DOE/EA-1977

EXECUTIVE SUMMARY FOR THE

FINAL ENVIRONMENTAL ASSESSMENT

FOR THE

ACCEPTANCE AND DISPOSITION OF SPENT NUCLEAR FUEL CONTAINING U.S.-ORIGIN HIGHLY ENRICHED URANIUM FROM THE FEDERAL REPUBLIC OF GERMANY

December 2017

U.S. DEPARTMENT OF ENERGY

SAVANNAH RIVER OPERATIONS OFFICE

AIKEN, SOUTH CAROLINA

ABBREVIATIONS and ACRONYMS

AVR	Arbeitsgemeinschaft Versuchsreaktor
CFR	Code of Federal Regulations
DOE	U.S. Department of Energy
EA	environmental assessment
HEU	highly enriched uranium
LCF	latent cancer fatality
LEU	low-enriched uranium
LLW	low-level radioactive waste
NEPA	National Environmental Policy Act
rem	Roentgen equivalent man
SNF	spent nuclear fuel (also called used nuclear fuel)
SRS	Savannah River Site
THTR	Thorium High Temperature Reactor - 300
U.S.	United States

CONVERSIONS

METRIC TO ENGLISH			ENGLISH TO METRIC		
Multiply	**by**	**To get**	**Multiply**	**by**	**To get**
Area					
Square meters	10.764	Square feet	Square feet	0.092903	Square meters
Square kilometers	247.1	Acres	Acres	0.0040469	Square kilometers
Square kilometers	0.3861	Square miles	Square miles	2.59	Square kilometers
Hectares	2.471	Acres	Acres	0.40469	Hectares
Concentration					
Kilograms/square meter	0.16667	Tons/acre	Tons/acre	0.5999	Kilograms/square meter
Milligrams/liter	1 [a]	Parts/million	Parts/million	1 [a]	Milligrams/liter
Micrograms/liter	1 [a]	Parts/billion	Parts/billion	1 [a]	Micrograms/liter
Micrograms/cubic meter	1 [a]	Parts/trillion	Parts/trillion	1 [a]	Micrograms/cubic meter
Density					
Grams/cubic centimeter	62.428	Pounds/cubic feet	Pounds/cubic feet	0.016018	Grams/cubic centimeter
Grams/cubic meter	0.0000624	Pounds/cubic feet	Pounds/cubic feet	16,018.5	Grams/cubic meter
Length					
Centimeters	0.3937	Inches	Inches	2.54	Centimeters
Meters	3.2808	Feet	Feet	0.3048	Meters
Kilometers	0.62137	Miles	Miles	1.6093	Kilometers
Radiation					
Sieverts	100	Rem	Rem	0.01	Sieverts
Temperature					
Absolute					
Degrees C + 17.78	1.8	Degrees F	Degrees F - 32	0.55556	Degrees C
Relative					
Degrees C	1.8	Degrees F	Degrees F	0.55556	Degrees C
Velocity/Rate					
Cubic meters/second	2118.9	Cubic feet/minute	Cubic feet/minute	0.00047195	Cubic meters/second
Grams/second	7.9366	Pounds/hour	Pounds/hour	0.126	Grams/second
Meters/second	2.237	Miles/hour	Miles/hour	0.44704	Meters/second
Volume					
Liters	0.26418	Gallons	Gallons	3.7854	Liters
Liters	0.035316	Cubic feet	Cubic feet	28.316	Liters
Liters	0.001308	Cubic yards	Cubic yards	764.54	Liters
Cubic meters	264.17	Gallons	Gallons	0.0037854	Cubic meters
Cubic meters	35.314	Cubic feet	Cubic feet	0.028317	Cubic meters
Cubic meters	1.3079	Cubic yards	Cubic yards	0.76456	Cubic meters
Cubic meters	0.0008107	Acre-feet	Acre-feet	1233.49	Cubic meters
Weight/Mass					
Grams	0.035274	Ounces	Ounces	28.35	Grams
Kilograms	2.2046	Pounds	Pounds	0.45359	Kilograms
Kilograms	0.0011023	Tons (short)	Tons (short)	907.18	Kilograms
Metric tons	1.1023	Tons (short)	Tons (short)	0.90718	Metric tons
ENGLISH TO ENGLISH					
Acre-feet	325,850.7	Gallons	Gallons	0.000003046	Acre-feet
Acres	43,560	Square feet	Square feet	0.000022957	Acres
Square miles	640	Acres	Acres	0.0015625	Square miles

a. This conversion is only valid for concentrations of contaminants (or other materials) in water.

METRIC PREFIXES

Prefix	Symbol	Multiplication factor
exa-	E	1,000,000,000,000,000,000 = 10^{18}
peta-	P	1,000,000,000,000,000 = 10^{15}
tera-	T	1,000,000,000,000 = 10^{12}
giga-	G	1,000,000,000 = 10^{9}
mega-	M	1,000,000 = 10^{6}
kilo-	k	1,000 = 10^{3}
deca-	D	10 = 10^{1}
deci-	d	0.1 = 10^{-1}
centi-	c	0.01 = 10^{-2}
milli-	m	0.001 = 10^{-3}
micro-	µ	0.000 001 = 10^{-6}
nano-	n	0.000 000 001 = 10^{-9}
pico-	p	0.000 000 000 001 = 10^{-12}

SUMMARY

S.1. Introduction

In accordance with the Council on Environmental Quality's National Environmental Policy Act (NEPA) regulations at 40 Code of Federal Regulations (CFR) Parts 1500 through 1508, Executive Order 12114, *Environmental Effects Abroad of Major Federal Actions*, and U.S. Department of Energy (DOE) NEPA implementing procedures at 10 CFR Part 1021, DOE has prepared this Environmental Assessment (EA) to evaluate the receipt, storage, processing and disposition of certain spent nuclear fuel (SNF) from a research and development program of the Federal Republic of Germany (Germany).[1] Consistent with the U.S. policy objective to reduce, and eventually to eliminate, highly enriched uranium (HEU) from civil commerce, DOE is considering the feasibility of accepting this SNF containing U.S.-origin HEU[2] at DOE's Savannah River Site (SRS) for processing and disposition. Feasibility is contingent upon successfully developing technology to separate and process the SNF from Germany. The United States provided the HEU to Germany between 1965 and 1988 under the Atoms for Peace program. A final decision regarding whether to accept the SNF from Germany will be made if the technology proves feasible, and upon successful resolution of any related technical, financial, and legal issues.

DOE and Germany have signed a Statement of Intent (included as Appendix A to this EA) to cooperate in conducting preparatory work necessary to support DOE's consideration of the proposed use of SRS facilities for these activities. If DOE and Germany decide to proceed with the proposed action, the German government would be responsible for transporting the SNF from storage in Germany to the United States, at which point the United States would take responsibility for the SNF. The Statement of Intent specifies that Forschungszentrum Jülich, an interdisciplinary research center funded primarily by the German government, is bearing the cost of the preparatory phase – feasibility studies and NEPA analysis – and if there is a decision to proceed with the project, would also bear the costs associated with acceptance, processing, and disposition of the SNF.

In September 2015, the responsibility for the Arbeitsgemeinschaft Versuchsreaktor (AVR) facility and resulting SNF was transferred to Jülicher-Entsorgungsgesellschaft Für Nuklearanlagen mbH. The German government has not indicated whether the Thorium High Temperature Reactor-300 (THTR) SNF would be proposed for return to the United States. If there is a decision by DOE and Germany to proceed with the project, and the THTR fuel were included, the additional costs would be negotiated with the understanding that all costs

---

[1] This environmental assessment was announced as the *Environmental Assessment for the Acceptance and Disposition of Used Nuclear Fuel Containing U.S.-Origin Highly Enriched Uranium from the Federal Republic of Germany* in DOE's Notice of Intent (NOI) on June 4, 2014 (79 FR 32256).

[2] Highly enriched uranium has a concentration of 20 percent or greater of the isotope uranium-235. Natural uranium contains approximately 0.7 percent uranium-235.

associated with acceptance, processing, and disposition of the AVR and THTR fuel would be the responsibility of the appropriate German entity.

S.2 Background

The SNF that is the subject of this proposal was irradiated in two German reactors that operated as part of Germany's research and development program for pebble bed, high-temperature, gas-cooled reactor technology: the AVR, which operated from 1967 to 1988; and the THTR, which operated from 1983 to 1989. The AVR SNF has been stored in Jülich, Germany, and the THTR SNF has been stored in Ahaus, Germany, since the reactors were shut down and defueled. Although the analyses in this EA are based on the total quantity of pebbles from both AVR and THTR, the German government has not indicated whether the THTR SNF would be proposed for return to the United States.

This SNF is in the form of small graphite (carbon) spheres, referred to as "pebbles." There are approximately one million pebbles[3,4] currently in storage in 455 CASTOR[5] casks. The pebbles contain varying quantities of uranium and thorium, with uranium enrichments up to 81 percent. Prior to irradiation, the fuel contained approximately 900 kilograms (1,980 pounds) of HEU provided by the United States (Schütte 2012). As a result of irradiation and decay, the SNF also contains actinides, fission products, and other radioactive isotopes.

This SNF contains U.S.-origin HEU provided to Germany under the Atoms for Peace program that was first announced by U.S. President Dwight D. Eisenhower during a speech to the United Nations in 1953 (Eisenhower 1953). This program provided the basis for the lease, or sale, of moderate quantities of fissionable material for peacetime reactors to other nations (NSC 1954). In its policy statement (NSC 5431/1), the National Security Council specified that the U.S. should "*seek to reserve the right to regain this fissionable material after usage in such other country's reactor, in order to … obtain all the by-products therefrom for peaceful purposes*."

German Request to Return U.S.-Origin HEU. The United States has a policy objective to reduce, and eventually to eliminate, HEU from civil commerce. In February 2012, the German government approached DOE about the possibility of the United States accepting the SNF for storage and disposition (Schütte 2012). As a result of discussions, Germany funded Savannah River National Laboratory to conduct initial research that would lead to a method to separate the fuel kernels from the graphite matrix, the first step in processing this fuel. DOE agreed to consider Germany's request for the following reasons: the SNF contains U.S.-origin HEU; success of the above-mentioned research on a laboratory scale; SRS expertise in nuclear

---

[3] The CASTOR casks of AVR fuel contain some low-enriched uranium (LEU) pebbles (less than 20 percent of the pebbles) mixed in with the HEU pebbles. Because the LEU and HEU pebbles are mixed together in the casks, separation of the LEU pebbles from the HEU pebbles is neither reasonable nor necessary since the process can handle both LEU and HEU. Approximately 6 percent of all pebbles are LEU.

[4] AVR = ~290,000 fuel elements; THTR = ~ 690,000 fuel elements.

[5] CASTOR is an abbreviation for "cask for storage and transport of radioactive material."

engineering and the management of nuclear materials; and availability of hardened SRS facilities that could be used as is or modified to process and disposition this type of SNF.

A Statement of Intent between DOE for the United States, the Ministry of Education and Research for the Federal Republic of Germany, and the Ministry for Innovation, Science, and Research for the State of North Rhine-Westphalia (on behalf of the North Rhine-Westphalian State Government), was signed in late March and early April 2014. The Statement of Intent enabled DOE and the German signatories to continue evaluating the feasibility of this proposed project, and to conduct additional studies and reviews required to determine whether to proceed with acceptance of the SNF for processing and disposition, including the preparation of this EA.

Future development activities to advance the technology will involve several important maturation activities. These include remote opening and handling of the CASTOR casks, design of a fully-integrated prototypical digestion system, operation of prototypical equipment in a remote-handle configuration, and obtaining critical process data using irradiated fuel kernels and individual pebbles. The maturation approach will also address essential safety, security, and facility interface issues which include facility permitting, waste disposal, and final fuel disposition. All of these research activities were initially evaluated under Categorical Exclusions B3.6 (small-scale research and development, laboratory operations, and pilot projects) and B1.30 (transfer actions) and documented in a series of Categorical Exclusion Determinations prepared by the SRS NEPA Compliance Officer (DOE 2013a, 2013b, 2014, 2015a, 2015b, 2017), and have also been considered in this EA in conjunction with the proposed processing activities.

Savannah River Site Capabilities. The facilities and capabilities proposed for processing this SNF are unique to DOE and SRS. H-Canyon, which began operating in 1955, is the only hardened nuclear chemical separations plant still in operation in the United States. H-Canyon continues to be used to separate and recover uranium from SNF and other highly radioactive materials for reuse and to prepare the residuals for disposal through the SRS Liquid Nuclear Waste Facilities.

L-Area was initially constructed as a nuclear reactor for use as a nuclear material production facility in the 1950s. The reactor was permanently shut down in the 1980s, but the ancillary facilities have continued to support SRS missions. In the early 2000s, research and development was conducted at SRS for the melt and dilute technology, a method for stabilizing SNF that is now proposed under the L-Area Alternative (see Section S.6). During that time frame, conceptual design for implementation of the melt and dilute technology in L-Area facilities was initiated but later halted.

The SRS Liquid Nuclear Waste Facilities are an extensive, integrated processing and disposition system comprising several facilities and technologies that do not exist elsewhere in the United States. The Liquid Nuclear Waste Facilities include storage, processing, and disposal facilities: tank farms, the Defense Waste Processing Facility, saltstone facilities, and existing and planned glass waste storage facilities.

S.3 Purpose and Need

DOE's purpose and need for the receipt, storage, processing, and disposition of the SNF from Germany is to support the U.S. policy objective to reduce, and eventually to eliminate, HEU from civil commerce (White House 1993). This action would further the U.S. HEU minimization objective by returning U.S.-origin HEU[6] from Germany to the United States for safe storage and disposition and is consistent with U.S. nonproliferation policy.

S.4 Proposed Action

If the feasibility studies show adequate promise, and DOE and Germany decide to proceed with the project, the German government would work with DOE to transport SNF in chartered ships across the Atlantic Ocean to Joint Base Charleston - Weapons Station, near Charleston, South Carolina. From Joint Base Charleston - Weapons Station, the casks would be transported to SRS on dedicated trains in accordance with applicable U.S. regulatory requirements. **Figure S-1** shows the locations of facilities for the proposed activities.

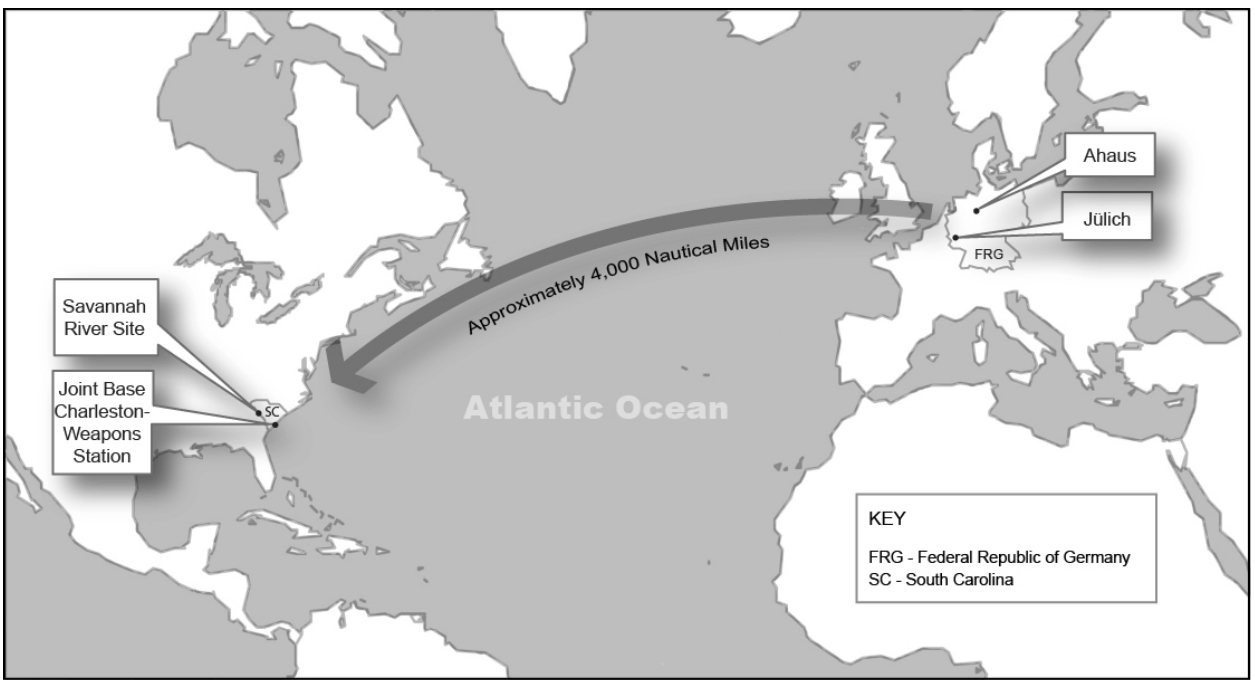

Figure S-1: Proposed Project Locations

[6] Prior to irradiation, the fuel contained approximately 900 kilograms (1,980 pounds) of HEU (Schütte 2012).

The SNF would be stored at SRS in CASTOR casks, the Type B transportation casks[7] in which it would be shipped, until installation of the new equipment needed for initial processing of the SNF is completed. SRS infrastructure and facilities in E-Area, H-Area (including H-Canyon), and L-Area, as well as the Liquid Nuclear Waste Facilities would be used to process the SNF from Germany. Alternatives for implementing the Proposed Action, including the facilities required, are described in Section S.6.

As specified in the Statement of Intent, any decision by the Participants (signatories to the Statement of Intent) to proceed with the transportation of the SNF for acceptance, processing, and disposition depends on compliance with all applicable requirements of United States law and DOE requirements, including NEPA, and resolution by the Participants of any technical, financial, and legal issues that may be identified during consideration of the feasibility of the project and development of an appropriate legal framework.

S.5 Public Involvement

DOE announced its intent to prepare the EA with publication of the notice of intent (NOI) in the *Federal Register* on June 4, 2014 (79 FR 32256). The public scoping period opened with the publication of the NOI, and closed on July 21, 2014. A public scoping meeting was held on June 24, 2014, in North Augusta, South Carolina. Two-hundred twenty-seven comment documents were received during the scoping period. DOE summarized the comments by subject area, prepared responses to the summary comments, and included both in the Draft EA. DOE considered all scoping comments in developing the Draft EA.

DOE announced the availability of the Draft EA in the *Federal Register* on January 25, 2016 (81 FR 4023). DOE provided email notification of the availability of the Draft EA, advertised availability in local newspapers, and posted the Draft EA on DOE websites. DOE informed the states of South Carolina, Georgia, and Nevada of the availability of the EA and solicited their comments. DOE also held a public meeting on the Draft EA on February 4, 2016, in North Augusta, South Carolina. In response to stakeholder requests, the original 45-day public comment period was extended to March 25, 2016.

Ninety comment documents containing 245 comments were received during the public comment period on the Draft EA. DOE summarized the comments by subject area and prepared responses to the summary comments. Copies of all the comment documents received with the specific comments identified, and the summary comments and responses are included in Appendix B to this Final EA. DOE considered all comments received in preparing the Final EA. Change bars are presented alongside the text in this Final EA to indicate where substantive changes were made and where text was added or deleted. Editorial changes in the Final EA are not marked.

[7] Type B packages are required for the transport of materials with high levels of radioactivity, including SNF. Type B packages must withstand, without loss of contents, normal transport conditions such as heat, cold, vibration, changes in pressure, being dropped, compressed, sprayed with water, or struck by objects, as well as more serious accident conditions. These requirements are demonstrated during the licensing process for each Type B package through rigorous testing in accordance with 10 CFR Part 71, Packaging and Transportation of Radioactive Material.

S.6 Description of Alternatives for Acceptance and Disposition of Spent Nuclear Fuel from Germany

DOE is evaluating the potential environmental impacts of two alternatives for acceptance and disposition of graphite-based SNF currently stored in Germany, and, as required by DOE's NEPA implementing procedures (10 CFR 1021.321(c)), a No Action Alternative. Under the No Action Alternative, the SNF would not be transported to the United States for management and disposition.

Under the action alternatives, the SNF would be transported from Germany and processed at SRS for final disposition as a proliferation-resistant waste form. The two action alternatives would both use either a molten salt or vapor digestion process to separate the fuel kernels from their graphite matrix. The two action alternatives differ in processing technology and location at SRS where the processing would occur. The H-Area Alternative (so named because most activities would involve H-Area facilities) has three processing options (Vitrification Option, Low-Enriched Uranium[8] (LEU) Waste Option, and LEU/Thorium Waste Option) that use H-Canyon to differing extents. The L-Area Alternative (so named because the alternative would involve mostly L-Area facilities) would use a melt and dilute process in L-Area. The action alternatives and the associated processing options are shown in **Figure S–2**. Any wastes generated would be processed, transported to, and disposed of at appropriate facilities.

[8] Low-enriched uranium has a concentration of the isotope uranium-235 above that of natural uranium (0.7 percent), but less than 20 percent.

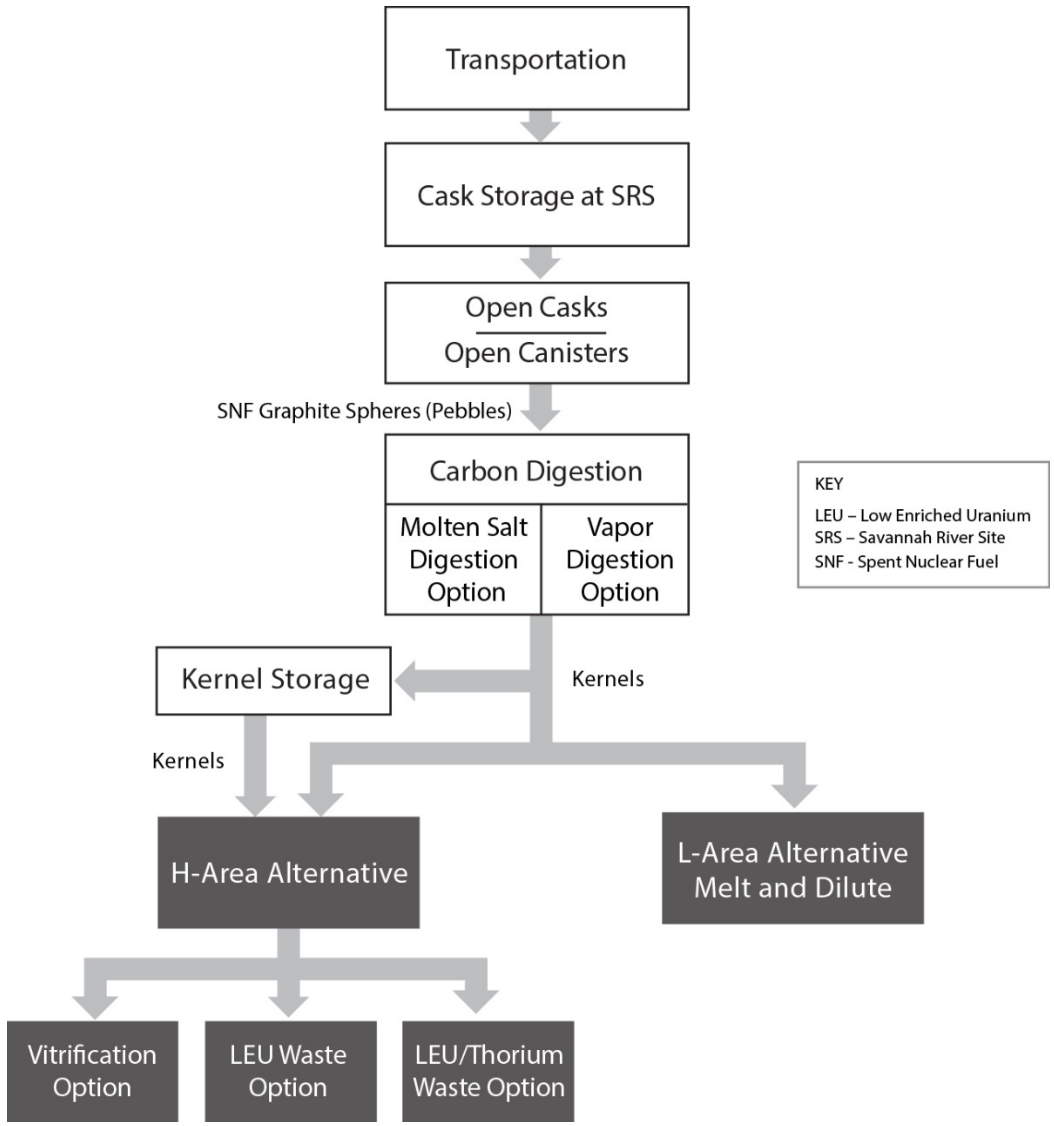

Figure S-2: H-Area and L-Area Alternatives

The German government would place the CASTOR casks into shipping containers and transport them from the Jülich and Ahaus[9] sites to a seaport in northern Germany where they would be secured aboard chartered ships certified to carry nuclear material. Consistent with Executive Order 12114, *Environmental Effects Abroad of Major Federal Actions*, the environmental

[9] Although the analyses in this EA are based on the total quantity of AVR and THTR SNF, the German government has not indicated whether the THTR SNF would be proposed for return to the United States.

impacts analysis in this EA starts at the point of the transport ships entering the global commons.[10]

The shipping campaign from Germany for the proposed action would involve about 30 shipments over approximately a 3.5-year period to transport the 455 CASTOR casks of SNF from Germany; a typical shipment would include 16 casks. At Joint Base Charleston - Weapons Station, railcars would be staged in advance of the arrival of the ship at the dock. Transport to SRS would be by a commercial carrier using a dedicated train. The National Nuclear Security Administration infrastructure and protocols for receipt of foreign research reactor SNF would be followed for these shipments, including Federal and State coordination protocols, and those for transport, security, and radiation control.

The CASTOR casks containing the SNF from Germany would be offloaded from the rail cars at SRS and stored on existing and/or new concrete or gravel storage pads in H-Area, L-Area, or a combination of the areas. Upon receipt, the shipment would be subject to visual inspection, radiological survey, and data verification to ensure that the casks meet all acceptance requirements.

The preliminary processing steps, from removing the pebbles from the casks through carbon digestion (white boxes in Figure S-2), but not the facilities in which the activities occur, are the same for both the H-Area Alternative and the L-Area Alternative. After carbon digestion, the processing steps for the two alternatives diverge (shaded boxes in Figure S-2). The H-Area and L-Area candidate facilities considered for processing have robust structural features, established perimeter security zones, and sufficient area for cask storage and staging or construction of new facilities, if needed.

The HEU kernels are embedded in a graphite (carbon) matrix that must be removed before the HEU kernels can be processed. Two methods for removing the graphite surrounding the fuel kernels (referred to as carbon digestion) are under consideration: a molten salt digestion process and a vapor digestion process. Both of the carbon digestion methods are evaluated in this EA for implementation in either H- or L-Area.

Four kernel processing options are being considered. Three options under the H-Area Alternative (these options would be implemented in H-Area) and one option under the L-Area Alternative that would be installed in a modified wing of the L-Area Material Storage Facility (Building 105-L). The four options for processing the kernels after carbon digestion are:

H-Area Alternative Options:

- **Vitrification Option –** Dissolution of the kernels in H-Canyon with direct transfer of the dissolver solution to the existing Liquid Nuclear Waste Facilities.
- **LEU Waste Option** – Dissolution of the kernels in H-Canyon followed by solvent extraction in H-Canyon for separation of the uranium. The uranium solution would be

[10] Global commons refers to areas that are outside the jurisdiction of any nation (e.g., the oceans or Antarctica).

down-blended and grouted (i.e., solidified by mixing with cement) to meet acceptance criteria for disposal as low-level radioactive waste (LLW). Thorium, other actinides, and fission products would be processed through the Liquid Nuclear Waste Facilities.

- **LEU/Thorium Waste Option** – Dissolution of the kernels in H-Canyon followed by solvent extraction in H-Canyon for separation of the uranium and thorium. The uranium/thorium solution would be down-blended and grouted to meet acceptance criteria for disposal as LLW. Other actinides and fission products would be processed through the Liquid Nuclear Waste Facilities.

L-Area Alternative Option:

- **Melt and Dilute Option:** Down-blending and conversion of the kernels to a uranium-aluminum alloy in a melt and dilute process in L-Area. The resulting ingots would be stored in concrete overpacks on a pad in L-Area. Unlike the H-Area processing methods, the kernels would not be dissolved prior to final processing.

Some modifications to the interiors of existing facilities (specifically, H-Canyon or the L-Area Material Storage Facility) would be required to implement any of these alternatives or options. In addition, construction of storage pads for cask storage and minor onsite road construction could be required, depending on the alternative. For the H-Area Alternative, LEU Waste and LEU/Thorium Waste Options, a separate uranium solidification building in H-Area would be constructed. For the L-Area Alternative, a sand filter, fan room, stack, and truck bay would be built in L-Area. Processing, from kernel dissolution through production of the final waste form, would take slightly less than 5 years for the H-Area Alternative Vitrification Option, and approximately 5 years for the LEU and LEU/Thorium Options. The L-Area Melt and Dilute Option would take approximately 7.5years.

Radiological Impacts

In this EA, radiological consequences of operations and accidents are reported as doses and latent cancer fatalities (LCFs). An LCF is a death from cancer resulting from, and occurring some time after, exposure to ionizing radiation. A factor of 0.0006 LCFs per rem or person-rem is used to calculate the risk associated with radiation doses (DOE 2003); for acute individual doses above 20 rem, the risk factor is doubled (NCRP 1993).

For a group (for example, the offsite population), doses are reported in person-rem and LCFs are reported as a whole number, representing the number of people in the group statistically expected to develop an LCF as a result of the exposure. When the value calculated by multiplying the dose by the LCF risk factor of 0.0006 is less than 1, the reported value is rounded to 0 or 1 and the calculated value is shown in parentheses. For an individual, doses are reported in rem or millirem, along with the risk or likelihood of the dose resulting in an LCF. Because it is assumed that there is some level of risk associated with radiation exposure, regardless of the magnitude, the individual risk is not reported as 0.

S.7 Summary of Environmental Consequences

No Action Alternative

The SNF containing U.S.-origin HEU from the AVR and THTR reactors would remain in storage in Germany. It would not be transported to the United States for management and disposition. Because DOE would not undertake any actions involving the global commons, Joint Base Charleston–Weapons Station, or SRS under the No Action Alternative, there would be no additional impacts on these areas.

Action Alternatives

Global Commons and Joint Base Charleston–Weapons Station. Because of the small number of shipments (about 30 over an approximately 3.5-year period, as compared to the several thousand vessels that annually traverse the global commons and the 35 to 45 vessels[11] that are received annually at Joint Base Charleston–Weapons Station) and environmental laws, regulations, and best practices, nonradiological impacts on the global commons and Joint Base Charleston–Weapons Station from shipment of SNF from Germany are expected to be minimal. The public would not receive a radiation dose from incident-free ocean transport or unloading at Joint Base Charleston–Weapons Station. The total radiation dose among all ship crew members from ocean transport of the fuel would be 2.9 person-rem. No latent cancer fatalities (LCFs) would be expected (calculated value of 2×10^{-3}) as a result of this collective dose. The total dose among all dock workers from unloading at Joint Base Charleston–Weapons Station is projected to be approximately 0.24 person-rem, with no LCFs expected from this dose (calculated value of 1×10^{-4}).

The probability of an accident that could result in a CASTOR cask being submerged in coastal waters was estimated to be 2.9×10^{-11} (1 in 34 billion) for a damaged cask, and 1.5×10^{-8} (1 in 67 million) for an undamaged cask. The probability of an accident that could result in a CASTOR cask being submerged in deep ocean waters was estimated to be 1.1×10^{-6} (1 in 910,000) (the cask was assumed to be damaged). The probabilities of accidents at Joint Base Charleston–Weapons Station that could release radioactivity are expected to range from 6.5×10^{-6} (1 in 150,000) to 6.0×10^{-10} (1 in 1.7 billion) with no population LCFs (calculated values: 3×10^{-6} to 3×10^{-2}) expected. The total risk of an LCF in the population due to a SNF from Germany accident at Joint Base Charleston–Weapons Station is estimated at 9.8×10^{-8}.

Savannah River Site. Table S–1 summarizes the potential impacts at SRS for those resource areas having the greatest potential for environmental impacts (Air Quality, Human Health, Socioeconomics, Waste Management, Transportation, and Environmental Justice) for the action alternatives evaluated in this German Fuel EA. Activities related to the evaluated alternatives would largely occur in existing industrial areas far from offsite areas. In addition, little land would be disturbed, contaminated water would not be discharged, and resource use would be low. Therefore, minimal or no impacts are expected to the other resources areas regardless of the alternative.

Cumulative Impacts. Incident-free ocean transport of SNF from Germany would not result in radiation exposures to members of the general public. Therefore, there would be no cumulative radiation impact to members of the general public. Cumulative radiation doses and risks to ship crews and dock handlers from transport of radioactive materials from foreign countries to U.S. seaports would result in a dose of 91 person-rem and no LCFs (calculated value of 5×10^{-2}). Shipments of the SNF from Germany would represent approximately 3 percent of the cumulative

[11] Joint Base Charleston–Weapons Station is able to handle this potential increase in vessels and would provide the staff necessary for safe unloading operations (JBC 2016).

dose and risk resulting from all shipments of radioactive materials from foreign countries to U.S. seaports.

Because construction activities at SRS would be minor and small areas of land would be disturbed, air quality impacts would be minor and are not likely to contribute substantially to cumulative impacts. Because the operation of facilities for processing SNF from Germany would produce relatively small quantities of criteria air pollutants and hazardous air pollutants, these emissions are not likely to contribute substantially to cumulative impacts.

The annual cumulative dose from SRS and offsite sources to the regional population is estimated to be 26 to 32 person-rem. This population dose is not expected to result in any LCFs (calculated value of 0.02). The annual contribution to the cumulative population dose from activities evaluated in this EA would be 7.3 to 7.8 person-rem for the H-Area Alternative and 2.3 person-rem for the L-Area Alternative, with no associated LCFs for either alternative (calculated values of 4×10^{-3} to 5×10^{-3} and 1×10^{-3} respectively). For perspective, the annual doses to the same population from naturally occurring radioactive sources (311 millirem per person) would be about 270,000 person-rem, from which approximately 160 LCFs would be inferred. The cumulative annual SRS worker dose from current and reasonably foreseeable activities is estimated to be 850 to 880 person-rem, which is not expected to cause an LCF (calculated value of 0.5) among the involved worker population. Activities evaluated in this EA could result in annual worker doses of 28 to 41 person-rem for the H-Area Alternative and 8 person-rem for the L-Area Alternative with no associated LCFs for either alternative (calculated values of 0.02 and 0.005, respectively).

The construction, modification, and operation of SRS facilities that DOE would use to disposition the SNF from Germany are not expected to impact current or future site activities, remediation efforts, or site closure. Because Germany would pay for disposition of this SNF, U.S. government funding for other SRS projects would not be affected. Modification of existing facilities to implement the alternatives would not impact future decommissioning, decontamination, and demolition efforts since these activities would be a small subset of activities at the facilities being impacted. The new uranium solidification facility, that would be part of the H-Area Alternative under the LEU and LEU/Thorium Options, would be designed to facilitate decommissioning, decontamination, and demolition at the end of the project. The waste volumes that would be generated from decontamination and demolition would be a small fraction of those from decontamination and demolition of existing facilities; decontamination and demolition would likely be performed concurrently. The scheduled timeframe for operational closure of the high-level radioactive tanks is fiscal year 2039 (SRR 2016), many years after completion of the project. Therefore, the impacts on site closure, if any, would be the additional time for disposing of the wastes associated with decommissioning, decontamination, and demolition of the facilities used to process the German fuel. DOE anticipates that the impacts of decommissioning, decontamination, and demolition of the facilities used to process the German fuel would be on the order of a few months to a year.

Table S-1: Summary Comparison of Environmental Consequences at SRS

Resource Area / Parameter		Action Alternative [a]: H-Area Alternative: Vitrification Option	H-Area Alternative: LEU Waste Option	H-Area Alternative: LEU/Thorium Waste Option	L-Area Alternative: Melt and Dilute Option
Air Quality	***Construction***				
	Criteria Air Pollutant Emissions:	Emissions not expected to exceed existing permit levels	Same as Vitrification Option, but Air Construction Permit may be required.	Same as Vitrification Option, but Air Construction Permit may be required.	Same as H-Area Alternative, Vitrification Option
	Operations				
	Criteria Air Pollutant Emissions:	Increase in nitrogen dioxide emissions would require a permit review to determine whether revisions to the Title V Air Operating Permit would be required [b]	Same as Vitrification Option	Same as Vitrification Option	Increase in L-Area emissions may require a permit revision [b]
	HAPs:	HAPs emitted in small quantities			HAPs emitted in small quantities
	GHG emissions	GHG emissions would be a marginal increase over the No Action Alternative			GHG emissions would be a marginal increase over the No Action Alternative
Human Health – Normal Operations, Workers	***Construction***				
	Total Worker Dose (person-rem) Total Worker LCFs [c]	50 0 (0.03)	Same as Vitrification Option	Same as Vitrification Option	Work would not be performed in a radiation area; meaningful doses would not be expected
	Operations				
	Total Worker Dose (person-rem) Total Worker LCFs [c]	74 0 (0.04)	66 0 (0.04)	Same as LEU Waste Option	54 0 (0.03)
Human Health – Normal Operations, General Population	***Construction***				
	Radiological Exposure to the Public	None expected	Same as Vitrification Option	Same as Vitrification Option	Same as H-Area Alternative Vitrification Option
	Operations				
	Annual Population Dose (person-rem) Annual Population LCFs [c] Total Project Population LCFs [c]	7.3 0 (0.004) 0 (0.01)	7.8 0 (0.005) 0 (0.01)	7.6 0 (0.005) 0 (0.01)	2.3 0 (0.001) 0 (0.009)
	Annual MEI Dose (millirem) Annual MEI LCF Risk Total Project MEI LCF Risk	0.084 5×10^{-8} 1×10^{-7}	0.12 6×10^{-8} 1×10^{-7}	0. 012 6×10^{-8} 1×10^{-7}	0.029 2×10^{-8} 1×10^{-7}
		Risk to the public would be small	Risk to the public would be small	Risk to the public would be small	Risk to the public would be small

Resource Area / Parameter		Action Alternative [a]			
		H-Area Alternative			L-Area Alternative
		Vitrification Option	LEU Waste Option	LEU/Thorium Waste Option	Melt and Dilute Option
Human Health – Facility Accidents	Operational Accident Frequency[d] Consequences Population LCFs MEI LCF Risk Beyond-Design-Basis Accident Frequency[d] Consequences Population LCFs MEI LCF Risk	SNF Processing Accident Extremely unlikely 47 8×10^{-4} Earthquake with fire Beyond extremely unlikely Not evaluated 0.1	Same as Vitrification Option	Same as Vitrification Option	Melter fire Extremely unlikely Not evaluated 8×10^{-4} Earthquake induced spill Beyond extremely unlikely 13 0.0003
Socioeconomics	***Construction***				
	Peak Direct Employment Percent of SRS Employment	Up to 100 1.4 No noticeable impact.	Up to 201 2.8 No noticeable impact.	Same as LEU Waste Option.	Up to 155 2.1 No noticeable impact.
	Operations				
	Peak Direct Employment Percent of SRS Employment	125 to 150 1.7 to 2.1 No new jobs. Small beneficial impact by preserving existing jobs.	125 to 150 1.7 to 2.1 Most would be existing employees: as many as 20 new jobs for uranium solidification facility. Small beneficial impact by preserving existing jobs.	Same as LEU Waste Option.	135 1.9 No new jobs. Small beneficial impact by preserving existing jobs.
Waste Management (The values in parenthesis represent the percent of SRS waste management facility capacity)	***Construction***				
	Solid LLW (cubic meters) Solid Hazardous (cubic meters) Liquid Hazardous (liters) Solid Nonhazardous (cubic meters: Liquid Nonhazardous (liters)	320 (0.1) 0.15 (0.02) 190 (0.02) 110 (0.0009) 9,500 (0.0002) Waste management capacities are sufficient for these waste streams.	320 (0.1) 1.7 (0.3) 570 (0.1) 340 (0.004) 32,000 (0.001) Waste management capacities are sufficient for these waste streams.	Same as LEU Waste Option	390 (0.1) NG NG NG NG Waste management capacities are sufficient for these waste streams.
	Operations				
	Solid LLW (cubic meters) Liquid LLW (liters) Solid Hazardous (cubic meters) Solid Nonhazardous (cubic meters) Liquid Nonhazardous (liters) HLW Canisters (number) Saltstone Grout (liters):	2,000 (0.7) NG NG NG NG 101 (2) 5,500,000 (16 to 24)[f] Waste management capacities are sufficient for these waste streams.	2,300 (0.8) 280,000 (0.03) 0.15 (0.03) 75 (0.001) 2,800,000 (0.1) 32 (0.7) 6,200,000 (18 to 27) [f] Waste management capacities are sufficient for these waste streams.	2,600 to 2,900 (0.9 to 1.0) 280,000 (0.03) 0.15 (0.03) 75 (0.001) 2,800,000 (0.1) 15 (0.3) 6,200,000 (18 to 27) [f] Waste management capacities are sufficient for these waste streams.	2,000 (0.7) NG NG NG NG 82 (NA [e]) 3,700,000 (5 to 8)[f] Waste management capacities are sufficient for these waste streams.

Resource Area / Parameter		Action Alternative [a]			
		H-Area Alternative			L-Area Alternative
		Vitrification Option	LEU Waste Option	LEU/Thorium Waste Option	Melt and Dilute Option
Transportation (total health effects)	Shipments	30	330	540	30
	Incident-free				
	- Crew LCF risk	7×10^{-5}	4×10^{-3}	7×10^{-3}	7×10^{-5}
	- Population LCF risk	3×10^{-4}	2×10^{-3}	3×10^{-3}	3×10^{-4}
	Accidents				
	Population LCF Risk	5×10^{-13}	5×10^{-6}	5×10^{-6}	5×10^{-12}
	Traffic fatalities	9×10^{-4}	5×10^{-2}	9×10^{-2}	9×10^{-4}
Environmental Justice	***Construction***				
	Impacts on minority or low-income populations	No disproportionately high and adverse impacts on minority or low-income populations are expected.			
	Operations				
	Impacts on minority or low-income populations	No disproportionately high and adverse impacts on minority or low-income populations are expected.			

GHG = greenhouse gas; HAP = hazardous air pollutant; HLW = high-level radioactive waste; LCF = latent cancer fatality; LEU = low-enriched uranium; LLW = low-level radioactive waste; MEI = maximally exposed (offsite) individual; NA = not applicable; NG = not generated in meaningful quantities; SNF = spent nuclear fuel; SRS = Savannah River Site.

[a] Under the No Action Alternative, the SNF from Germany would not be transported to the United States for management and disposition. The SNF would remain in storage in Germany. Because DOE would not undertake any actions under the No Action Alternative, there would be no incremental impacts at SRS.

[b] Any time major modifications or new emissions sources are incorporated at a major source such as SRS, the Title V Air Operating Permit must be reviewed and/or updated in order to maintain compliance with the Clean Air Act. This does not mean that there would be major changes in the emissions or significant impacts, only that the required regulatory process would be followed to account for new emissions and demonstrate that emissions would remain within regulatory limits.

[c] The number of excess LCFs in the population would occur as a whole number. If the number is zero, the value calculated by multiplying the dose by a risk factor of 0.0006 LCF per person-rem (DOE 2003) is presented in parenthesis.

[d] Frequencies are on an annual basis and defined as: extremely unlikely = 10^{-6} to 10^{-4}, beyond extremely unlikely = less than 10^{-6}.

[e] The capacity for HLW canisters under this German Fuel EA is determined by comparison with storage capacity at the S-Area Glass Waste Storage Buildings. However, multi-canister overpacks from melt and dilute operations at L-Area would be stored on an L-Area pad rather than at S-Area.

[f] The quantity of saltstone grout is the total for the project; however, the percent of capacity (value in parenthesis) is based on the annual saltstone processing rate.

Notes: To convert cubic meters (solid) to cubic yards, multiply by 1.3079; cubic meters (liquid) to cubic feet, multiply by 35.314; liters to gallons, multiply by 0.26418; acres to hectares, multiply by 0.40469.

Source: DOE 2015c.

S.8. References

DOE (U.S. Department of Energy). 2003. *Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE), ISCORS Technical Report No. 1, DOE/EH-412/0015/0802*. Washington, DC: Office of Environmental Policy and Guidance.

DOE (U.S. Department of Energy). 2013a. *U.S. Department of Energy Categorical Exclusion Determination Form: Thermal-Chemical Decomposition of Graphite.* EEC No. TC-A-2013-0041-0. April 2013.

DOE (U.S. Department of Energy). 2013b. *U.S. Department of Energy Categorical Exclusion Determination Form: Thermal-Chemical Decomposition of Graphite.* EEC No. TC-A-2013-0041-1. October 2013.

DOE (U.S. Department of Energy). 2014. *U.S. Department of Energy Categorical Exclusion Determination Form: Thermal-Chemical Decomposition of Graphite.* EEC No. TC-A-2013-0041-2. October 2014.

DOE (U.S. Department of Energy). 2015a. *U.S. Department of Energy Categorical Exclusion Determination Form: Thermal-Chemical Decomposition of Graphite.* EEC No. TC-A-2013-0041-3. April 2015.

DOE (U.S. Department of Energy). 2015b. *U.S. Department of Energy Categorical Exclusion Determination Form: Engineering Development Laboratory (EDL) Testing of Thermal-Chemical Decomposition of Graphite.* EEC No. TC-A-2105-0035 June 2015.

DOE (U.S. Department of Energy). 2015c. *Data Call for German Fuel Environmental Assessment. Savannah River Site, South Carolina.* October 22, 2014. (**Official Use Only**)

DOE (U.S. Department of Energy). 2017. *U.S. Department of Energy Categorical Exclusion Determination Form: Thermal-Chemical Decomposition of Graphite.* EEC No. TC-A-2013-0041-4. August 2017.

Eisenhower, Dwight D. 1953. *Before the General Assembly of the United Nations on peaceful Uses of Atomic Energy*. December 8, 1953.

JBC (Joint Base Charleston). 2016. Letter from Robert K. Lyman, Commander, Department of the Air Force, Headquarters 628th Air Base Wing, Charleston, South Carolina, to Maxcine Maxted, Spent Nuclear Fuel Program Manager, DOE Savannah River Site. re: *German Graphite Project*. March 31. (**Official Use Only**)

NCRP (National Council on Radiation Protection and Measurements). 1993. *Risk Estimates for Radiation Protection, NCRP Report No. 115*. Bethesda, Maryland. December 31.

NSC (National Security Council). 1954. *Statement of Policy by the National Security Council with Other Nations in the Peaceful Uses of Atomic Energy*. Found in Foreign Relations of the

United States, 1952-1954, Volume II, Part 2, National Security Affairs, Document 237, NSC 5431/1. Declassified.

Schütte. 2012. *Letter from Dr. Georg Schütte, State Secretary, Federal Republic of Germany Ministry of Education and Research (Bundesministerium fur Bildung und Forschung) to Thomas P. D'Agostino, Under Secretary for Nuclear Security, Department of Energy, Washington, D.C.,* February 27.

SRR (Savannah River Remediation, LLC). 2016. *Liquid Waste System Plan, SRR-LWP-2009-00001, Rev. 20.* Savannah River Site. Aiken, SC. May.

White House. 1993. *Nonproliferation and Export Control Policy, Fact Sheet*, Office of the Press Secretary, Washington, DC. September.