste. The EIS is considering several DOE and generic commercial sites, and several technologies, such as geologic repositories, intermediate depth boreholes, and enhanced near surface disposal. A report to the U.S. Congress on disposal alternatives and action by Congress is required before a decision can be reached.

C.3 Overview of Research and Development (R&D) Programs

Both industry and the Federal Government conduct research and development to understand and improve waste management science and technology. Work in association with WIPP and new disposal options is conducted by DOE through several national laboratories, the United States Geological Survey (USGS), and private sector contractors. Scientific and engineering activities continue at WIPP, focused on performance confirmation, monitoring and waste characterization. DOE continues to develop and execute a research and development program that will address critical scientific and technical issues associated with the long-term management and disposal of spent fuel and HLW. This R&D will be performed on functions in storage, transportation, and disposal including research in a variety of geologic environments. An additional objective is the demonstration of technologies necessary to allow commercial deployment of solutions for the sustainable management of used nuclear fuel that is safe, economic and secure.

C.4 Financing of Waste and Spent Fuel Management

Each generator funds radioactive waste management from its operating budget (producer pays). LLW disposal site operators levy fees on waste generators upon receipt of the wastes for disposal. Management of spent fuel and HLW is funded by the waste

generators and owners through a fee on the commercial generation of nuclear power. This fee, which is assessed at 1/10 U.S.-cent per kilowatt-hour (kWh), is deposited in the Nuclear Waste Fund to be used for waste management. The fee is currently suspended. Congress appropriates funds for DOE waste management programs, including a separate annual appropriation to cover disposal costs for DOE spent fuel and HLW.

D. Radioactive Waste Classification, Quantities, and Inventory

Summary information for radioactive waste inventory is provided in Table 1, and is split between commercial and DOE facilities. The U.S. does not maintain a national inventory system for commercial LLW in storage. Table 2 provides a summary of waste disposed, and is split between commercial and DOE facilities. Table 3 provides a summary of spent fuel storage facilities and inventory. No spent fuel has been sent for reprocessing, hence no Table 4. The U.S. radioactive waste classes were discussed in C.1. The U.S. has developed a matrix which allows a summary level translation from U.S. waste classes to IAEA waste classes, provided as Table 5.

E. Tabulation of Processing, Storage, and Disposal Facilities

Summary information for spent fuel and radioactive waste disposal, storage and treatment facilities is provided in Table 6 and is split between commercial and DOE facilities. Table 7 provides a summary of major sources of waste produced in the U.S.

F. Trends and Future Prospects

Table 8 provides information on spent fuel and waste management trends and future prospects.

TABLE 1: Radioactive Waste in Storage

COMMERCIAL WASTE IN STORAGE (AS STORED VOLUME)[1]									
WASTE CLASS	**PROCESSED FOR DISPOSAL**	**TOTAL VOLUME (m3)**	**DISTRIBUTION (m3)**						
			RO	**FFE**	**RP**	**NA**	**DF**	**DC/RE**	**ND**
HLW	YES	2.08E+02			2.08E+02				
GTCC LLW	NO	4.30E+01				4.30E+01			
Class C LLW	NO	No Data							No Data
Class C LLW	YES	No Data							No Data
Class B LLW	NO	No Data							No Data
Class B LLW	YES	No Data							No Data
Class A LLW	NO	No Data							No Data
Class A LLW	YES	No Data							No Data
Residual Rad. Mat.	YES	No Data							No Data

DOE WASTE IN STORAGE (AS STORED VOLUME)									
WASTE CLASS	**PROCESSED FOR DISPOSAL**	**TOTAL VOLUME (m3)**	**DISTRIBUTION (m3)**						
			RO	**FFE**	**RP**	**NA**	**DF**	**DC/RE**	**ND**
HLW	NO	3.61E+05					3.61E+05		
HLW	YES	3.00E+03					3.00E+03		
TRU	NO	4.91E+04			6.77E+02		4.85E+04		
TRU	YES	Incl above							
LLW	NO	3.29E+04				6.03E+03	2.53E+03		2.43E+04
LLW	YES	Incl above							Incl above

RO – Reactor Operations
FFE – Fuel Fabrication/Enrichment
RP – Fuel Reprocessing
NA – Nuclear Applications
DF – Defense Waste
DC/RE – Decommissioning/Remediation
ND - Not Determined

[1] The U.S. does not maintain a national inventory system for commercial LLW in storage

TABLE 2: Radioactive Waste Disposal

COMMERCIAL WASTE DISPOSED (AS DISPOSED VOLUME)									
WASTE CLASS	**PROCESSED FOR DISPOSAL**	**TOTAL VOLUME (m3)**	**DISTRIBUTION (m3)**						
			RO	**FFE**	**RP**	**NA**	**DF**	**DC/RE**	**ND**
ALL LLW - Closed	YES	4.38E+05	3.64E+05			3.71E+04		3.42E+04	2.47E+03
ALL LLW - Ocean Disposal Closed	YES	2.26E+04							2.26E+04
Class C LLW	YES	2.99E+04	2.88E+04			3.10E+02		7.91E+02	1.20E+01
Class B LLW	YES	5.72E+04	5.67E+04			5.60E+01		4.89E+02	2.00E+00
Class A LLW	YES	4.54E+06	2.03E+06			2.99E+04		2.41E+06	8.12E+04
Residual Rad Mat.	YES	1.42E+06		1.401E+06			2.12E+04		
Mill Tailings (dry metric ton)	YES	2.48E+08		2.48E+08					

DOE WASTE DISPOSED (AS DISPOSED VOLUME)									
WASTE CLASS	**PROCESSED FOR DISPOSAL**	**TOTAL VOLUME (m3)**	**DISTRIBUTION (m3)**						
			RO	**FFE**	**RP**	**NA**	**DF**	**DC/RE**	**ND**
TRU	YES	9.10E+04					9.10E+04	Incl. in DF	
LLW	YES	1.51E+07				5.28E+05	4.14E+06	1.04E+07	
Residual Rad Mat.	YES	3.03E+06					3.03E+06	Incl. in DF	

Table 3: Spent Fuel in Storage (MTHM)		
Type	**Current Amount at NPP[2]**	**Current Amount at Research Reactors [3]**
Total Spent Fuel Storage		
Wet Storage (At reactor incl. pools and ISFSI)		
Commercial	4.96E+04	1.08E+00
Government	0	0
Wet Storage (Away from reactor)		
Commercial	6.74E+02	0
Government	1.20E-01	3.43E+01
Dry Storage (At reactor incl. pools and ISFSI)		
Commercial	2.38E+04	1.00E-01
Government	0	0
Dry Storage (Away from reactor)		
Commercial	0	0
Government	9.40E+01	2.33E+03
Total Spent Fuel (held for other countries)	0	0

[2] Includes GE Morris and Utah Private Fuel Storage, which are not located at a nuclear power source.
[3] Includes DOE facilities test reactors and other research facilities

Table 5: Translation Matrix

IAEA Safety Guidance Class	U.S. Class (See table below for definition)
High Level Waste	100% HLW
Intermediate Level Waste	100% GTCC LLW and TRU waste
Low Level Waste	40% of Class A; 100% of Class B and C LLW
Very Low Level Waste	60 % of Class A LLW*
Very Short Lived Waste	LLW held for decay storage (no national inventory available)
Exempt Waste	No national clearance standard; case-by-case analysis for disposition

* The U.S. does not have a Very Low Level Waste Class. To approximate the IAEA conceptual waste class and do a translation, a split was arrived at, based on analysis of isotope activities and associated volumes disposed in commercial facilities for 2009 through 2013, as documented in the Manifest Information Management System (MIMS) maintained by DOE. For this report an assumption was made that Very Low Level Waste was considered to be the volume disposed for which the isotope activities were less than 0.01% of the criteria for Class A waste per 10 CFR 61.55.

U.S. Commercial Radioactive Waste Classification	
Waste Class	**Description**
HLW	The highly radioactive material resulting from the reprocessing of spent fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations and other highly radioactive material that NRC determines by rule requires permanent isolation.
Class A LLW	Class A waste is determined by characteristics listed in 10 CFR 55(a)(2)(i) and physical form requirements in 10 CFR 61.56(a). (U.S. does not have a minimum threshold for Class A waste).
Class B LLW	Waste that must meet more rigorous requirements on waste form than class A waste to ensure stability.
Class C LLW	Waste that not only must meet more rigorous requirements on waste form than Class B waste to ensure stability but also requires additional measures at the disposal facility to protect against inadvertent intrusion.
GTCC LLW	LLW not generally acceptable for near-surface disposal.
AEA Section 11e.(2) Byproduct Material	Tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore processed primarily for its source material content, including discrete surface wastes resulting from uranium solution extraction processes. Underground ore bodies depleted by such solution extraction operations do not constitute "byproduct material" within this definition

TABLE 6: Processing, Storage & Disposal Facilities

PROCESSING, STORAGE AND DISPOSAL FACILITIES								
TYPE	PLANNED	CONSTRUCTION	COMMISSIONING	IN OPERATION	SHUTDOWN	DECOMM	OTHER	TOTAL
SPENT FUEL STORAGE								
Government	0	0	0	15	0	0	0	15
Commercial	28	1	0	152	0	0	0	181
SPENT FUEL REPROCESSING & RECYCLING								
Government	0	0	0	0	0	1	0	1
Commercial	0	0	0	0	0	0	0	0
SPENT FUEL CONDITIONING								
Government	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
SPENT FUEL DISPOSAL								
Government	1	0	0	0	0	0	0	1
Commercial	0	0	0	0	0	0	0	0
WASTE PROCESSING & CONDITIONING								
HLW (Government)	1	2	1	1	1	1	0	7
TRU (Government)	1	0	0	2	0	0	0	3
LLW (Government)	0	0	0	See Storage	0	0	0	0
LLW (Commercial)	0	0	0	57	0	0	0	57
WASTE STORAGE								
HLW (Commercial)	0	0	0	0	0	0	0	0
HLW (Government)	0	1	0	6	0	0	0	7
TRU (Government)	0	0	0	11	0	0	0	11
LLW (Commercial)	0	0	0	0	0	0	0	0
LLW (Government)	0	0	0	17	0	0	0	17
Residual Radioactive Mat (Commercial)	0	0	0	0	1	0	0	1
Residual Radioactive Mat (Government)	0	0	0	1	0	0	0	1
WASTE DISPOSAL								
HLW[4]								
TRU (Government)	0	0	0	1	0	1	0	2
LLW (Government)	2	0	1	12	5	0	0	20
LLW (Commercial)	0	0	0	4	0	4	2	10
GTCC LLW (Government)	1	0	0	0	0	0	0	1
Residual Radioactive Mat. or tailings (Government)	0	0	0	2	2	26	0	30
Residual Radioactive Mat. or tailings (Commercial)	0	0	0	16	22	6	0	44

[4] See Spent Fuel Disposal

TABLE 7: Summary of Major Sources of Waste

SUMMARY OF MAJOR SOURCES OF WASTE								
TYPE	**PLANNED**	**CONST.**	**COMMISSIONING**	**IN OPERATION**	**SHUT DOWN**	**DECOMM**	**OTHER**	**TOTAL**
RESEARCH REACTORS[5]	0	0	0	31	11	83	0	125
NUCLEAR POWER REACTORS[6]	28	1	0	104	29	0	0	162
SPENT FUEL REPROCESSING & RECYCLING[7]	0	0	0	0	0	1	0	1
OTHER (Fuel Cycle Facilities)[8]	3	2	0	8	1	0	0	14

[5] 2012-2013 NRC Information Digest- Pages 43, 44
[6] 2012-2013 NRC Information Digest- Pages 30,45,127, 128-129
[7] West Valley
[8] 2012-2013 NRC Information Digest- Pages 72, 74, 146

TABLE 8: TRENDS & FUTURE PROSPECTS						
TYPE	**CURRENT AMOUNT[9]**	**Units**	**ESTIMATED CURRENT AMOUNT WHEN PREPARED FOR DISPOSAL**	**CURRENT DISPOSAL CAPACITY**	**TOTAL FORECAST AT 2030[10]**	**TOTAL FORECAST AT 2050**
SPENT FUEL STORAGE WET STORAGE (AR)						
Commercial	4.96E+04	MTHM			4.96E+04	4.96E+04
Government	0	MTHM			0	0
WET STORAGE (AFR)						
Commercial	6.74E+02	MTHM			6.74E+02	6.74E+02
Government	3.40E+01	MTHM			3.40E+01	3.40E+01
DRY STORAGE (AR)						
Commercial	2.38E+04	MTHM			6.17E+04	9.35E+04
Government	0	MTHM			0	0
DRY STORAGE (AFR)						
Commercial	0	MTHM			0	0
Government	2.42E+03	MTHM			2.42E+03	2.42E+03
TOTAL AMOUNT SPENT FUEL SENT TO REPROCESSING & RECYCLCING	0	MTHM			0	0
TOTAL AMOUNT OF SPENT FUEL DISPOSED	0	MTHM		0	0	TBD
WASTE IN STORAGE						
HLW Commercial	2.08E+02	m^3	2.08E+02		2.08E+02	2.08E+02
HLW Government	3.64E+05	m^3	2.28E+04		2.40E+05	2.28E+04
TRU Government	4.91E+04	m^3	5.36E+04		TBD	TBD
LLW Commercial	No Data	m^3	No Data		No Data	No Data
LLW Government	3.29E+04	m^3	3.29E+04		6.50E+04	6.50E+04
GTCC Commercial	4.30E+01	m^3	4.30E+01		TBD	TBD

[9] As of November 2014

[10] Projected inventory is based on an assumption that estimated commercial reactor pool and government inventory remain at currently estimated levels.

TABLE 8: TRENDS & FUTURE PROSPECTS						
TYPE	**CURRENT AMOUNT**	**Units**	**ESTIMATED CURRENT AMOUNT WHEN PREPARED FOR DISPOSAL**	**CURRENT DISPOSAL CAPACITY[11]**	**TOTAL FORECAST AT 2030**	**TOTAL FORECAST AT 2050**
WASTE DISPOSAL						
HLW Commercial	0	m^3		0	0	TBD
HLW Government	0	m^3		0	0	TBD
TRU Government	9.10E+04	m^3		1.76E+05	TBD	1.45E+05
LLW Government	1.51E+07	m^3		5.89E+06	1.86E+07	2.01E+07
Class A LLW Com.	4.54E+06	m^3		5.62E+06	5.64E+06	6.93E+06
Class B LLW Com.	5.72E+04	m^3		included in Class A	6.40E+04	7.19E+04
Class C LLW Com.	2.99E+04	m^3		included in Class A	3.48E+04	4.07E+04
GTCC LLW Com.	0	m^3		0	ND	ND

[11] Remaining capacity as of September 2013.