Chapter 2
Description of Alternatives

2.0 DESCRIPTION OF ALTERNATIVES

2.1 Introduction

This chapter describes the alternatives being considered for the construction and operation of a new U.S. Department of Energy (DOE) facility, the Versatile Test Reactor (VTR). In order to fulfill the mission for which the VTR is proposed, DOE must operate additional facilities (either newly constructed or modified existing) and develop specialized capabilities. These associated facilities and capabilities are required in order to:

- Produce fuel for the VTR,
- Perform post-irradiation examination of test specimens, and
- Manage spent nuclear fuel.

In determining where in the DOE complex to construct the VTR and to establish the associated facilities, DOE goals include (1) co-locating the VTR and post-irradiation examination facilities, (2) using existing post-irradiation examination facilities to the extent practical, (3) leveraging (by adapting and using) current reactor and post-irradiation examination facility knowledge and experience, and (4) managing spent fuel on site, pending a DOE decision on disposition.

DOE identified two alternatives for the VTR: constructing and operating the VTR at the Idaho National Laboratory (INL) Site and constructing and operating the VTR at the Oak Ridge National Laboratory (ORNL). These alternatives include the siting, construction, and operation of the VTR, post-irradiation examination facilities, and spent fuel treatment and storage facilities. To the extent possible, existing facilities (modified as necessary) would be used for the VTR support facilities.

Regardless of the VTR alternative selected, nuclear fuel would be required to operate the reactor. The type of fuel planned for the VTR is not available from commercial nuclear fuel vendors, so DOE would produce the fuel. DOE identified the INL Site and the Savannah River Site (SRS) as options for fuel production. Site selection decisions for the VTR and fuel production capabilities are evaluated independently of each other in this environmental impact statement (EIS).

This chapter is organized as follows:

Section 2.1, Introduction – This section describes the purpose and intent of this chapter, as well as its organization.

Section 2.2, Proposed Versatile Test Reactor – This section describes the proposed VTR and its associated facilities.

Section 2.3, No Action Alternative – This section describes the No Action Alternative for a VTR.

Section 2.4, Idaho National Laboratory Versatile Test Reactor Alternative – This section presents the INL VTR Alternative. It describes the location, construction, and operation of the VTR at the INL Site, the modifications of existing INL facilities, and construction of a new spent fuel pad (a concrete slab for storage) to support VTR operation.

Section 2.5, Oak Ridge National Laboratory Versatile Test Reactor Alternative – This section presents the ORNL VTR Alternative. It describes the location, construction, and operation of the VTR, its associated facilities, and spent fuel pad at ORNL. It also discusses the operation of existing ORNL facilities that would support the VTR.

Section 2.6, **Reactor Fuel Production** – This section describes the options for producing VTR reactor fuels. It describes the possible sites and facilities for VTR fuel production at the INL Site and SRS. These options are evaluated independently from the VTR siting alternatives. The selection of reactor fuel production options can be made independently of the site selection for the VTR.

Section 2.7, Alternatives Considered and Dismissed from Detailed Analysis – This section covers alternatives and options considered by DOE but dismissed from further analysis in this EIS. It identifies each alternative and option and explains the rationale for dismissal.

Section 2.8, Preferred Alternative – This section addresses DOE's preferred alternative for the construction and operation of the VTR and its associated facilities. It also addresses DOE's preferred options for producing reactor fuel.

Section 2.9, Summary of Environmental Consequences – This section summarizes and compares the potential environmental consequences of the VTR alternatives and the reactor fuel production options. It also summarizes potential cumulative impacts of alternatives and options considered in this EIS and other existing or reasonably foreseeable actions.

Appendix B contains additional information describing the facilities required for the VTR project.

2.2 Proposed Versatile Test Reactor

DOE proposes to construct and operate the VTR at a suitable DOE site. DOE would use or expand existing, co-located, post-irradiation examination capabilities to accomplish this mission. Where necessary, requirements for expanding capabilities would involve the construction of new facilities. DOE would also use or expand existing facility capabilities to fabricate VTR driver fuel and test items[1] and to manage radioactive wastes. The following subsections provide non-site-specific descriptions of the VTR and associated facilities that would be included under both VTR action alternatives.

Driver (fuel) assembly located in the core contains the fuel needed to power the reactor and produces the fast neutron flux necessary for irradiation of test assemblies or specimens.

Reflector assembly surrounds the core and contains material to reflect neutrons back into the central part of the core.

Shield assembly is positioned outside of the reflector assemblies and contains material to absorb neutrons that pass through the reflector to reduce neutron damage to the reactor structural components.

Test assembly contains the test specimen and any in-core equipment needed to support the experiment. Instrumented test assemblies could be as long as 65 feet and are located in the core. Non-instrumented assemblies would be the same length as driver fuel assemblies (less than 13 feet) and may be located in the core or with the reflector assemblies.

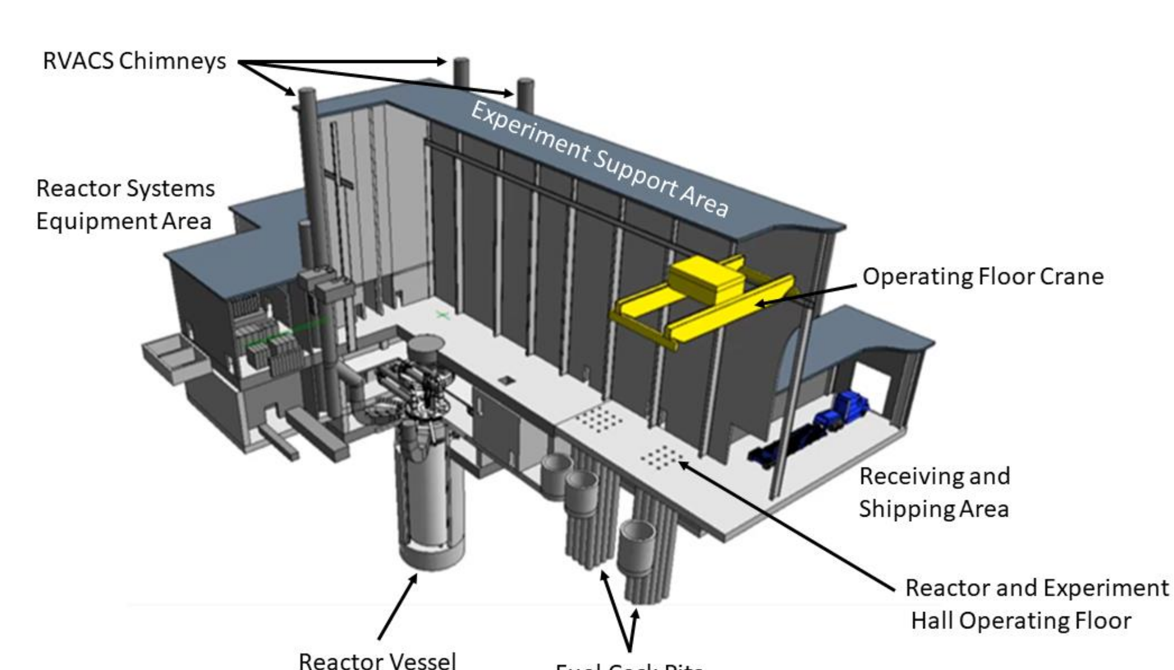
Test specimen is the material being exposed to a fast-neutron flux to determine the effects of the exposure and includes any capsule necessary to support the test. The test specimen can be no more than about 31 inches long.

2.2.1 Versatile Test Reactor

The principal objective of the VTR is to create a high flux of high-energy or "fast" neutrons within reactor test volumes (see Appendix B). This requires a departure from the light-water-moderated technology of current U.S. power reactors and the use of other reactor cooling technologies. The most mature technology that could generate the high-energy neutron flux is a sodium-cooled reactor. Experience with a pool-type configuration and metallic alloy fuels afford the desired level of technology maturity and safety approach. Sodium-cooled reactor technology has been successfully used in Idaho at the Experimental Breeder Reactor II (EBR-II), in Washington at the Fast Flux Test Facility (FFTF) and in Michigan at the Enrico Fermi Nuclear Generating Station Unit 1.

[1] As a user facility, the VTR would provide experimental capabilities for entities outside of DOE. These other entities could also fabricate test items for placement in the reactor.

The current VTR concept (see **Figure 2–1**) would make use of technologies incorporated into the GE Hitachi Nuclear Energy (GEH) Power Reactor Innovative Small Module (PRISM) design. The PRISM design[2] of a sodium-cooled, pool-type reactor satisfies the need to use a mature technology. The VTR would be an approximately 300-megawatt, thermal reactor, based on and sharing many design and safety features of the GEH PRISM. It also would incorporate technologies adapted from previous sodium-cooled fast reactor technologies (e.g., EBR-II and FFTF). The VTR's reactor, primary heat removal system, and safety systems would be similar to those of the PRISM design. VTR, like PRISM, would use metallic alloy fuels. The conceptual design for the first VTR driver fuel core proposes to use a uranium-plutonium-zirconium alloy fuel. Such an alloy fuel was tested previously in EBR-II, FFTF, and the INL Transient Reactor Test Facility. Later, reactor fuel could consist of varying enrichments of uranium and plutonium and could use other alloying metals in place of zirconium.



Key:
RVACS = Reactor Vessel Auxiliary Cooling System
Source: Modified from Bumgardner 2019.

Figure 2–1. Conceptual Design for the Versatile Test Reactor Facility

The VTR core design (see **Figure 2–2**), however, would differ from the PRISM core because it needs to meet the requirement for a high flux test environment that accommodates several test and experimental assemblies. Experiments would be placed in some locations normally occupied by driver fuel in the PRISM reactor. The VTR is not a power reactor. Therefore, no PRISM power conversion system and associated systems for the generation of electricity are needed. Heat generated by the VTR during operation would be dissipated through a secondary heat rejection system consisting of intermediate heat exchangers within the reactor vessel, a secondary sodium-cooling loop, and air-cooled heat exchangers. This system and the Reactor Vessel Auxiliary Cooling System (RVACS) would provide shutdown and emergency cooling. The RVACS would remove decay heat from the sodium pool by transferring the thermal energy through

[2] The PRISM design is based on the EBR-II reactor, which operated for over 30 years. The PRISM design most similar to the VTR is the 471 megawatt thermal MOD-A design. The U.S. Nuclear Regulatory Commission review of the PRISM reactor, as documented in NUREG-1368, *Preapplication Safety Evaluation Report for the Power Reactor Innovative Small Module (PRISM) Liquid-Metal Reactor* (NRC 1994), concluded that "no obvious impediments to licensing the PRISM design had been identified."

the reactor and guard vessel walls (with convective heat transfer through the argon gas in the annular gap between vessels). Heat is removed by naturally circulating air being drawn down through the inlets of four cooling chimneys, through risers on the exterior of the guard vessel, and up through the outlets of the cooling chimneys. No water would be used in either of the reactor cooling systems. The VTR reactor building's longest external dimensions would be about 280 feet by 180 feet with an experiment support area that extends 90 feet above the ground surface. The RVACS chimneys would be about 100 feet tall, extending above the experiment support area. Below-ground elements of the facility would include a structure that houses the reactor head access area, secondary coolant equipment rooms, the reactor vessel, test assembly storage areas, and fuel cask pits. The deepest of these, the reactor vessel silo, would extend to a floor level 93 feet below ground.

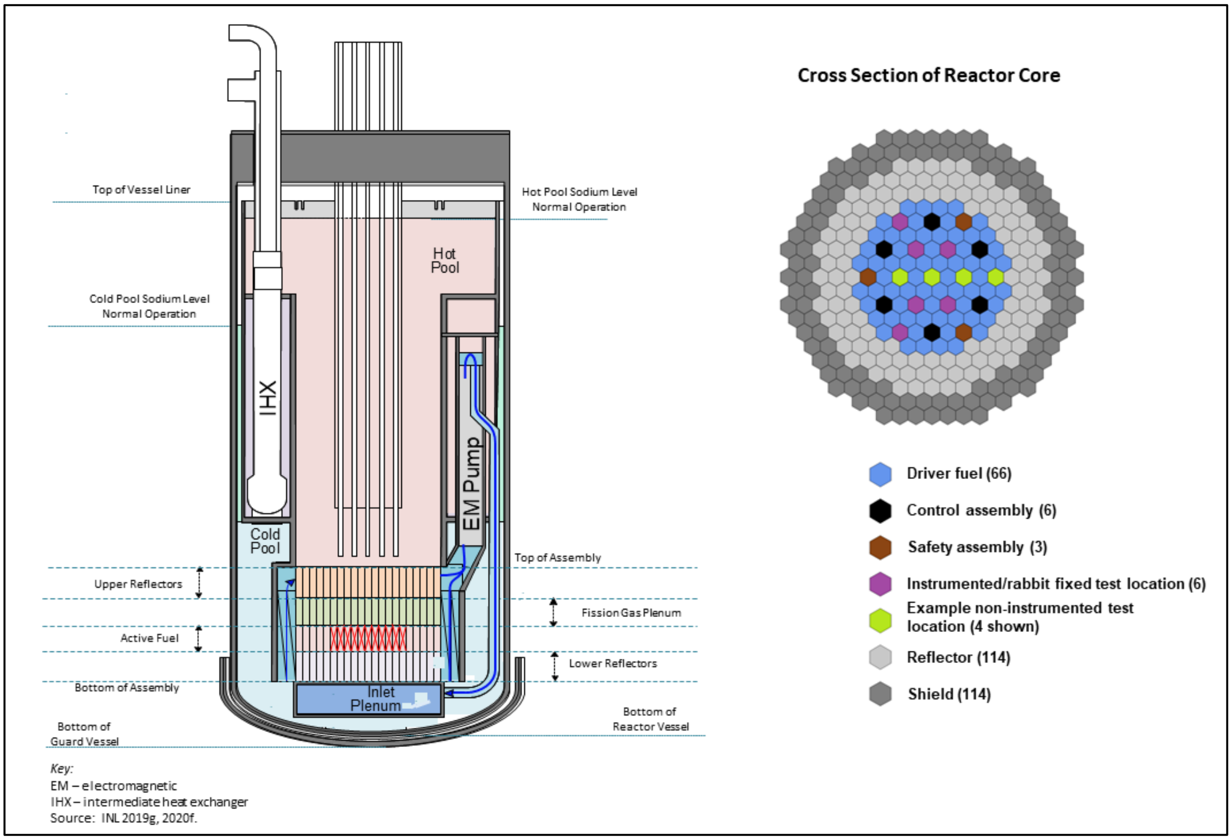


Figure 2–2. Versatile Test Reactor and Core Conceptual Designs

The core of the VTR would comprise 66 driver fuel assemblies. (See Section 2.6 for a discussion of the fuel and fuel production.) The VTR core would be surrounded by rows of reflector assemblies (a total of 114 assemblies) made of nonfuel material (HT-9 stainless steel). The reflector assemblies would be surrounded by rows of shield assemblies, totaling 114 assemblies, made of HT-9 stainless steel and containing neutron-absorbing boron carbide.

Non-instrumented experiments (containing test specimens) could be placed in multiple locations in the core or in the reflector region, by replacing a fuel or reflector assembly.[3] (Test pins may also be placed within a driver fuel assembly.) Instrumented experiments that would provide real-time information while

[3] Generally, the number of non-instrumented test locations are 4 in the core and an additional 10 in the reflector. However, the number of non-instrumented test locations relies upon the specific cycle-dependent physics and safety calculations. In any given test cycle the number of non-instrumented test assemblies could be more or less than these estimates. Also, non-instrumented test assemblies could be placed in an instrumented location.

the reactor is operating would require a penetration in the reactor cover for the instrumentation stalk and could only be placed in six fixed locations. At any time, one of these six locations could accommodate a "rabbit" test assembly that would allow samples to be inserted and/or removed while the reactor is in operation. The number of instrumented test locations, plus the flexibility in the number and location of non-instrumented tests, would strengthen the versatility of the reactor as a test facility.

Each test location could accommodate an experiment about the height of the core (80 centimeters) and could accommodate a test volume of more than 7 liters. Extended test assemblies would be used in the instrumented test locations. These test assemblies extend through the reactor head, and typically have various instrumentation leads, which are routed to the experiment rooms. Test specimens in these assemblies may be encapsulated in cartridges, so that the material being tested is fully contained. **Figure 2–3** shows one such test cartridge for testing materials that would require isolation from the primary coolant. Such a cartridge would allow testing of fuels and test materials in different coolant types (including sodium, gas, molten salts, and lead/lead-bismuth eutectic). Once operational, the VTR would run 3 test cycles per year, with each cycle averaging about 100 days long. After a typical cycle, a little less than one quarter of the driver fuel would be replaced. The VTR would annually generate up to 45 spent nuclear driver fuel assemblies or about 1.8 metric tons of heavy metal as spent fuel.

- 80 centimeters = 31 inches
- 7 liters = 0.24 cubic feet

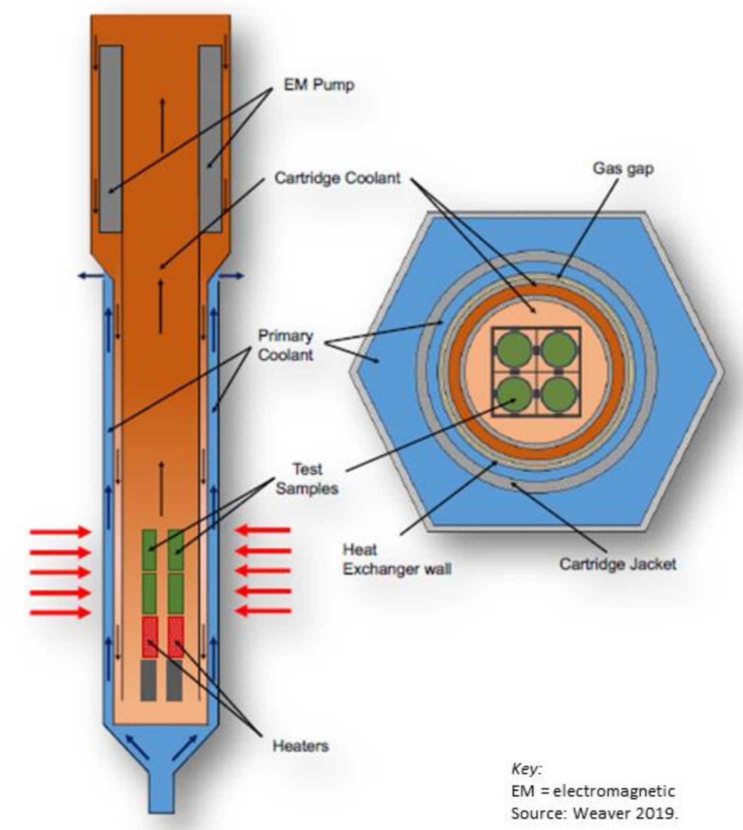


Figure 2–3. Experimental Cartridge

The VTR would provide the capability to test fuels, materials, instrumentation, and sensors for a variety of existing and advanced reactor designs, including sodium-cooled reactors, lead/lead-bismuth eutectic cooled reactors, gas-cooled reactors, and molten-salt reactors. Test vehicles for coolants other than sodium would consist of enclosed cartridges that contain coolant and test material, thus isolating the experiments from the primary coolant. Due to the high flux possible in the VTR, accelerated testing for reactor materials would be possible. These experiments would expand the state-of-the-art knowledge of reactor technology. Tests and experiments could also be developed that would improve safeguards technologies. In addition to fast reactor test and experimentation, the VTR could be used for research on long-term fuel cycles, fusion reactor materials, and neutrino science/detector development.

The VTR would not be used as a breeder reactor. All of the driver fuel removed from the reactor core would be stored to allow radioactive decay to reduce decay heat and dose rates, and then conditioned for disposal. No nuclear materials would be removed from the fuel for the purpose of reuse as fuel.

2.2.2 Post-Irradiation Examination Facilities

Concurrent with the irradiation capabilities generated by the VTR, the mission requires the capabilities to examine the test specimens (irradiated in the reactor) to determine the effects of a high flux of high-energy or fast neutrons. Depending on the nature of the test requirements, highly radioactive test specimens would be removed from the reactor after a period of irradiation, ranging from days to years. Test specimens would then be transferred to a fully enclosed, radiation-shielded facility where they could be disassembled, analyzed, and evaluated remotely. The examination facilities are “hot-cell” facilities (see **Figure 2–4**).[4] These hot cells include concrete walls and multi-layered, leaded-glass windows several feet thick. Remote manipulators allow operators to perform a range of tasks on test specimens within the hot cell while protecting them from radiation exposure. An inert atmosphere is required in some hot cells. An inert atmosphere of argon would be used[5] in the hot cell to which test assemblies are initially transferred after removal from the VTR. The inert atmosphere may be necessary to prevent test specimen degradation or unacceptable reactions (e.g., pyrophoric) that could occur in an air atmosphere. To minimize on- or offsite transportation of the highly radioactive specimens, DOE intends that these post-irradiation hot cell facilities would be in close proximity to the VTR. After initial disassembly and examination in the inert atmosphere hot cell, test specimens may be transferred to other hot cells or other post-irradiation examination facilities for additional analysis.

Figure 2–4. Exterior and Interior Views of Hot Cell Facilities

[4] A 360-degree tour of the exterior of the INL Hot Fuel Examination Facility hot cell is available at https://inl.gov/360-tour/hot-fuel-examination-facility.

[5] Not all test specimens would require an inert atmosphere during disassembly, analysis, and evaluation. However, separate facilities are not proposed for test specimens that do not require initial post-irradiation examination in an inert atmosphere.

2.2.3 Other Support Facilities

Key nuclear infrastructure components required to support the VTR and post-irradiation examination include:

- Facilities for VTR driver fuel production and test item fabrication, and
- Facilities for management of spent VTR driver fuel.

Nuclear materials (specifically, plutonium and uranium) for the VTR driver fuel could be acquired from several sources, including the DOE complex, commercial facilities, or foreign countries. The nuclear materials would be converted into metallic form,[6] as necessary, and formed into ingots (oblong blocks of metal) from which the fuel would be fabricated. The ingots could be produced at one of the locations providing the nuclear materials. Alternatively, plutonium (that may require polishing,[7] conversion to metal, or both) could be shipped to one of the DOE sites being considered for reactor fuel production for feedstock preparation and creation of feedstock ingots. At the fuel fabrication facility, ingots of nuclear material would be melted and combined with zirconium to make the alloy for fabrication of the fuel pins and assemblies ready for insertion into the VTR. DOE plans to acquire metal uranium for fabricating VTR fuel from a commercial vendor.

DOE would collaborate with a range of university, commercial industry, and national laboratory partners for experiment development. Fabrication of the test and experimental articles could occur at DOE facilities or at university or commercial industry partners' facilities. As shown in Figure 2–1, the VTR facility would have experiment support areas in which final assembly (e.g., insertion of the test specimen into the test assembly) and verification of the test assemblies would be performed before insertion into the VTR reactor core.

Once it is operational, the VTR would generate up to 45 spent driver fuel assemblies per year.[8] DOE would use existing or new facilities at the locations identified in the site-specific alternatives for the management of spent driver fuel. Spent driver fuel would be temporarily stored at the VTR within the reactor vessel for about 1 year. After the fuel radioactively decays and cools sufficiently, driver fuel assemblies would be removed from the vessel, the surface sodium coolant would be washed off the assembly, and the assembly would be transferred in a cask to a new onsite spent fuel pad. After several years (at least 3 years), during which time the radioactive constituents would further decay, the assemblies would be transported in a transfer cask to a spent fuel treatment facility. The sodium that was enclosed within the driver fuel pins to enhance heat transfer would be removed using a melt-distill-package process. The entire spent driver fuel assembly would be chopped. The chopped material would be consolidated, melted, and vacuum distilled to separate the sodium from the fuel. To meet safeguards requirements, the nonfuel elements of the driver fuel assembly would serve as a diluent for the remaining spent fuel to reduce the fissile material concentration. The resulting material would be packaged in containers and temporarily stored in casks on a spent fuel pad, pending transfer to an offsite storage location. The location would be either an interim storage facility or a permanent repository when either becomes available for VTR spent driver fuel. The sodium removed from the fuel would be converted into a

[6] The nuclear materials can exist in forms other than metal. For example, uranium can exist as uranium hexafluoride or uranyl nitrate. It would need to be processed in order to produce an oxide or metal. Both uranium and plutonium could exist as an oxide that would be chemically reduced to convert it to a metal.

[7] Polishing is the term used for removing undesirable components from plutonium. For example, americium-241 builds up from the decay of plutonium-241, so polishing to remove americium may be necessary to facilitate production (by minimizing worker radiation dose) and allow the use of gloveboxes instead of hot cells.

[8] Typically less than a quarter of the driver fuel assemblies would be replaced at the end of a test cycle. However, there could be atypical conditions when it would be necessary to replace a larger number of assemblies. In such instances, more than 45 assemblies could be removed from the core in a single year.

nonreactive salt, stabilized (if necessary), and packaged in containers as remote-handled low-level radioactive waste. End fittings and other nonfuel hardware could be incorporated in the melted fuel or removed, packaged, and disposed of as transuranic or low-level waste in accordance with their radiological characteristics. Radioactive waste would be processed, packaged, and disposed of (either on site or at an offsite facility).

Specific action alternatives proposed for analysis in this EIS include alternative DOE national laboratory sites for the construction and operation of the VTR, the provision of post-irradiation examination facilities, and the interim management of spent fuel. Under all action alternatives, the VTR would be an approximately 300-megawatt thermal, sodium-cooled, pool-type, metal-fueled reactor based on the GEH PRISM.

The reactor fuel production (feedstock preparation and fuel fabrication) options are considered independently of the alternatives for the VTR site. DOE identified two sites with the technological capabilities and capacities for feedstock preparation or fuel fabrication: the INL Site and SRS. The feedstock preparation and fuel fabrication options are discussed in Section 2.6.

2.3 No Action Alternative

Under the No Action Alternative, DOE would not pursue the construction and operation of a VTR. To the extent they are capable and available for testing in the fast-neutron-flux spectrum, DOE would continue to make use of the limited capabilities of existing facilities, both domestic and foreign. Domestic facilities that would likely be used, without modification, would include the INL Advanced Test Reactor (ATR) and the ORNL High Flux Isotope Reactor (HFIR). DOE would not construct new or modify existing post-irradiation examination or fuel treatment facilities to support VTR operation. Existing post-irradiation examination and fuel treatment facilities would continue to support operation of the existing reactors. Because there would not be a VTR under the No Action Alternative, there would be no need to produce VTR fuel. Therefore, no new reactor fuel production capabilities would be pursued. The No Action Alternative would not meet the purpose and need identified for the VTR (see Chapter 1, Section 1.3).

2.4 Idaho National Laboratory Versatile Test Reactor Alternative

Under the INL VTR Alternative, DOE would site the VTR near the Materials and Fuels Complex (MFC) at the INL Site (see **Figures 2–5** and **2–6**) and use existing hot cell and other facilities at MFC for post-irradiation examination and spent fuel treatment. MFC is the location of the Hot Fuel Examination Facility (HFEF), the Irradiated Materials Characterization Laboratory (IMCL), the Experimental Fuels Facility (EFF), the Fuel Conditioning Facility (FCF), the Fuel Manufacturing Facility (FMF) and the decommissioned Zero Power Physics Reactor (ZPPR). HFEF and IMCL (and other analytical laboratory facilities) would be used for post-irradiation examination and FCF for spent fuel treatment. EFF, FCF, FMF, and ZPPR would be used for reactor fuel production (see Section 2.6.2).

As shown in Figure 2–6, the VTR would be located on the east side of MFC. This location was selected primarily because the project would make use of numerous facilities at MFC. In addition, it is anticipated that relatively few environmental impacts would result from siting the facility there. The VTR complex would occupy about 25 acres. Additional land would be disturbed during the construction of the VTR complex for such items as temporary staging of VTR components, construction equipment, and worker parking In total, construction activities (anticipated to last 51 months) would result in the disturbance of about 100 acres, inclusive of the 25 acres occupied by the completed VTR complex. The 4 largest structures that would comprise the VTR are the reactor facility, electrical switchyard, 10 sodium-to-air heat exchangers, and an operations support facility. Various additional structures and equipment enclosures would be required. The existing Perimeter Intrusion Detection and Assessment System (PIDAS) security fencing around FMF and ZPPR would be extended to encompass most of the facility.

Figure 2–5. Proposed Versatile Test Reactor and Idaho National Laboratory Location Map

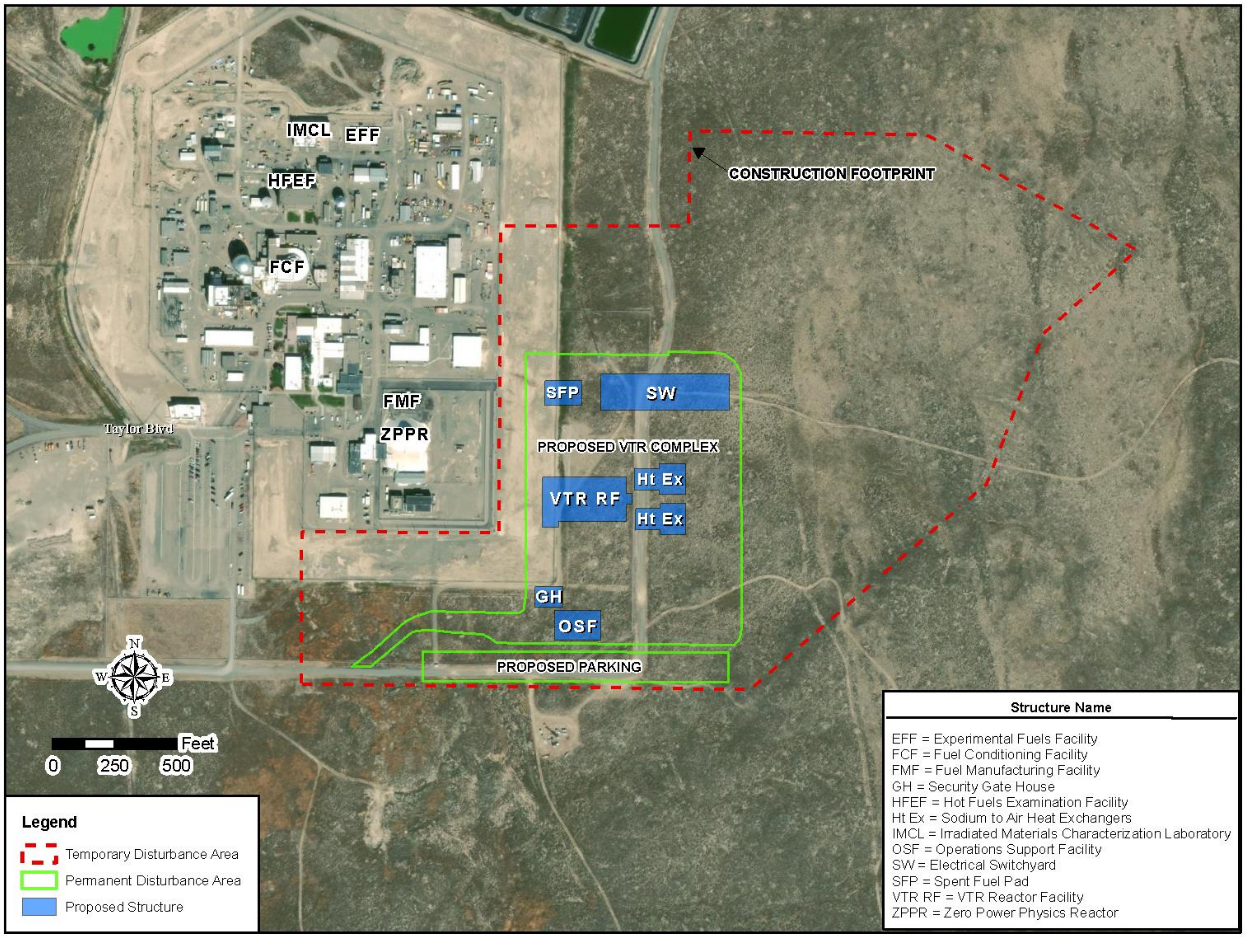


Figure 2–6. Versatile Test Reactor Facilities at the Materials and Fuel Complex at Idaho National Laboratory

Existing facilities would be used for post-irradiation examination of test and sample articles. Test and sample articles would be transferred to HFEF first. HFEF, a Hazard Category 2 nuclear facility[9] contains two large hot cells. The main cell is 70 feet by 30 feet with an inert argon atmosphere. This main cell employs 15 workstations. The second cell has an air atmosphere and includes five workstations. HFEF has the capability to handle fuel pins up to 13 feet long and the VTR test assemblies (excluding extensions removed prior to transfer to HFEF) would be less than 13 feet long. HFEF hot cells provide shielding and containment for remote examination (including destructive and non-destructive testing), processing, and handling of highly radioactive materials.

IMCL, a Hazard Category 2 nuclear facility, is the newest nuclear energy research facility at MFC, with a modular design that provides flexibility for future examination of nuclear fuel and materials. IMCL would be used for the study and characterization of radioactive fuels and materials at the micro- and nanoscale to assess irradiation damage processes. Shielded hot cell, glovebox, and hood capabilities are included in the facility. IMCL has free space for user-defined capability, such as the VTR project.

[9] DOE defines hazard categories of nuclear facilities by the potential impacts identified by hazard analysis and has identified radiological limits (quantities of material present in a facility) corresponding to the hazard categories. Hazard Category 1 – Hazard Analysis shows the potential for significant offsite consequences (reactors are included in this category). Hazard Category 2 – Hazard Analysis shows the potential for significant onsite consequences beyond localized consequences. Hazard Category 3 – Hazard Analysis shows the potential for only significant localized consequences. Below (Less Than) Hazard Category 3 applies to a nuclear facility containing radiological materials with a final hazard categorization less than Hazard Category 3 facility thresholds (DOE 2018c).

Materials and Fuels Complex Facilities to Support the Versatile Test Reactor

Fuel Fabrication

EFF – Experimental Fuels Facility
FCF – Fuel Conditioning Facility
FMF – Fuel Manufacturing Facility
ZPPR – Zero Power Physics Reactor

Post-Irradiation Examination

HFEF – Hot Fuel Examination Facility
IMCL – Irradiated Materials Characterization Laboratory

Fuel Treatment

FCF – Fuel Conditioning Facility

HFEF, IMCL, and EFF are not within a PIDAS, whereas FCF, FMF, and ZPPR are. The need for a PIDAS is determined by the type, quantity, and form of controlled material (e.g., plutonium) that a facility could contain at one time. HFEF, IMCL, and EFF are not expected to reach this threshold.

The existing facilities within MFC would not need to be modified to support fabrication of test articles or to support post-irradiation examination of irradiated test specimens withdrawn from the VTR. (HFEF would need new, in-cell handling equipment for experiment movement and examination.) These types of activities are ongoing within the MFC. These facilities and their associated operational staff provide an extensive capability to perform the anticipated post-irradiation examination activities that the VTR would create (INL 2020f).

Spent driver fuel would be temporarily stored at the VTR within the reactor vessel, followed by a period of storage on a spent fuel pad constructed to the east of ZPPR within the VTR complex. After the fuel cools sufficiently, it would be transported in a transfer cask to FCF. FCF contains two hot cell facilities: one with an air atmosphere and one with an inert argon atmosphere. Its primary mission is to support the treatment of DOE-owned, sodium-bonded metal fuel. DOE anticipates completing the processing of the current inventory of sodium-bonded driver fuel by the end of 2028. DOE also anticipates the identification and use of more efficient disposition options for the sodium-bonded EBR-II blanket material. Thus, FCF would be available and have the capacity to treat VTR fuel when the first fuel is available for treatment, no earlier than 2030. FCF is located within a PIDAS and is a Hazard Category 2 nuclear facility. It also supports DOE's Fuel Cycle Research and Development Program in the assessment of spent nuclear fuel treatment technologies involving high-temperature chemical and electrochemical methods for separation, purification, and recovery of fissile elements. DOE does not intend to separate, purify, or recover fissile material from VTR spent fuel.

Sodium would be removed from the driver fuel before packaging for storage and disposal. The process proposed for conditioning the fuel is a melt-distill-package process. The fuel would be chopped, using existing equipment at FCF. The chopped material would be consolidated, melted, and vacuum distilled to separate the sodium from the fuel. A diluent would be added to the spent driver fuel, most probably scrap HT-9 stainless steel from the driver fuel assembly. The mixture would be packaged in containers, placed in storage casks, and temporarily stored at a new spent fuel pad until shipped to an offsite location (either an interim storage facility or a permanent repository when either becomes available for spent VTR fuel). The sodium removed from the fuel would be converted into a nonreactive salt, stabilized (if necessary), and packaged in containers as low-level radioactive waste that would be stored at the Radioactive Waste Management Complex until it is shipped to a low-level radioactive waste disposal site (INL 2019e).

FCF would require modifications to support spent fuel treatment for the spent driver fuel. FCF would need new, in-cell handling equipment for spent fuel treatment and a hot cell window would need to be replaced to accommodate the transfer of driver fuel into the hot cells. Spent fuel treatment (EBR-II fuel) is an ongoing activity within MFC. These facilities and their associated operational staff would provide an extensive capability to perform the anticipated post-irradiation examination activities that the VTR would create (INL 2020f).

A new spent fuel pad would be constructed within the VTR site, adjacent to the VTR switchyard. A spent fuel pad would consist of a concrete slab of about 11,000 square feet with an approach pad of about 2,500 square feet.

Under the conceptual design, MFC's existing infrastructure, including utilities and waste management facilities, would be used to support construction and operation of the VTR. The current infrastructure is adequate to support the VTR with minor upgrades and modifications.

Driver fuel for the VTR would be fabricated at MFC or SRS, depending on multiple factors. Factors include the source of the nuclear material, as well as the availability and capabilities of DOE, commercial or foreign suppliers, and manufacturers (see Section 2.6).

2.5 Oak Ridge National Laboratory Versatile Test Reactor Alternative

Under the ORNL VTR Alternative, the VTR would be sited at ORNL at a site previously considered for other projects, about a mile east of the ORNL main campus (see **Figure 2–7** and **2–8**). The major structures for the VTR would be the same as those described for the INL VTR Alternative.

Although there are facilities with hot cells and other laboratories at ORNL that would be used for post-irradiation examination of test materials, none of the available hot cells operates with an inert atmosphere. All ORNL hot cells use an air atmosphere. A hot cell with an inert atmosphere would be needed for the VTR operation and for the treatment and conditioning of spent fuel. Converting existing hot cells at ORNL to operate with an inert atmosphere would require modifications that would interrupt their availability for ongoing mission work. Additionally, VTR-related operations in the hot cell(s) with an inert atmosphere have the potential to adversely impact the ongoing missions of these facilities. Based on these two considerations, conversion of an existing hot cell(s) to an inert atmosphere was not considered viable. Therefore, a new hot cell, a joint post-irradiation examination and spent fuel treatment facility, would be constructed adjacent to the VTR.

Additionally, a new spent fuel pad would be constructed as part of the VTR project to store treated fuel pending shipment to an offsite repository. All three facilities (the VTR facility, hot cell facility, and spent fuel pad) would be located within a single PIDAS.

The new hot cell facility would be approximately 172 feet by 154 feet and comprise four levels (including one level extending 19 feet below grade). The lower three levels would be constructed of concrete and brick masonry. The fourth level, a high bay area, would be of mostly steel construction and would rise to about 84 feet above grade. The facility would house four hot cells: two for post-irradiation examination and two for spent fuel treatment. Each pair of hot cells would include a decontamination hot cell and an inert atmosphere hot cell. Construction would occur in parallel with the construction of the VTR and be completed in the same 51-month period. Construction activities would result in disturbance of about 150 acres, with the completed VTR complex, including the hot cell facility and spent fuel storage pad, occupying fewer than 50 acres.

The new hot cell facility could be attached to the VTR and would support both spent fuel treatment and post-irradiation examination activities. In addition to this new hot cell facility, existing facilities at ORNL would be used for supplemental or advanced post-irradiation examination for materials that do not require an inert environment. Hot cells within the Irradiated Fuels Examination Laboratory (Building 3525) and the Irradiated Material Examination and Testing Facility (Building 3025E) would be used to supplement the capabilities of the new post-irradiation examination facility. In addition, the Low Activation Materials Design and Analysis Laboratory (LAMDA) would be used for testing of low dose samples that do not require the use of hot cells. The Irradiated Fuels Examination Laboratory is a Hazard Category 2 nuclear facility and contains hot cells that are currently used for examination of a wide variety of fuels. The Irradiated Material Examination and Testing Facility is a Hazard Category 3 nuclear facility and contains hot cells that are used for mechanical testing and examination of highly irradiated structural alloys and ceramics. LAMDA is a laboratory for the examination of materials with low radiological content that do not require remote manipulation. LAMDA supports the measurement of physical, chemical, and electric properties of samples.

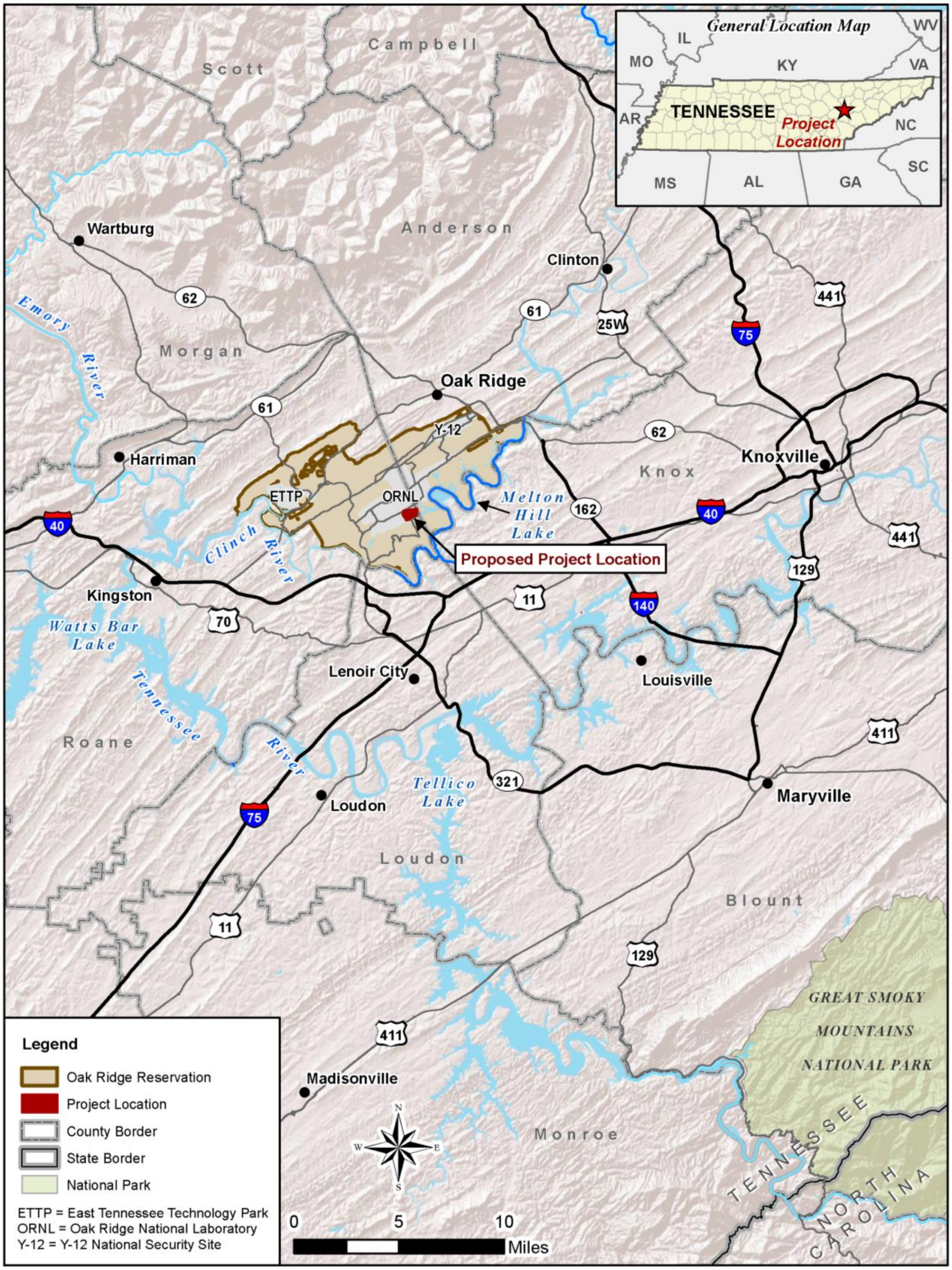


Figure 2–7. Proposed Versatile Test Reactor Facilities and Oak Ridge National Laboratory Location Map

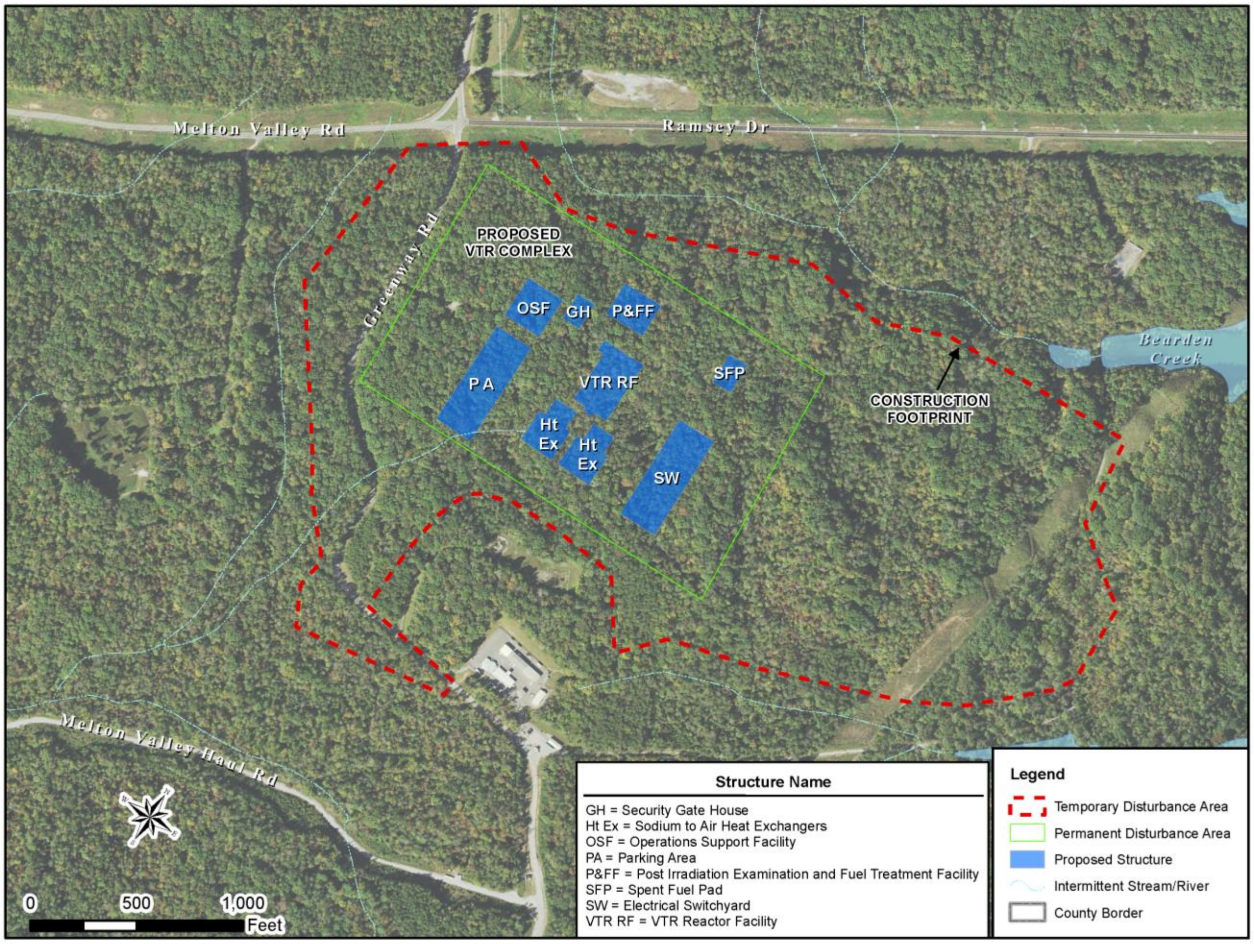


Figure 2–8. Proposed Versatile Test Reactor Site at Oak Ridge National Laboratory

Spent driver fuel would be temporarily stored, for at least a year, at the VTR, within the reactor vessel. Spent fuel would then be transferred to a storage pad for temporary storage (at least 3 years). At the end of this storage period, the fuel would be transferred to the spent fuel treatment facility. Treatment of the spent fuel would use the same processes described under the INL VTR Alternative, Section 2.4. Fuel treatment would occur in an inert atmosphere hot cell located in the new hot cell facility adjacent to VTR. Containerized spent fuel would be placed in storage casks and temporarily stored at a new spent fuel pad until shipped to an offsite location (either an interim storage facility or a permanent repository when either becomes available for VTR fuel). The sodium removed from the fuel would be low-level radioactive waste and would be packaged in containers, stored temporarily on site and transferred to a low-level waste disposal facility.

A new spent fuel pad would be constructed within the PIDAS for the VTR facility. It would consist of a concrete pad of about 11,000 square feet with an approach pad of about 2,500 square feet.

Under the conceptual design, the existing ORNL infrastructure would be extended to the VTR site. The location selected for the VTR is relatively undeveloped and does not have sufficient infrastructure (e.g., roads, utilities, security) to support construction and operation of the VTR. Existing waste management facilities within ORNL would be used to support waste management during construction and operation of the VTR.

Fuel for the VTR would be fabricated elsewhere, as determined by a number of factors. Factors include the source of the nuclear material, as well as the availability and capabilities of DOE, commercial or foreign suppliers and manufacturers (see Section 2.6.).

2.6 Reactor Fuel Production

The VTR design envisions the use of metallic fuel. DOE has conducted parametric studies to estimate the size of the reactor needed to obtain the desired experiment performance. Fuel compositions in the parametric study range from mixes of uranium, plutonium, and zirconium to mixes of only uranium and zirconium using high assay, low-enriched uranium (HALEU). The initial VTR core driver fuel would consist of a uranium/plutonium/zirconium alloy (U/Pu/Zr). Initially, the U/Pu/Zr fuel would be 70 percent uranium (enriched to 5 percent uranium-235[10]), 20 percent plutonium, and 10 percent zirconium, a blend identified as U-20Pu-10Zr. VTR driver fuel used in later operations could consist of these elements in different ratios and could use plutonium with uranium of varying enrichments, including depleted uranium or uranium enriched above 5 percent. After the completion of the parametric fuel study, DOE determined that HALEU fuel would not be available for use in the VTR. Current supplies of HALEU are insufficient to meet outstanding commitments and, despite projected increases in production, future supplies will not be sufficient to provide VTR fuel for its initial startup (DOE 2020h). Additionally, to meet the specifications for the VTR, a fast test reactor fueled with HALEU would need to be about a 700 megawatts thermal (MWth) reactor, which is beyond the size that is practical for a test reactor.

Annual heavy metal requirements would be approximately 1.8 metric tons of fuel material[11] (between about 1.3 metric tons and 1.4 metric tons of uranium and between 0.40 and 0.54 metric tons of plutonium, depending upon the ratio of uranium and plutonium in the fuel) (INL 2019e; Pasamehmetoglu 2019). The nuclear materials for the fuel could be acquired from several existing sources. Enriched uranium would be available from sources within the DOE complex and from commercial vendors. Existing sources of excess plutonium[12] within the DOE complex would be sufficient to meet the needs of the VTR project. Potential plutonium materials would include pit plutonium (metal), oxide, and plutonium from other sources (DOE 2015a). From a performance perspective, DOE's pit plutonium would be the technologically preferable source of plutonium for VTR fuel. However, should this material not be available for the VTR, sources of plutonium from Europe would be sought. Potential impacts from transportation of plutonium from Europe are evaluated in Appendix F of this EIS.

Uranium

Uranium enriched to 5 percent uranium-235 for use in fabricating VTR fuel could be provided from a number of sources. It could be supplied by purchase of commercially enriched uranium or by down-blending various DOE enriched uranium materials. DOE materials could include national security low-assay or scrap materials, unalloyed metals, oxides, or other uranium in various forms (DOE 2015c). All of this material could be down-blended (mixed with either natural or depleted uranium) to make 5 percent enriched uranium. (Depleted uranium is stored currently at two uranium enrichment sites in Paducah, Kentucky, and Portsmouth, Ohio). Low-enriched uranium and possibly depleted uranium, would be available through commercial sources.

The VTR project currently assumes that the 5 percent enriched uranium feed materials would come from commercial sources. DOE's plan for providing uranium for fabricating VTR fuel is to acquire metallic

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[10] Enriched refers to the concentration of the isotope uranium-235, usually expressed as a percentage, in a quantity of uranium. Low-enriched uranium, highly enriched uranium and high assay, low-enriched uranium are all enriched forms of uranium. Depleted uranium is a byproduct of the enrichment process and refers to uranium in which the percentage of uranium-235 is less than occurs naturally.

[11] The cited quantities are for finished fuel as it is placed in the reactor and corresponds to fuel that is from 20 to 27 percent plutonium. Allowing for the additional material that ends as waste during the reactor fuel production process, up to 34 metric tons of plutonium could be needed for startup and 60 years of VTR operation.

[12] Excess plutonium describes U.S. excess weapons-usable plutonium and includes pit (the central core of a primary assembly in a nuclear weapon that is typically composed of plutonium metal [mostly plutonium-239]) and non-pit plutonium that is no longer needed for U.S. national security purposes.

uranium from a domestic, U.S. Nuclear Regulatory Commission (NRC)-licensed, commercial supplier. Modifications needed to make metallic uranium, if necessary, at a commercial supplier may require NRC safety and environmental reviews. If another source of uranium were to be selected, DOE would conduct a review to determine if additional National Environmental Policy Act (NEPA) analysis would be needed.

Plutonium

As indicated above, there are various sources that could provide feedstock plutonium for the production of VTR driver fuel. In 1994 and 1995, the United States designated 38.2 metric tons of weapons-grade plutonium as excess to national security needs. DOE in 1996 identified an additional 14.3 metric tons and in 2006 another 9 metric tons (a total of 23.3 metric tons) of non-weapons-grade plutonium with no defined programmatic use. Since that time, DOE/National Nuclear Security Administration (NNSA) has had an ongoing program with the express purpose of effecting permanent disposition of certain inventories of excess plutonium. This material is stored at several locations within the DOE complex: the INL Site near Idaho Falls, Idaho; Los Alamos National Laboratory (LANL) near Los Alamos, New Mexico; the Pantex Plant near Amarillo, Texas; and SRS near Aiken, South Carolina.

> **Ingot** is an oblong block of metal (e.g., plutonium, uranium, zirconium, an alloy).
>
> **Fuel slug** is a cylindrical rod of alloyed fuel to be inserted into the fuel pin.
>
> **Fuel pin** is a single rod of fuel. The pin consists of a cladding tube, with top and bottom end plugs, containing fuel slugs, sodium-bonded to the cladding, and an inert gas plenum above the fuel.
>
> **Fuel assembly** (sometimes called a subassembly) is a hexagonal array of 217 fuel pins, top and bottom reflectors (shields), surrounded by an assembly duct with assorted mechanical components.
>
> Additional information is in Appendix B.

This plutonium exists in several forms and is of different isotopic mixes. Some of the more desirable forms include clean plutonium metal (e.g., unalloyed "buttons," billets, ingots, castings, finished machined weapon components, and miscellaneous small metal pieces), clean (low-impurity content) plutonium oxides, and alloy/oxide reactor fuels. For a number of technical reasons, the VTR would best be able to achieve the project's technical goals with the use of high-quality, excess pit plutonium as a component of the driver fuel. Less desirable material is in the form of impure metals and oxides, alloys, and uranium-plutonium oxides. Plutonium in spent nuclear fuel is not a candidate source for VTR fuel. DOE and NNSA have disposed of a portion of the excess inventory and continue to manage more than 50 metric tons of excess plutonium.

DOE/NNSA have evaluated the potential environmental impacts of disposition of excess plutonium in several NEPA documents prepared for the Surplus Plutonium Disposition Program (e.g., DOE 1999b, 2015a, and 2020d). Among other activities, these analyses included transportation of pits from storage at Pantex, disassembly of the pits, and various alternatives for dispositioning the plutonium. The analyses also addressed disposition of various other forms of excess plutonium. DOE/NNSA have issued Records of Decision regarding some of this material (81 FR 19588 and 85 FR 53350) and continue planning activities to ensure safe and secure disposition of additional material. DOE/NNSA could decide in the future to make a portion of the excess plutonium available as feedstock for VTR driver fuel. To the extent that excess plutonium becomes available, the VTR Program would be responsible for any technical activities and process changes that may be necessary to accept this source of feedstock. Any changes to allow use of excess plutonium as feedstock for VTR fuel production would be the subject of future NEPA analysis. That analysis would evaluate the different activities that would be required to make excess plutonium available as feedstock as opposed to preparing it for disposition in accordance with current planning.

This VTR EIS evaluates the potential environmental impacts of transporting excess plutonium that could be made available to the VTR project from LANL or SRS to the site where VTR fuel production would occur. It also evaluates the potential environmental impacts of performing the feedstock preparation activities necessary to remove contaminants from the plutonium and, if needed, convert it to metal for use in fuel fabrication. It does not evaluate the impacts of preparing disassembled pits, still in metal form, into a state suitable for packaging and transport to a site for use in VTR. These impacts would be evaluated in the future, if a decision is made to provide excess plutonium as feedstock material to the VTR project.

DOE is also exploring the possibility of acquiring plutonium from foreign stockpiles of plutonium. Both the United Kingdom and France have been reprocessing spent fuel from commercial power reactors and extracting plutonium from that spent fuel. Most of this material is reactor-grade plutonium and acceptable, though not preferable, for VTR fuel. The VTR would perform better with higher-grades of plutonium. In addition, use of reactor-grade plutonium may require more feedstock preparation to make it suitable for use in VTR fuel.[13] Both countries have adequate supplies of separated, reactor-grade plutonium to supply feedstock for the life of the VTR. Appendix F presents an assessment of the environmental consequences of transporting this material to the United States.

Feedstock Preparation

Depending on the impurities of the source material, a polishing process, or a combination of processes, would be required. Several processing options are available to chemically remove impurities from the plutonium prior to mixing with uranium and zirconium. These processes may require the conversion of the material from metal to oxide and oxide to metal and dissolution in acid solutions. Some of the processes must be performed at elevated temperatures to take advantage of the chemical properties of plutonium at different temperatures. These processes would be performed in a series of gloveboxes[14] in order to limit worker radiological exposure (see **Figure 2–9**).

Three potential feedstock preparation processes are under consideration: an aqueous capability, a pyrochemical capability, and a combination of the two. In the aqueous process, the plutonium feed (containing impurities) is dissolved in a nitric acid solution and through a series of extraction and precipitation steps a more polished plutonium oxide is produced. The oxide is converted to a metal in a direct oxide reduction process. In one form of the pyrochemical process (molten salt extraction), the metallic plutonium feed is combined with a salt, the mixture raised to the melting point. Impurities (americium) react with the salt, and the plutonium is collected at the bottom of the reaction crucible. If the pyrochemical process were selected, a direct oxide reduction process would also be required to convert plutonium dioxide feeds to plutonium metal. Either process (aqueous or pyrochemical) could be used to reclaim unusable fuel from the fuel fabrication process. If a combination of the two processes were to be selected, a smaller aqueous line to prepare this fuel could be incorporated into the pyrochemical process (SRNS 2020).

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[13] The source of plutonium impacts the ultimate disposal path for some of the waste generated during fuel production. Transuranic waste is eligible for disposal at the WIPP facility if it has been generated by atomic energy defense activities that meet the requirements of the WIPP Land Withdrawal Act (Public Law 102-579 as amended by Public law 104-201) and meets the WIPP Waste Acceptance Criteria. Transuranic waste resulting from activities using DOE excess plutonium could be eligible for disposal at the WIPP facility. Transuranic waste not eligible for disposal at the WIPP facility, would require disposal in a greater-than-Class-C low-level radioactive waste disposal facility. DOE evaluated potential environmental impacts of alternatives for the disposal of greater-than-Class-C low-level radioactive waste and DOE greater-than-Class-C-like waste in the *Final Environmental Impact Statement for the Disposal of Greater-Than-Class C (GTCC) Low-Level Radioactive Waste and GTCC-Like Waste* (DOE 2016a) and the *Environmental Assessment for the Disposal of Greater-Than-Class C (GTCC) Low-Level Radioactive Waste and GTCC-Like Waste at Waste Control Specialists, Andrews County, Texas* (DOE 2018d). If it is determined that the VTR Project waste is not eligible for disposal at the WIPP facility, additional National Environmental Policy Act analysis may be required as the EIS for GTCC disposal does not address VTR-generated waste. As of September 2020, DOE has not announced its decision on a disposal location for GTCC low-level waste and GTCC-like waste.

[14] Gloveboxes are sealed enclosures with gloves that allow an operator to manipulate materials and perform other tasks while keeping the enclosed material contained. In some cases, remote manipulators may be installed in place of gloves. The gloves, glass, and siding material of the glovebox are designed to protect workers from radiation contamination and exposure.

Figure 2–9. Representative Glovebox

Fuel Fabrication

Fuel fabrication would use an injection casting process to combine and convert the metallic ingots into fuel slugs. DOE has developed a conceptual design for this capability, based on existing equipment at INL's FMF. In a glovebox, a casting furnace would be used to melt and blend the three fuel components, uranium, plutonium, and zirconium. The molten alloy then would be injected into quartz fuel slug molds. After cooling, the molds would be broken, and the fuel slugs retrieved.

- 0.625 centimeters = 0.246 inches
- 80 centimeters = 31 inches
- 165 centimeters = 65 inches

Fuel pins would be created, using 0.625-centimeter-diameter, 165-centimeter-long, HT-9 stainless steel tubes (cladding) into which a slug of solid sodium would be inserted, followed by two or three of the alloy fuel slugs. The fuel slugs and sodium would occupy about half of the volume of the fuel pin with the remainder containing argon gas at near atmospheric pressure. The ends of the tubes would be closed with top and bottom end plugs. All of these activities would take place in gloveboxes with inert atmospheres. Once fully assembled, the fuel pins would be heated sufficiently to melt the sodium and create the sodium bond with the fuel. The sodium-bonded fuel would fill about half the length of the fuel pin (80 centimeters). Fuel pins would be assembled into a driver fuel assembly with each driver fuel assembly containing 217 fuel pins. Sodium bonding and producing the fuel assemblies would be performed in an open environment. No gloveboxes would be required (INL 2019e).

Fresh fuel assemblies would be kept in storage racks at the fuel fabrication facility until shipped to the VTR. At the VTR, fuel could be loaded directly into the core or temporarily placed in fuel cask pits.

This EIS evaluates the INL Site and SRS as potential locations for performing the activities necessary for reactor fuel production for the VTR. DOE would establish and operate feedstock preparation capabilities at either of the two sites. Independently, DOE would establish and operate all or part of the fuel fabrication capability at either site.

Operationally, the feedstock preparation and fuel fabrication capabilities would need to generate about 66 driver fuel assemblies for the initial VTR core. Thereafter, the capabilities would need to produce up to 45 driver fuel assemblies per year.

2.6.1 No Action Alternative

As discussed in Section 2.3, under the No Action Alternative, DOE would not pursue the construction and operation of the VTR nor the facilities required to support the VTR. Therefore, DOE would not construct, modify, nor operate any feedstock preparation or driver fuel fabrication capabilities to support VTR operation.

2.6.2 Idaho National Laboratory Reactor Fuel Production Options

The INL Site is a potential site for both feedstock preparation and for fuel fabrication. These activities, alone or together, could be located at INL. All activities would occur in existing facilities, but new equipment would need to be installed. As described in the following paragraphs, DOE has identified existing MFC facilities that would be capable of supporting all fuel production activities. All of these facilities are currently in use and some (e.g., the ZPPR cell) have been identified as possible locations for future programmatic missions other than VTR reactor fuel production. Based on DOE programmatic and scheduling priorities, use of these facilities by other programs may result in their being unavailable to the VTR Program. Should this happen, modifications to enlarge an existing facility or the use of other MFC or VTR facilities would be evaluated to assess their capability to support the VTR Program. Any changes to the facilities being considered to host VTR reactor fuel production would be subject to future review under NEPA.

Under the INL Feedstock Preparation Option, polishing and conversion capabilities would be located in the FCF operating floor/high bay, the mockup area, and workshop. FCF is located within a PIDAS and is a Hazard Category 2 nuclear facility. The primary feature of the FCF is its two hot cell facilities, one with an air atmosphere and one with an inert argon atmosphere. However, neither of these hot cells would be used to support feedstock preparation. These activities would be performed in space outside the hot cells converted for feedstock preparation (INL 2020d).

After removal of unneeded equipment (current activities within these areas would be relocated), DOE would install new equipment in glove box lines (a series of two or more related gloveboxes) to perform plutonium polishing and conversion. The number of glovebox lines required would depend upon the processes selected. As noted above, three process combinations are being considered for feedstock preparation. If the aqueous processing were to be selected an estimated 10 glovebox[15] lines may be necessary. Glovebox lines would be constructed for feed preparation, plutonium dissolution, plutonium extraction, oxide conversion, waste processing, and acid recycling. This scenario considers the most equipment-intensive process under consideration. Other processes would be expected to require fewer glovebox lines and less operational space. All feedstock preparation equipment would be newly installed equipment (INL 2020d).

Under the INL Fuel Fabrication Option, the VTR fuel fabrication process would be located in the existing FMF and ZPPR, both Hazard Category 2 nuclear facilities located within a PIDAS. FMF, adjacent to ZPPR, consists of multiple workrooms and a material storage vault. FMF has the ability to develop and store transuranic metallic and ceramic fuels and produce and purify transuranic and enriched uranium feedstock. The reactor and auxiliary systems portion of ZPPR have been removed, and the facility is now used, among other tasks, for the storage, inspection, and repackaging of transuranic elements and

[15] The feedstock preparation operations design uses gloveboxes. However, the design is at a conceptual stage and subject to change. Potential changes include the use of heavily shielded or highly automated gloveboxes or even the use of hot cells. Design considerations that might affect these decisions include limiting worker dose.

enriched uranium. The ZPPR facility includes a workroom, cell area, material storage vault, and the Material Control Building.

Fuel fabrication activities in FMF would occur in a series of gloveboxes. A representative glovebox located in the ZPPR facility and used in the handling of nuclear material is shown in Figure 2–9 (INL 2019e). As proposed, DOE would install gloveboxes for casting (two gloveboxes), demolding (two gloveboxes), and rod loading (one glovebox), to fabricate the fuel pins (see **Figure 2–10**). Additional gloveboxes would be required for slug and pin inspection and scrap recovery. Two gloveboxes are proposed for scrap recovery.

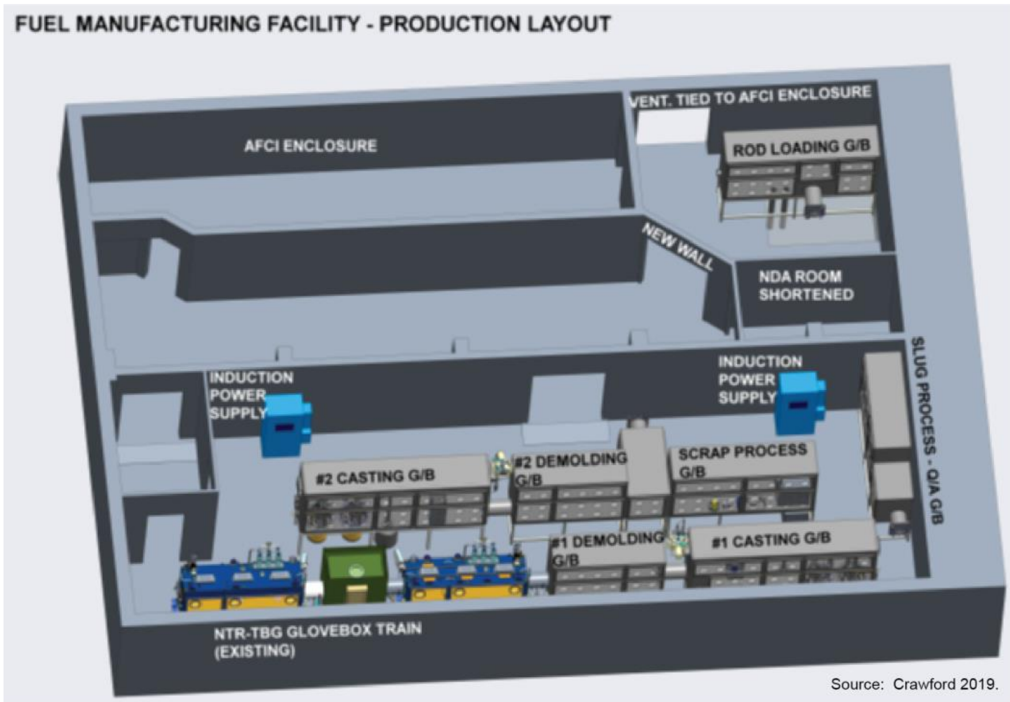

Figure 2–10. Proposed Fuel Fabrication Capability

One would be modified from an existing glovebox, and the second would be new. All of this activity would occur in FMF. After fabrication, fuel pins would be transferred to ZPPR. Bonding the sodium to the fuel (through heating) and assembling fuel pins into driver fuel assemblies would occur in the reactor cell room of ZPPR. This room is sufficiently high to allow fuel pins and driver fuel assemblies to be vertically raised into and out of the vertical assembly device used for driver fuel assembly fabrication.

Fuel fabrication at INL would require additional analytical chemistry capability. Sample analysis for process qualification and product quality assurance would require additional analytical workspace. DOE would install new equipment in existing space at FCF as an analytical chemistry laboratory to support VTR fuel fabrication (INL 2019e).

Driver fuel cladding would be tested in EFF. EFF, a less than Hazard Category 3 nuclear facility, is used to support both DOE and private industry customers. Basic uses of EFF include uranium and uranium alloy casting and extrusion, processing uranium metal and ceramics, and fabrication and handling of alloys and powders. Equipment available to support these activities include radiological fume hoods, metal-forming and machining equipment, equipment for high temperature applications (furnaces, molten salt baths, casting and annealing furnaces), and fuel experiment assembly equipment (INL 2016a).

2.6.3 Savannah River Site Reactor Fuel Production Options

SRS is a potential site for both feedstock preparation and for fuel fabrication. These activities, alone or together, could be located at SRS.[16]

The facilities and equipment required for reactor fuel production could be installed in either the K Area Complex or the similar L Area Complex. The reactor buildings in K Area and L Area are of the same design, and like the K-Reactor Building, the nuclear fuel and equipment needed for reactor operations have been removed from the L-Reactor Building. This EIS specifically evaluates the potential environmental impacts of using the K Area Complex in support of the VTR project, but the impacts would be similar if the L Area Complex were used. The reactor buildings are only 2.5 miles apart and each is within a PIDAS. At either location, activities would largely occur indoors with small (fewer than 3 acres), previously disturbed locations outside required for construction laydown areas or ancillary facilities (e.g., heating, ventilation, and air conditioning equipment). At L Area, space on the ground floor of the facility would be available, as well as space at minus-20- and minus-40-foot levels. A comparative analysis shows that the offsite impacts from radiological releases would be within 3 percent of each other, with those from L Area being slightly lower.

At K Area, all core process activities would occur on the minus-20- and minus-40-foot levels (floor levels 20 and 40 feet below grade) of the K-Reactor Building[17] or in the adjacent 108-K Buildings in the K Area Complex (see **Figure 2–11)**. Approximately 22,600 square feet and 13,500 square feet of space would be made available at the minus-20- and minus-40-foot levels, respectively for fuel fabrication. A minimum of 10,000 square feet of space would be made available for feedstock preparation. This space could be in either the K-Reactor Building or in the adjacent 108-K Buildings. To establish any new capabilities, DOE would install new hot cells, gloveboxes, and equipment.

Under the SRS Feedstock Preparation Option, capabilities would be located primarily on the minus-20-foot level in the K Area Complex, although a substantial portion of the minus-40-foot level would be used. The identified area would be suitable for pretreatment operations like molten salt removal of the americium from plutonium (polishing), electrorefining, and direct oxide reduction to convert fuel compounds (e.g., fuel oxides) into their metallic form. The facility floorplan has available space to install the gloveboxes required for these operations. All of the equipment for fuel processing and conversion (as described in Section 2.6.2) would be newly installed (SRNS 2020).

Under the SRS Fuel Fabrication Option, the fuel fabrication capability would be located on the minus-20- and minus-40-foot levels. A portion of this area is currently occupied by excess equipment and stored drums of heavy water. The heavy water would be removed to a new onsite storage location. The disposition path for the excess equipment would be determined by characterization of the material at the time of disposal. A portion of the space at the minus-20-foot level has a high bay area that would allow for the vertical assembly of driver fuel assemblies, or, provided some heat exchangers would be removed from the minus-20-foot level, space on the minus-40-foot level would be used for vertical assembly of driver fuel assemblies. Another option would be to locate vertical assembly of the driver fuel assemblies in the 108-K Buildings. The space in several additional pump rooms would also be used if necessary. The identified area would be suitable for the fuel fabrication glovebox processes being designed at INL (as described in Section 2.6.2). All of the enclosures and equipment for fuel fabrication would be newly installed (SRNS 2020).

[16] The identified locations for process space allocation are notional and are intended to demonstrate that sufficient space would be available. The final location of equipment would be determined after additional review of facility use options.
[17] Due to its use as a special nuclear material storage facility, the K-Reactor Building is a Hazard Category 1 nuclear facility.

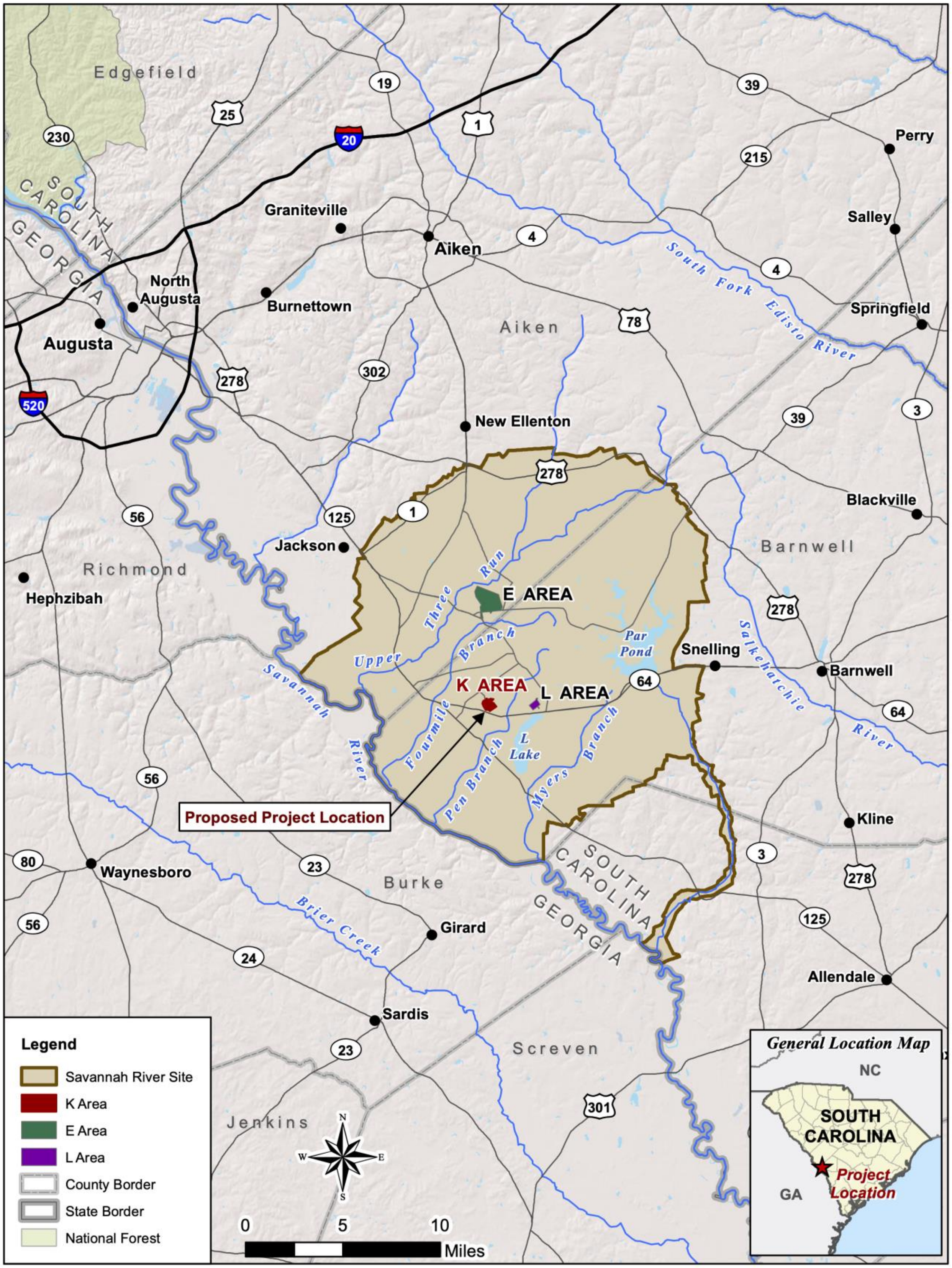

Figure 2–11. K Area Complex and Savannah River Site Location Map

The facility could support fuel manufacturing activities under all of the options being considered. But changes to the facility HVAC (heating, ventilation, and air conditioning) system and supporting equipment may be required. These changes could result in the construction of a new steel frame structure atop one of the 108-K Buildings or adjacent to the building to house the new HVAC equipment.

2.7 Alternatives Considered and Dismissed from Detailed Analysis

The Nuclear Energy Innovation Capabilities Act of 2017 amended the Energy Policy Act of 2005 and directed the Secretary of Energy to determine the need for a versatile reactor-based, fast-neutron source. If the need for such a reactor was identified, the Act directed the Secretary "to the maximum extent practicable, complete construction of, and approve the start of operations for, the user facility by not later than December 31, 2025." DOE considered several alternatives for different aspects of the VTR project. For the VTR design, DOE considered 16 concepts, primarily reactor concepts, but also some non-reactor concepts. The alternatives considered for the reactor design, but ultimately dismissed from detailed analysis, are discussed in Section 2.7.1. Two potential sites for locating the VTR and its associated post-irradiation examination facilities were discussed previously in this chapter. These two sites were selected after consideration of two additional sites. The two alternatives considered for facility site location but later dismissed from detailed analysis are discussed in Section 2.7.2. There were no alternative locations considered in this EIS for the fabrication of driver fuel required for VTR operation other than those discussed in Section 2.6.

2.7.1 Versatile Test Reactor Designs Considered but Dismissed from Detailed Analysis

In its *Analysis of Alternatives, Versatile Test Reactor Project* (AoA) (DOE 2019d), DOE evaluated 18 design concepts (including the sodium-cooled fast test reactor concept) for the VTR. The AoA also considered the status quo, which is effectively the No Action Alternative of this EIS. The concepts considered included retaining existing facilities (either with modification or by keeping the status quo of no new facilities and no modifications to existing facilities), building new fast test reactors, and establishing a new accelerator-driven system. (Although evaluated in the AoA, the sodium-cooled fast test reactor is not discussed in this section, because it is the proposed technology for the VTR.)

The AoA performed an initial screening of these concepts against six criteria based on the requirements of the Nuclear Energy Innovation Capabilities Act of 2017 and the *Mission Need Statement for the Versatile Test Reactor (VTR) Project* (DOE 2018a). Because they failed to meet one or more of these criteria, twelve concepts[18] were eliminated from further evaluation in the AoA. In particular, DOE determined that 10 of the 12 concepts failed to meet the criteria: "*Provides an intense, fast-neutron irradiation environment with prototypic spectrum to determine irradiation tolerance and chemical compatibility of reactor fuels, materials, and coolants, with the versatility to address diverse technology options and sustained and adaptable testing environments*". Six of the 12 concepts failed the criteria: "*The alternative shall become operational on an accelerated schedule to regain and sustain U.S. technology leadership and to enable the competitiveness of U.S.-based industry entities in the advanced reactor markets*" (DOE 2019d).

Three existing facilities and two new fast test reactors (in addition to the sodium-cooled reactor) passed the initial screening criteria. The three existing facilities that passed the initial screening criteria were ATR, HFIR, and FFTF. The two new reactor designs that passed the screening criteria were the molten-salt fast test reactor (MSFTR) and a lead/lead-bismuth-cooled fast test reactor (LFTR).

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[18] The status quo alternative was evaluated in the AoA for completeness and as a comparison for the remaining alternatives evaluated. As noted above, this is the No Action Alternative of this EIS.

ATR is a light-water-cooled reactor located at the INL Site. The reactor's primary "customer" is the U.S. Navy, but over the past several years, the reactor has been used to irradiate a broad spectrum of fuels and cladding materials of interest for other customers. The reactor is typically operated at a power level in the range of 110 to 120 MWth [megawatts thermal]. It has a maximum thermal flux of 1×10^{15} neutrons per square centimeter per second, and maximum fast flux of 5×10^{14} neutrons per square centimeter per second. There has been interest in using the ATR to support the testing of fuels and materials for fast-spectrum systems. To respond to this need (which included a fast-neutron flux of 2×10^{15} neutrons per square centimeter per second), the Advanced Fuel Campaign developed and applied an irradiation capsule design with a "thermal flux absorber" (e.g., cadmium). The design minimized the thermal component of the flux to approximate a fast spectrum. The campaign also proposed a Boosted Fast Flux Loop to increase the fast flux into the required range.

HFIR is a light-water-cooled reactor located at ORNL. The reactor has a power level of 85 MWth and associated maximum thermal and fast fluxes of 3×10^{15} and 1×10^{15} neutrons per square centimeter per second, respectively. The primary application of the HFIR is isotope production and neutron generation for scientific applications via beam ports and a cold neutron source. HFIR has been used to irradiate fuels and cladding materials. Irradiations designed to approximate a fast spectrum also use a "thermal flux absorber" to minimize the thermal component of the flux. Options to boost the flux to the desired target may be feasible.

FFTF is a deactivated fast test reactor located at DOE's Hanford Site (Hanford) in Washington. This reactor was a 400 MWth sodium-cooled fast reactor that used mixed oxide driver fuel and operated from 1982 through 1992. FFTF was used to test fuels and materials for fast reactors. It is potentially capable of being reactivated to meet the fast-neutron irradiation requirements of the VTR project.

An MSFTR would be a fast-spectrum reactor cooled and possibly fueled by molten salt. Options include both a solid-fuel, salt-cooled concept or, more likely, a molten-salt fuel concept. Molten fuel allows greater flexibility in accommodating test assemblies due to the absence of solid fuel assemblies. Molten fuel can achieve high power density and high flux for irradiation. The reactor could be leveraged off of any one of several conceptual designs for molten-salt fast power reactors. MSFTRs would be modified to incorporate test irradiation locations in the core to accommodate both static and dynamic experiments. Fast-spectrum MSFTR designs are amenable to high power density cores and could achieve the desired irradiation conditions with a reactor in the 250 to 400-MWth range. A typical fuel/coolant would be chloride salt loaded with dissolved uranium or plutonium. A pool-type design could facilitate experiment access, with above-pool access to experimental channels. Molten salt fuel has advantages in thermal capacity, low-pressure operation, retention of actinides and fission products, high thermal margin to voiding, transparency, and low chemical reactivity. Challenges include new fuel and core materials and proliferation concerns. One thermal molten salt (test) reactor (MSR) has been built, and there is both foreign and domestic interest in both thermal and fast MSR concepts.

An LFTR would be a new fast-spectrum reactor, cooled by either lead or a lead-bismuth eutectic (an alloy with a comparatively low melting point). A test reactor could be based on any one of several conceptual designs for a lead/lead-bismuth-cooled power reactor. While none of the designs is for a test reactor, they could be modified to incorporate test irradiation locations. A pool-type design would be amenable to high power density cores and could achieve the desired irradiation conditions with a reactor in the 250- to 400-MWth range. Unlike sodium fast reactors, the preferred fuel would probably be a uranium/plutonium-nitride. A pool-type design could facilitate experiment access, with above-pool access to experimental channels. No heavy metal-cooled reactors have been built in the United States, but a number have been tested and fielded abroad.

The five designs (in addition to the sodium-cooled fast reactor evaluated in this EIS) that passed the initial screening were evaluated against the criteria shown in **Table 2–1**. These criteria are adapted from the 20 criteria[19] used in the AoA to assess designs that passed the screening evaluation. They have been aggregated here into a set of eight criteria that describe the reasons why the alternatives were not further analyzed as part of this EIS. (The AoA criteria were derived from the Mission Need Statement [DOE 2018a], and the Nuclear Energy Innovation Capabilities Act of 2017, with some added as part of the AoA evaluation.)

Table 2–1. Criteria for Evaluation of Alternatives Not Screened

Number	***Criteria***
1	**Provides an intense fast-neutron irradiation environment with prototypic spectrum that meets the specifications of the VTR program** • Provides a source of fast neutrons at a neutron flux sufficient to enable research for an optimal base of prospective users • Provides high neutron dose rate for materials testing [quantified as displacement per atom] • Provides capabilities for irradiation with neutrons of a lower energy spectrum
2	**Provides testing capacity that meets the specifications of the VTR program** • Provides a large irradiation volume within the core region • Provides an irradiation length that is typical of fast reactor designs – Expedites experiment life cycle by enabling easy access to existing support facilities for experiments fabrication and post-irradiation examination • Provides capabilities that support experimental high-temperature testing • Provides the ability to test advanced sensors and instrumentation for the core and test positions • Provides innovative testing capabilities through flexibility in testing configuration, testing closed-loop environments
3	**Capable of becoming operational on an accelerated schedule, compliant with the operational start date set in the Nuclear Energy Innovation Capabilities Act of 2017 (P.L. 115-248)** • High technical confidence with the facility so that the facility can be available for testing as soon as possible • Shortest schedule to initiate operations
4	**Availability of existing facilities and infrastructure to support the VTR mission** • The facility should have sufficient test capability to add the VTR mission to existing and continuing facility missions without impacting those missions
5	**Programmatic risk - Factors that could impact programmatic risks (primarily to schedule) include** • Maturity of design both for new reactor types and preferred fuel types • Required updates/modifications to existing facilities • Higher confidence in stakeholder acceptance • Greater ease and confidence of compliance with codes, standards, regulations
6	**Ability to regain and sustain U.S. technology leadership and to enable the competitiveness of U.S.-based industry entities in the advanced reactor markets**
7	**Costs associated with alternative development** • Present value of life-cycle costs • Capital investment (total project cost) • Annual operating and maintenance costs during operations
8	**Life cycle management** • Capability to manage test fuels and driver fuel while minimizing cost and schedule impacts, including management of discharged fuel

P.L. = Public Law; VTR =Versatile Test Reactor.

[19] One criterion included in the AoA was not considered in this evaluation: security. All options evaluated scored high on this criteria because existing facilities are located at sites with appropriate security capabilities, and new designs were assumed to be located at similarly secure sites.

Despite two existing operating facilities—ATR and HFIR—having favorable qualities for the VTR project (e.g., they have existing infrastructure and established fuel management), they are *primarily* thermal-spectrum reactors. Even with modification, neither reactor would fully meet the test capabilities required for the VTR. They could not provide the fast-neutron flux, the neutron dose rate, or the required experimental volume. Additionally, as operating facilities, both reactors support other programs and have prior test commitments. Use of either as the VTR could interfere with the current test capabilities of the reactors and could result in conflicts between tests and experiments requiring a fast flux and those requiring a thermal flux. This would result in the loss of thermal flux test capacity at the facilities. That capacity could not be replaced using existing U.S. test capabilities, nor could it provide the full fast flux testing capability identified for the VTR. Modifying either of these reactors would create some fast flux testing capability, but could compromise the United States' ability to regain and sustain a technology leadership position. Therefore, these two reactors were dismissed from further evaluation in this EIS.

FFTF operated for many years as a fast flux test reactor and, as a result, has a demonstrated history of performing the type of testing for which a VTR is proposed. Because the FFTF would be modified as part of a restart, appropriate testing capabilities could be factored into the design. However, there are uncertainties associated with modifying the design. These include required studies to determine the scope of modifications. For example, would the modified facility meet current codes and standards? Would it meet current seismic requirements? In addition, the support facilities originally constructed to support the FFTF would also need to be modified as they are either currently inactive or not fully constructed. A restart of the FFTF has been considered on several occasions since the last shutdown and has been a contentious issue in the region. Public opposition to a restart could introduce schedule risks to the VTR project. (In the ROD [66 FR 7877] for an earlier EIS [DOE 2000b], DOE decided that FFTF would be permanently deactivated.)

The DOE Office of Nuclear Energy reviewed the AoA results and determined that a further examination of the Modify and Restart FFTF Alternative was warranted given its evaluation score, technology-related risk score, site-specific risk score, and costs relative to the Sodium-Cooled Fast Spectrum Test Reactor Alternative. This examination included a facility walk down of FFTF conducted in October 2019 by a team composed of the VTR Program Director, DOE Richland Assistant Manager, VTR Project Manager, and industry experts. Based on the facility walk down, extensive pre and post-tour discussions and a review of a study by the Columbia Basin Consulting Group, the team had significant concerns about the viability of restarting FFTF. These concerns include:

- FFTF was operated for 10 of its 20-year design life with a potential for an additional 10 years;
- there are an extensive number of electrical and mechanical systems that would have to be replaced since last operated in the mid-1990s;
- the Columbia Basin Consulting Group study, conducted in 2007, based its cost estimate on a 2000 restart study when the systems were in relatively good condition;
- an extensive effort would be necessary to obtain a viable cost and schedule restart estimate; and
- FFTF would require extensive design changes to accommodate testing of alternate coolant technologies (lead, salt, or gas).

While it is believed that the entire suite of design documents exists, there is also a concern that an extensive design and safety-basis reconstitution effort, including seismic analysis, would be costly and time-consuming and has the potential to identify additional necessary upgrades. Subsequent discussions with the VTR Project Team concluded that these issues would result in a restart effort significantly longer and more costly than characterized in the AoA. The schedule and cost could increase further to accommodate upgrades to address the full suite of VTR test requirements and to respond to the current design-basis safety philosophy. Therefore, FFTF was removed from further analysis in this EIS.

The most significant shortcoming of the two new reactor designs (MSFTR and LFTR) is the current level of development and technical maturity for these reactor concepts. In an assessment of the technical readiness level of various reactor concepts, the *Advanced Demonstration and Test Reactor Options Study* concluded that salt-cooled reactors (e.g., a fluoride-cooled high-temperature reactor) and lead-cooled fast reactors are less mature than sodium-cooled fast reactors and require additional research and development (INL 2017d). There is considerably less knowledge base for these designs than for the sodium-cooled fast test reactor concept. Only one small thermal molten-salt test reactor has been built, and no molten salt fast reactors have been built in the United States. Experience with building and operating lead-cooled reactors is limited, not readily available, and related to submarine propulsion. For both reactor concepts, a demonstration reactor might be necessary, which would result in greater costs and unacceptable schedule delays for the construction and operation of the VTR. These reactor technologies were dismissed from further evaluation in this EIS because of the technical and schedule risk associated with their technical maturity.

Table 2–2 presents DOE's rationale for dismissing these alternatives from further consideration.

Table 2–2. Rationale for Dismissal of Alternative from Further Consideration

Alternative	*Rationale for Dismissal*
Modify Advanced Test Reactor (ATR)	• Does not meet VTR performance criteria, even with modifications – Primarily a thermal flux test reactor – Achievable fast flux is factor of 4 less than required VTR flux – Available test volume at the maximum fast flux would be less than 10% of VTR 7 liter requirement – Limited ability to support experimental high-temperature testing • Negative impact on thermal flux testing availability/competition for resource. Alternatives for current thermal flux test missions not readily available among existing facilities. Thermal flux capability required for – Main mission of Navy program support – Nuclear Science User Facility commitments – Plutonium-238 production for radioisotope thermoelectric generators (National Aeronautics and Space Administration support) • Operational efficiency would be less than that for other design concepts resulting in lowered testing capability, and fewer test cycles per year. • Adverse impacts between fast flux and thermal flux experiments. Use as a fast flux facility would adversely impact thermal flux experiments being performed at the same time. • Does not fully support regaining and sustaining U.S. technology leadership and enabling the competitiveness of U.S.-based industry entities in the advanced reactor markets
Modify High Flux Isotope Reactor (HFIR)	• Does not meet VTR performance criteria even with modifications – Primarily a thermal flux test reactor – Achievable fast flux is factor of 2 to 4 less than required VTR flux – Available test volume of 4.6 liters is less than the 7 liter VTR requirement – Limited ability to support experimental high-temperature testing • Negative impact on thermal flux testing availability/competition for resource. Alternatives for current missions are not readily available among existing facilities. Facility is heavily used for thermal flux testing with this capability required for – Main mission of isotope production and neutron science – Plutonium-238 production for radioisotope thermoelectric generators (National Aeronautics and Space Administration support) • Adverse impacts exist between fast flux and thermal flux experiments. Use as a fast flux facility could adversely impact thermal flux experiments being performed at the same time. • Does not fully support regaining and sustaining U.S. technology leadership and enabling the competitiveness of U.S.-based industry entities in advanced reactor markets

Alternative	Rationale for Dismissal
Modify and Restart the Fast Flux Test Facility (FFTF)	• Significant technical challenges to the restart of the FFTF exist: – FFTF is a deactivated facility. Studies are needed to determine the condition of the facility and the ability to refurbish it. Issues include system/component age-related material degradation; repair/replacement/certification of systems modified for deactivation; upgrades to meet current codes and standards. – Uncertainties of the cost and schedule to restart. Estimates have been generated, but additional study would be required to develop updated cost and schedule estimates for modifications needed to support VTR operations. – FFTF safety basis would require updating, potentially requiring modifications to the facility to meet current requirements. For example, the seismic design of the facility is not based on the current peak ground level acceleration for the Hanford area. Seismic reanalysis would be required and upgrades are likely. • FFTF was not designed for the 60-year mission of VTR. Only 10 years remain of the facility's original 20-year operational lifetime. • Post-irradiation examination facilities are either deactivated or construction was halted. (MASF has been repurposed to support cleanup operations and FMEF is a largely vacant structure.) • Legal considerations (agreements to deactivate FFTF) impose schedule risks on attempts to reactivate the reactor. • Reversing earlier decisions and agreements would require renegotiating deactivation milestones in the Tri-Party Agreement (with Washington State and the U.S. Environmental Protection Agency). • Minimally supports regaining and sustaining U.S. technology leadership and enabling the competitiveness of U.S.-based industry entities in advanced reactor markets
Molten-Salt-Cooled/Fueled Fast Test Reactor	• First-of-a-kind design for a fast flux test reactor; technology maturity is an issue – Could require construction of a technology demonstration facility – Lack of experience regulating this type of reactor – New codes, standards, and practices may need to be developed. • Potential programmatic risks to – Cost (large capital investment, including a demonstration prototype) – Schedule (Aggressive schedule is longer than other technologies. A more likely schedule is even longer) – Performance (little stakeholder support for using the VTR itself as a technology innovation experiment). • Reactor system and operational complexity. With molten fuel, additional systems would be required to handle heat removal and fuel; uncertainties in fuel cycle management (processing).
Lead-Cooled Fast Test Reactor	• First-of-a-kind design for a fast flux test reactor, limited U.S. experience in operating reactor of any design, limited technology maturity – Could require construction of a technology demonstration facility – Lack of experience regulating this type of reactor – new codes, standards, and practices may need to be developed. • Potential programmatic risks to – Cost (large capital investment, including a demonstration prototype) – Schedule (aggressive schedule is longer than other technologies, a more likely schedule is even longer) – Performance (little stakeholder support for using the VTR itself as a technology innovation experiment) • Preferred fuel (nitride) would require additional development/demonstration

ATR = Advanced Test Reactor; FFTF = Fast Flux Test Facility; FMEF = Fuels and Materials Examination Facility; MASF = Maintenance and Storage Facility; VTR = Versatile Test Reactor.

2.7.2 Site Selection

DOE used a variety of factors in narrowing down the potential VTR reactor and support sites for assessment in this EIS. Chief among the factors is the realistic and pragmatic assessment of whether the site had an adequate location and the technical infrastructure necessary to support the key VTR activities. Most importantly, the site needed to have established technical infrastructure to support construction and operation of a test reactor; to operate hot cells for post-irradiation examination of test items; to use hot cells for the disassembly of spent fuel and processing it to a form suitable for long-term disposal; and to manufacture VTR driver fuel, including feedstock preparation and fuel fabrication.

DOE recognized that choosing a site that has the human resources with the requisite experience to build and operate a test reactor like the VTR is essential to the success of the VTR mission. Only two DOE sites currently have a large enough technical staff (including scientists, engineers and operational and support staff), who have operated test reactors and conducted missions similar to VTR. Those sites are the INL Site with ATR and Transient Reactor Test Facility (TREAT) and ORNL with HFIR. Other DOE site staff have some past experience, but their current technical resources are limited. While it is expected that some technical resources might move to the chosen VTR site, it is not realistic to move to a site where personnel have limited or no experience specific to test reactors.

An equally important site selection consideration is that VTR support activities include operation of hot cells for two critical purposes: post-irradiation examination and spent fuel treatment. These critical VTR support activities require a substantial technical staff with direct experience in use of hot cells. While at one time DOE had hot cell facilities at multiple sites, most of those hot cells have been shut down. As such, most of the scientists, engineers, and technical staff (especially operators) have moved or retired. Hot cell operation is a highly specialized field and it requires years to train new staff and gain the experience necessary to conduct the operations. Most of the remaining experience is at the INL Site and ORNL, both of which have multiple operating hot cells and, to a lesser extent, at the Pacific Northwest National Laboratory (PNNL) and Savannah River National Laboratory (SRNL). While building new hot cell facilities is straightforward if needed to support the VTR mission, the key factor for success of the mission is having the technical staff to lead and conduct the research at the post-irradiation examination hot cells and to operate the spent fuel treatment hot cell activities.

VTR fuel manufacturing, including feedstock preparation and fuel fabrication, requires several key factors. Because of the quantities of plutonium handled each year, a site must be able to support DOE's security requirements. DOE has only a few remaining facilities that can securely handle the quantities of plutonium and fabricate fuels necessary to support the VTR's fuel needs. These facilities are principally at SRS and at the INL Site.

As with hot cell operation, fuel manufacturing success depends on having the technical staff to support feedstock preparation and fuel fabrication. These activities are highly specialized, and most of the past DOE activities of this nature have been closed. As such, the DOE personnel with expertise in these areas have moved or retired. The principal remaining facilities with expertise in plutonium fuels and processing are SRS, LANL, Lawrence Livermore National Laboratory (LLNL), PNNL, and INL. However, LANL, LLNL, and PNNL staff and facilities are fully dedicated to missions that preclude these sites from detailed analysis. The only practical, readily available locations for VTR fuel manufacturing are SRS and the INL Site.

The AoA performed a preliminary assessment of candidate sites for the location of VTR technology. Four DOE sites were considered. Three sites have operational test reactors: ATR and TREAT at INL, HFIR at ORNL, and the deactivated FFTF at Hanford. AoA selected the fourth site, SRS to represent a generic DOE site without a test reactor. Additionally, a generic non-government site was evaluated. Sites were assessed only to the degree to which they have the capability to meet the preliminary assessment criteria.

Unlike the assessment of VTR alternatives, no quantitative ranking of the sites against these criteria was performed.

No specific non-government sites were identified for the location of the VTR in the AoA (DOE 2019d); the AoA assessed a generic non-government site. Finding a non-government site with (1) available infrastructure (power, water, post-irradiation examination facilities, etc.); (2) staff experienced in preparation of test assemblies, test reactor operation, and post-irradiation examination; (3) spent fuel storage; and (4) security required for the VTR facilities would be unlikely. Additionally, any non-government site would fall under the regulatory authority of the NRC. While the NRC has extensive experience in licensing research and test reactors, NRC licensing of the VTR and its associated facilities would add activities (including NRC license application, NRC license review, licensing hearings, preparation of an NRC EIS, and review by the Advisory Committee on Reactor Safeguards) to the project timeline (NRC 1996). Many of these activities would have to be completed before beginning construction and do not have a fixed duration, adding programmatic risk to the project schedule. Stakeholder acceptance, ultimately, would have to be assessed if a non-government site were to be selected. Given the existence of DOE sites that have demonstrated capabilities to support the VTR and given the potential schedule impact of the added licensing activities, locating the VTR at a non-government site was not considered a viable alternative.

The AoA concluded that the INL Site "appears to be the best equipped to handle the new VTR mission." However, several of the assessment criteria did not provide any differentiation between the three remaining DOE sites considered: Hanford/PNNL, ORNL, and SRS. For example, all three sites were identified as having at least some hot cells (with air and, in the case of Hanford/PNNL and SRS, inert[20] atmospheres) and the associated infrastructure that could support post-irradiation examination of test specimens. The availability of facilities, staff, and infrastructure capable of supporting both existing missions and the VTR project is the major discriminator among the sites.

Hanford/Pacific Northwest National Laboratory

Although much of the site is in the process of environmental cleanup and closure, Hanford/PNNL has a full range of supporting infrastructure for potential VTR-related transportation, construction and operation, safety, security, nuclear material management, and regulatory compliance. Hanford, itself, has no operational post-irradiation examination facilities. Yet the deactivated Fuels and Materials Examination Facility and the Maintenance and Storage Facility could be reactivated, refurbished, and equipped to support pre- and post-irradiation examination of test fuels. Substantial support capabilities exist at PNNL, including hot cells (the Shielded Analytical Laboratory) for post-irradiation examination and laboratories for chemistry, materials, and instrumentation at the Radiochemical Processing Laboratory.

Additionally, the last of Hanford's test reactors, FFTF, has not operated since 1992 and is currently in a long-term surveillance and maintenance condition. This means that the organizational infrastructure needed to support operation of a test reactor no longer exists at Hanford. After nearly 30 years, experienced test reactor operational staff would not be available. Compared to ORNL, Hanford's PNNL has more limited capability to support experiment fabrication and fuel and experiment disassembly and inspection. ORNL currently performs these activities in association with the operation of HFIR.

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[20] ORNL does not have operating hot cells with an inert atmosphere. However, the AoA identified dormant hot cells that could be refurbished for about $5 million.

Stakeholder support for a new operational mission at Hanford would be mixed. There would likely be pockets of community support for the restart of FFTF or another nuclear mission. However, there would be extensive State or regional opposition to anything that could potentially impact the environmental closure mission. At public meetings held during the Nuclear Infrastructure EIS[21] process, attendees declared opposition to any activity (for example, the restart of FFTF as considered in that EIS) that would change the Hanford mission from "clean up" back to "production." Stakeholders also called for DOE to continue to honor its commitment to clean up the site. Additionally, they raised concerns about the impact of new operations on the existing waste cleanup at Hanford. The prospect of even temporary storage of additional spent nuclear fuel at Hanford potentially faces public opposition, which could pose programmatic risks and schedule delays for the VTR project.

Savannah River Site/Savannah River National Laboratory

SRS and SRNL have extensive history in nuclear reactor operation and offer a full range of supporting infrastructure for potential VTR-related transportation, construction and operation, safety, security, nuclear material management, and regulatory compliance. There are also substantial support capabilities currently available at SRNL, including hot cells and laboratories for chemistry, materials, and instrumentation. SRNL has bench-scale hot cell capability. These hot cells, however, are currently used to support DOE's Office of Environmental Management missions at SRS.

SRS has no test reactor experience and the last of the onsite operating reactors shut down in 1992. This means that the organizational infrastructure needed to support operation of a test reactor does not exist at SRS. Compared to ORNL, SRS also has more limited capability (primarily located at SRNL) to support experiment fabrication and fuel and experiment disassembly and inspection. ORNL currently performs these activities in association with the operation of HFIR.

2.8 Preferred Alternative

DOE's Preferred Alternative is the INL VTR Alternative. DOE would build and operate the VTR at the INL Site adjacent to the existing MFC. Existing facilities within MFC would be used for post-irradiation examination of test assemblies. Post-irradiation examination would be performed in HFEF, IMCL, and other MFC facilities. Spent nuclear fuel (spent VTR driver fuel) would be treated to remove the sodium-bonded material at FCF. Modifications to FCF may be required to carry out this process. The intent of this treatment is to condition and transform the spent nuclear fuel into a form that would meet the acceptance criteria for a future permanent repository. This treated fuel would be temporarily stored at a new VTR spent fuel pad at MFC.

DOE has no preferred options at this time for where it would perform driver fuel production (i.e., feedstock preparation and driver fuel fabrication) for the VTR. This EIS evaluates options for both processes at the INL Site and at SRS. DOE could choose to use either site or a combination of both sites to implement either option. DOE will state its preferred options for feedstock preparation and driver fuel fabrication in the Final VTR EIS, if preferred options are identified before issuance.

[21] *Programmatic Environmental Impact Statement for Accomplishing Expanded Civilian Nuclear Energy Research and Development and Isotope Production Missions in the United States, Including the Role of the Fast Flux Test Facility*, DOE/EIS-0310, December 2000.

2.9 Summary of Environmental Consequences

This section summarizes the environmental impacts of the VTR alternatives and reactor fuel production options evaluated in this EIS. Section 2.9.1 presents the impacts for each alternative and option at each site. Section 2.9.2 discusses the cumulative impacts of the alternatives in the context of past, present, and reasonably foreseeable future actions at each site.

2.9.1 Comparison of Alternatives and Options

Under the No Action Alternative, DOE would make use of the limited capabilities available at existing facilities, both domestic and foreign, for testing in the fast-neutron-flux spectrum. DOE would not construct or modify any facilities or effect any substantial change in the level of operations for post-irradiation examination. There would be no need for new reactor fuel production nor would any VTR spent driver fuel be generated. Whereas the impacts presented in **Tables 2–3, 2–4,** and **2–5** represent potential incremental increases, under the No Action Alternative there would be no increase in environmental impacts at the INL Site, ORNL, and SRS above the existing conditions described in Chapter 3, Affected Environment.

Table 2–3 summarizes and allows side-by-side comparison of the potential environmental impacts of the INL VTR Alternative and the ORNL VTR Alternative. Impacts are analyzed for constructing the VTR, modifying existing facilities for post-irradiation examination and spent driver fuel treatment, and operating these facilities at the INL Site. Impacts for constructing and operating the VTR and a hot cell facility at ORNL are also given. The impacts, as presented, include the operation of the VTR, post-irradiation examination activities, and spent fuel management.

Table 2–4 summarizes and allows comparison of the impacts from establishing the capabilities for and performing feedstock preparation and fuel fabrication at the INL Site or SRS.

Table 2–5 summarizes the potential environmental consequences that could occur if DOE were to decide to implement all actions at the INL Site. This table presents the potential consequences if DOE selected the INL Site to: (1) construct and operate the VTR, which includes post-irradiation examination activities and spent fuel management; (2) modify and operate facilities to prepare feedstock for use in VTR fuel; and (3) modify and operate facilities for fabrication of VTR fuel.

Table 2–3. Summary of Versatile Test Reactor Alternative Environmental Consequences

<table>
<tr><th rowspan="2">Resource Area</th><th colspan="2">Alternatives</th></tr>
<tr><th>INL VTR</th><th>ORNL VTR</th></tr>
<tr><td colspan="3">Land Use and Aesthetics (Chapter 4, Section 4.1)</td></tr>
<tr><td rowspan="2">Land Use</td><td>Construction:
There would be minor impacts on land use from the disturbance of approximately 100 acres during construction activities.</td><td>Construction:
There would be minor impacts on land use from the disturbance of approximately 150 acres during construction activities.</td></tr>
<tr><td colspan="2">Operations:
Land use would be consistent with existing land use and activities currently occurring at each location. Approximately 25 acres of previously unused area would be converted permanently for industrial use at the INL Site. Approximately 50 acres of vegetated area at ORNL would be cleared and converted permanently for industrial use.</td></tr>
<tr><td rowspan="2">Aesthetics</td><td colspan="2">Construction:
There would be minimal impacts on aesthetics as newly constructed facilities would not dominate the local landscape and would be similar in design to existing facilities. Though not visible from offsite areas, approximately 150 acres of vegetated/forested area at ORNL would be cleared during construction.</td></tr>
<tr><td colspan="2">Operations:
There would be minimal impacts on aesthetics from operation of the newly constructed facilities that would be similar in design to existing facilities, but only from areas within line of sight of the new facilities. Impacts on International Dark Sky Park, Craters of the Moon National Monument would not be expected from additional exterior lighting required for the VTR at the INL Site.</td></tr>
<tr><td colspan="3">Geology and Soils (Chapter 4, Section 4.2)</td></tr>
<tr><td rowspan="2"></td><td>Construction:
Area disturbed would be 100 acres. Volume of excavated materials would be 135,000 cubic yards; backfill/soil needed would be 202,000 cubic yards; deficit fill volume of 67,000 cubic yards would be obtained from onsite borrow sources such as Rye Grass Flats. Rock/gravel needed would be 45,000 cubic yards. The total quantities of geologic and soil materials needed during construction would represent small percentages of regionally plentiful resources and are unlikely to adversely impact geology and soil resources.</td><td>Construction:
Area disturbed would be 150 acres. Volume of excavated material would be 886,000 cubic yards; backfill/soil needed would be 989,000 cubic yards; deficit fill volume of 103,000 cubic yards would be obtained from onsite borrow sources such as the Copper Ridge borrow area. Rock/gravel needed would be 74,000 cubic yards. The total quantities of geologic and soil materials needed during construction would represent small percentages of regionally plentiful resources and are unlikely to adversely impact geology and soil resources.</td></tr>
<tr><td>Operations:
Area occupied would be 25 acres. No additional land disturbance, no additional excavation, and little or no use of geologic and soil materials.</td><td>Operations:
Area occupied would be 50 acres. No additional land disturbance, no additional excavation, and little or no use of geologic and soil materials.</td></tr>
<tr><td colspan="3">Water Resources (Chapter 4, Section 4.3)</td></tr>
<tr><td></td><td>Construction:
All water required during the construction process would be drawn from existing wells that access the Snake River Plain Aquifer. Potable water would be treated through the existing Materials and Fuels Complex (MFC) system. The total water demand is estimated to be about 128 million gallons, including about 34 million gallons of potable water and about 94 million gallons for other construction activities. Water would be discharged to surface water (which could include MFC sewage lagoons or other surface discharges such as swales).</td><td>Construction:
All water required during the construction process would be drawn from the Clinch River. Potable water would be treated at a water treatment plant that is owned and operated by the City of Oak Ridge and located northeast of the Y-12 National Security Complex. The total water demand is estimated to be about 170 million gallons during the entire construction period, including about 46 million gallons of potable water and about 121 million gallons for construction activities. Water would be discharged to adjacent surface waters.</td></tr>
</table>

<table>
<tr><th rowspan="2">Resource Area</th><th colspan="2">Alternatives</th></tr>
<tr><th>INL VTR</th><th>ORNL VTR</th></tr>
<tr><td></td><td>Operations:
Water would be drawn from the Snake River Plain Aquifer and discharged as surface water to either the Industrial Waste Pond or active sewage lagoons. The total annual volume of water that would be discharged is estimated to be about 4.4 million gallons, which includes the volume required for personnel use and sanitation, firewater, and demineralized water. No water would be required for operation of the reactor itself.</td><td>Operations:
Water used during operations would be drawn from the Clinch River and discharged to Bearden Creek or Melton Branch. The total annual volume of water that would be discharged is estimated to be about 4.4 million gallons, which includes the volume required for personnel use and sanitation, firewater, and demineralized water. No water would be required for operation of the reactor itself.</td></tr>
<tr><td colspan="3">Air Quality (Chapter 4, Section 4.4)</td></tr>
<tr><td rowspan="2"></td><td>Construction:
Counties that encompass the INL Site currently are in attainment for all national ambient air quality standards (NAAQS) (i.e., for criteria pollutants). Annual nonradiological emissions estimated for construction of the VTR facilities would be well below the EPA prevention of significant deterioration (PSD) permitting threshold of 250 tons per year for a criteria pollutant. Construction at the INL Site would generate more fugitive dust compared to the effort at ORNL, as the INL Site has a more arid climate. Hazardous air pollutant (HAP) emissions from construction activities would not result in adverse air quality impacts on the public. Construction activities would not generate radiological air emissions.</td><td>Construction:
Counties that encompass ORNL currently are in attainment for all NAAQS. Annual nonradiological emissions estimated for construction of the VTR facilities would be well below the EPA PSD permitting threshold of 250 tons per year for a criteria pollutant. Construction at ORNL would result in higher emissions of most pollutants (compared to the INL Site), due to the larger area and more effort needed to clear and grade the project site. HAPs emissions from construction activities would not result in adverse air quality impacts on the public. Construction activities would not generate radiological air emissions.</td></tr>
<tr><td colspan="2">Operations:
Annual nonradiological emissions from operation of the VTR facilities would be similar and well below the annual indicator thresholds.
Impacts from radiological air emissions are addressed under Human Health – Normal Operations.</td></tr>
<tr><td colspan="3">Ecological Resources (Chapter 4, Section 4.5)</td></tr>
<tr><td></td><td>Construction:
Area disturbed: about 100 acres. Construction would result in a loss of sagebrush habitat. Losses to sagebrush habitat would be compensated for in accordance to the DOE's "no net loss of sagebrush habitat" policy on the INL Site under the Candidate Conservation Agreement (CCA) for the sage-grouse. Nesting bird surveys would occur prior to any ground disturbance or vegetation removal to confirm the absence of Migratory Bird Treaty Act-protected species, as well as sage-grouse, in the proposed project area. A 300-foot buffer would be established around active pygmy rabbit burrow systems to prevent direct impacts. Operational and administrative controls would be evaluated and implemented, if warranted, to reduce the potential for adverse effects on wildlife species and human-wildlife interactions.</td><td>Construction:
Area disturbed: about 150 acres. Construction would result in a loss of forested habitat, including up to thirty-seven hemlock trees, with potential for impacts on federally and state-listed species and aquatic resources. If the ORNL VTR alternative were selected, additional species-specific surveys would occur. Aquatic features (e.g., channels, tributaries, drainages, catchments, seeps, springs or wetlands) would be impacted. Potential impacts to aquatic resources would require wetland delineations, stream evaluations, and hydrologic determinations of currently unclassified channels and wet weather conveyances. Any potential Exceptional Tennessee Waterways would require additional assessment using the Tennessee Rapid Assessment Method.
In compliance with Section 404 of the Clean Water Act, a permit from U.S. Army Corps of Engineers would be obtained prior to any construction work within jurisdictional features and compensatory mitigation would be required for unavoidable impacts.</td></tr>
</table>

<table>
<tr><th rowspan="2">Resource Area</th><th colspan="2">Alternatives</th></tr>
<tr><th>INL VTR</th><th>ORNL VTR</th></tr>
<tr><td></td><td>Operations:
Area occupied by new structures would be about 25 acres. Operations would take place in new and existing facilities. No additional land disturbance would occur, and therefore no additional impacts would occur on ecological resources.</td><td>Operations:
Area occupied by new structures would be about 50 acres. Operations would take place in new and existing facilities. No additional land disturbance would occur, and therefore no additional impacts would occur on ecological resources.</td></tr>
<tr><td colspan="3">Cultural and Paleontological Resources (Chapter 4, Section 4.6)</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Construction:
No impacts on significant cultural and paleontological resources would occur from facility construction and land disturbance.</td></tr>
<tr><td colspan="2">Operations:
No impacts on cultural and paleontological resources would occur from facility operations.</td></tr>
<tr><td colspan="3">Infrastructure (Chapter 4, Section 4.7)</td></tr>
<tr><td rowspan="3"></td><td>Construction:
Construction electricity usage would average 1,000 megawatt-hours per year with a peak annual use of 2,000 megawatt-hours. Diesel fuel usage would total 2.3 million gallons. Total water usage would be 128 million gallons.</td><td>Construction:
Construction electricity usage would average 1,300 megawatt-hours per year with a peak annual use of 2,600 megawatt-hours. Diesel fuel usage would total 3.3 million gallons. Total water usage would be 170 million gallons.</td></tr>
<tr><td>Operations:
Operations at VTR would use 150,000 megawatt-hours per year of electricity, 4.7 million cubic feet of propane per year, and 4.4 million gallons of water per year.</td><td>Operations:
Operations at VTR would use 180,000 megawatt-hours per year of electricity, 4.7 million cubic feet of propane per year, and 4.4 million gallons of water per year.</td></tr>
<tr><td colspan="2">Discussion:
For construction, more resources would be used at ORNL because a new hot cell facility would be constructed in addition to the VTR. For operations, estimates for electrical usage differ because INL would primarily utilize two existing facilities for post-irradiation examination and spent fuel treatment and ORNL would use a new facility for most of these activities.</td></tr>
<tr><td colspan="3">Noise and Vibration (Chapter 4, Section 4.8)</td></tr>
<tr><td rowspan="2">Noise</td><td>Construction:
Due to the distance, estimated noise levels at the INL Site boundary (2.9 miles) and closest receptor (5.0 miles) would not be perceptible and would be consistent with ambient levels.</td><td>Construction:
Estimated noise levels at the closest receptor (6,750 feet) would be approximately 47 dBA, which given the distance, would be minimal and remain below the noise standards at the closest receptor.</td></tr>
<tr><td>Operations:
Due to the distance, noise levels at the INL Site boundary (2.9 miles) and closest receptor (5.0 miles) would not be perceptible and would be consistent with ambient levels.</td><td>Operations:
Noise levels would be similar to other existing equipment at ORNL and would not impact offsite receptors.</td></tr>
<tr><td rowspan="2">Vibration</td><td colspan="2">Construction:
Ground-borne vibration due to typical construction activities are expected to be below the threshold of human perception at offsite locations.</td></tr>
<tr><td colspan="2">Operations:
Ground-borne vibration due to typical operational activities are expected to be below the threshold of human perception at offsite locations.</td></tr>
</table>

Resource Area	Alternatives	
	INL VTR	***ORNL VTR***
Waste Management and Spent Nuclear Fuel Management (Chapter 4, Section 4.9)		
Waste Management	*Construction:* About 9,900 cubic meters of construction waste would be generated during construction activities.	*Construction:* About 13,000 cubic meters of construction waste would be generated during construction activities.
	Operations (annual impacts): During operations, 540 cubic meters of LLW, 38 cubic meters of MLLW, 0.89 cubic meters of TRU waste, and 7.2 cubic meters of hazardous and TSCA wastes would be generated. The characteristics of these wastes would be similar to wastes currently generated by existing activities. All wastes would be packaged for shipment off site. Treatment and disposal of these wastes are well within the current capacities of existing offsite facilities.	
Spent Nuclear Fuel	*Construction:* No spent fuel is generated during construction.	
	Operations: The heavy metal from 45 spent driver fuel assemblies produced annually (66 for the final core at the end of the VTR's operational life) would be treated and packaged as spent nuclear fuel and placed on the VTR spent fuel pad pending offsite shipment. The total number of spent fuel assemblies over the lifetime of the project represent about 110 metric tons of heavy metal.	
Human Health – Normal Operations (Chapter 4, Section 4.10)		
	Construction: Offsite population No impacts on the public; there would be no radiological releases during construction. Worker population – workers would receive exposures from installing equipment in existing facilities. Dose: 10 person-rem LCFs: 0 (calculated: 6×10^{-3}) Industrial accidents: 79 injuries with no fatalities expected.	*Construction*: Offsite population Same as INL Alternative Worker population No radiological impacts; all work would be performed in area of the site with no known radioactive contamination. Industrial accidents: 120 injuries with no fatalities expected.
	Operations (annual impacts): Offsite population Dose: 0.044 person-rem LCFs: 0 (calculated: 3×10^{-5}) Maximally exposed individual Dose: 0.0068 millirem LCF risk: 4×10^{-9} Worker population Dose: 53 person-rem LCFs: 0 (calculated: 3×10^{-2}) Industrial accidents: 9 injuries with no fatalities expected.	*Operations (annual impacts)*: Offsite population Dose: 0.58 person-rem LCFs: 0 (calculated: 3×10^{-4}) Maximally exposed individual Dose: 0.031 millirem LCF risk: 2×10^{-8} Worker population Dose: 44 person-rem LCFs: 0 (calculated: 3×10^{-2}) Industrial accidents: 9 injuries with no expected fatalities

<table>
<tr><th rowspan="2">Resource Area</th><th colspan="2">Alternatives</th></tr>
<tr><th>INL VTR</th><th>ORNL VTR</th></tr>
<tr><td></td><td colspan="2">Discussion:
For construction, a larger number of injuries is expected at ORNL due to the construction of a new hot cell facility in addition to the VTR. For operations, a lower worker population dose is expected at ORNL than INL because at INL additional MFC staff could be tasked to support VTR personnel. That same additional support was not assumed for ORNL as the post-irradiation examination and spent fuel treatment staff at ORNL would be new and dedicated to VTR operations only.</td></tr>
<tr><td colspan="3">Human Health – Facility Accidents (Chapter 4, Section 4.11)</td></tr>
<tr><td rowspan="3"></td><td colspan="2">Construction:
No impacts on the offsite public, maximally exposed individual, or noninvolved worker. No construction accidents are expected to release radiological or hazardous materials.</td></tr>
<tr><td>Operations (annual impacts):
Offsite population
Accident probability: less than one in 10,000 per year
Dose: 38 person-rem
LCFs: 0 (0.02)
Maximally exposed individual
Accident probability: less than one in 10,000 per year
Dose: 0.25 rem
LCF risk: 0.0001
Noninvolved worker
Accident probability: less than one in 10,000 per year
Dose: 160 rem
LCF risk: 0.2</td><td>Operations (annual impacts):
Offsite population
Accident probability: less than one in 10,000 per year
Dose: 1,400 person-rem
LCFs: 1
Maximally exposed individual
Accident probability: less than one in 10,000 per year
Dose: 14 rem
LCF risk: 0.009
Noninvolved worker
Accident probability: less than one in 10,000 per year
Dose: 400 rem
LCF risk: 0.5</td></tr>
<tr><td colspan="2">Discussion:
The risks to the maximally exposed individual and the general population from accidents at the INL Site and ORNL are very small, taking into account the very, very low probabilities (less than one in 10,000 per year) and consequences of the accidents. A fire involving VTR spent driver fuel subassemblies in the VTR Experiment Hall is the bounding operational accident at the VTR. Offsite impacts on the maximally exposed individual and general population from an accident at ORNL would be greater than impacts at the INL Site because of the proximity of the proposed VTR site to areas of public access and because the population near ORNL is larger and closer to the VTR. A hypothetical, beyond-design-basis event with an estimated frequency much less than 1 in 10 million is evaluated and discussed in Chapter 4, Section 4.11 and Appendix D.</td></tr>
</table>

<table>
<tr><th rowspan="2">Resource Area</th><th colspan="2">Alternatives</th></tr>
<tr><th>INL VTR</th><th>ORNL VTR</th></tr>
<tr><td colspan="3">Human Health – Transportation Impacts (Chapter 4, Section 4.12)</td></tr>
<tr><td rowspan="2"></td><td>Construction:
Shipments: 18,460, with 1 potential traffic accident fatality based on accident statistics.</td><td>Construction:
Shipments: 23,790, with 1 potential traffic accident fatality, based on accident statistics.</td></tr>
<tr><td>Operations (annual impacts):
Radioactive waste shipments: 130
Population:
Maximum dose: 8 person-rem with no LCFs. Individual doses from transportation would be well below DOE and regulatory limits.
Worker population:
Maximum dose: 7 person-rem with no LCFs. Individual worker doses from transportation would be limited to meet DOE administrative worker dose limits.
Accidents:
LCFs: None
Nonradiological traffic fatalities: 1 potential traffic fatality over the 60-year life of the project</td><td>Operations (annual impacts):
Radioactive waste shipments: 130
Population:
Maximum dose: 12 person-rem with no LCFs. Individual doses from transportation would be well below DOE and regulatory limits.
Worker population:
Maximum dose: 10 person-rem with no LCFs. Individual worker doses from transportation would be limited to meet DOE administrative worker dose limits.
Accidents:
LCFs: None
Nonradiological traffic fatalities: 1 potential traffic fatality over the 60-year life of the of project</td></tr>
<tr><td></td><td colspan="2">Discussion:
Radioactive wastes include contact-handled and remote-handled LLW, MLLW, TRU waste, and mixed TRU waste.
For incident-free operations, the affected population includes individuals living within 0.5 miles of each side of the road. For accident conditions, the affected population includes individuals living within 50 miles of the accident.</td></tr>
<tr><td colspan="3">Traffic (Chapter 4, Section 4.13)</td></tr>
<tr><td rowspan="2"></td><td colspan="2">Construction:
The average increases in daily traffic during construction are not expected to exceed existing level of service of offsite roads and no upgrades or improvements to onsite roads are anticipated.</td></tr>
<tr><td colspan="2">Operations:
Operations at each facility are expected to result in an increase in traffic from new employees. The changes would represent a minor increase in traffic at each facility (about 5 percent). Operations traffic is not expected to cause a change in the existing level of service of offsite roads and no upgrades or improvements to onsite roads are anticipated.</td></tr>
</table>

Resource Area	***Alternatives***	
	INL VTR	***ORNL VTR***
Socioeconomics (Chapter 4, Section 4.14)		
	Construction: The increase in jobs and income from construction would have a short-term beneficial impact on the local and regional economy. The population influx associated with an in-migrating workforce and their families is considered relatively small and would have no major adverse impacts on the region in terms of population, employment, income levels, housing, or community services.	
	Operations: The increase of 218 jobs would have a beneficial impact on the local and regional economy. The population influx associated with an in-migrating workforce and their families is considered relatively small and would have no major adverse impacts on the region in terms of population, housing, or community services.	*Operations*: The increase of 300 jobs would have a beneficial impact on the local and regional economy. The population influx associated with an in-migrating workforce and their families is considered relatively small and would have no major adverse impacts on the region in terms of population, housing, or community services.
Environmental Justice (Chapter 4, Section 4.15)		
	Construction and Operations: No disproportionately high and adverse impacts on minority or low-income populations are expected. Increased health risks to minority or low-income individuals or populations exposed to radiation would be negligible.	

dBA = decibels, A-weighted; EPA = U.S. Environmental Protection Agency; INL = Idaho National Laboratory; LCF = latent cancer fatality; LLW = low-level radioactive waste; MLLW = mixed low-level radioactive waste; ORNL = Oak Ridge National Laboratory; TRU = transuranic; TSCA = Toxic Substances Control Act; VTR = Versatile Test Reactor.

Note: Sums and products presented in the table may differ from those calculated from individual entries due to rounding.

Table 2–4. Summary of Environmental Consequences for Reactor Fuel Production Options

Resource Area	***Options***			
	INL Feedstock Preparation	***INL Fuel Fabrication***	***SRS Feedstock Preparation***	***SRS Fuel Fabrication*** [a]
Land Use and Aesthetics (Chapter 4, Section 4.1)				
Land Use	*Construction and Operations*: No impacts on land use as modifications/construction and operations would occur in existing facilities and not require construction of new facilities or additional land use.		*Construction and Operations*: No impacts on land use as modifications/construction and operations would occur in existing facilities or adjacent to those facilities. Up to 3 acres of previously disturbed land would be used. No impacts on land use as activities would occur in existing facilities and not require additional land use.	
Aesthetics	*Construction and Operations*: No impacts on aesthetics as modifications/construction would occur in existing facilities. No impact on aesthetics as operations would occur in existing facilities.		*Construction and Operations*: Construction would occur in or adjacent to existing facilities and be compatible with the current industrial setting.	
Geology and Soils (Chapter 4, Section 4.2)				
	Construction and Operations: No additional land disturbance, no additional excavation, and little or no use of geologic and soil materials because modifications/construction and operations would occur in existing buildings.		*Construction and Operations*: Most modifications/construction and operations would occur in existing buildings. Up to 3 acres of land disturbance, a small amount of excavation, and small quantities of geologic and soil materials maybe associated with constructing ancillary facilities.	
Water Resources (Chapter 4, Section 4.3)				
	Construction: An estimated 230,000 gallons of potable water would be required by construction personnel and 5,000 gallons of water would be needed for cleaning. The water would be drawn from groundwater and discharged as surface water (which could include the Materials and Fuels Complex sewage lagoons or other surface discharges such as swales).		*Construction*: An estimated 3 million gallons of potable water would be needed. An additional volume of non-potable water required during construction is expected to total about 6 million gallons.	
	Operations: The addition of 300 new full-time employees would require about 1.4 million gallons of water per year. An additional 50,000 gallons would be needed for process operations. Water would be drawn from groundwater. Sanitary waste would be discharged as surface water. Process waters would be transported off site for treatment and disposal.	*Operations*: The addition of 70 new full-time employees would increase potable water use by about 880,000 gallons per year. In addition, about 1,000 gallons per year would be needed for mopping and cleaning. This water would be drawn from groundwater and discharged as surface water.	*Operations*: The addition of 300 new full-time employees would increase water use by about 1.4 million gallons of water per year. An additional 50,000 gallons would be needed for process operations. Water would be drawn from groundwater and discharged as surface water.	*Operations*: The addition of 300 new full-time employees would increase water use by about 1.4 million gallons of water per year. This water would be drawn from groundwater and discharged as surface water.

<table>
<tr><th rowspan="2">Resource Area</th><th colspan="4">Options</th></tr>
<tr><th>INL Feedstock Preparation</th><th>INL Fuel Fabrication</th><th>SRS Feedstock Preparation</th><th>SRS Fuel Fabrication [a]</th></tr>
<tr><td></td><td colspan="4">Discussion:
The higher estimate of water use for construction of the feedstock preparation capability at SRS is because a greater level of effort is expected to make the facility modifications. More interior modifications (removing and constructing walls) are expected at SRS than at INL. Under the Fuel Fabrication Options, all new staff would be required at SRS, whereas at INL, a portion of the staff is existing and would be augmented with new hires.</td></tr>
<tr><td colspan="5">Air Quality (Chapter 4, Section 4.4)</td></tr>
<tr><td></td><td colspan="4">Construction and Operation:
he counties that encompass the INL Site and SRS currently are in attainment for all NAAQS. Annual nonradiological emissions from construction and operation would be well below the EPA prevention of significant deterioration (PSD) permitting threshold of 250 tons per year for a criteria pollutant. Construction and operation of the options SRS would result in slightly higher emissions compared to activities at the INL Site. Construction activities would not generate radiological air emissions at the INL Site and would generate radiological emissions at SRS. Operations would generate small quantities of radiological air emissions. See Human Health – Normal Operations below for the estimated impacts from these emissions.</td></tr>
<tr><td colspan="5">Ecological Resources (Chapter 4, Section 4.5)</td></tr>
<tr><td></td><td colspan="4">Construction and Operations:
There would be no impacts on ecological resources as modifications/construction would occur in existing facilities or adjacent to those facilities on previously disturbed land. Operations would occur in existing or new facilities.</td></tr>
<tr><td colspan="5">Cultural and Paleontological Resources (Chapter 4, Section 4.6)</td></tr>
<tr><td></td><td colspan="2">Construction and Operations:
No impacts on significant cultural resources as changes to the internal configuration of active laboratories or other experimental or testing properties to accommodate new experiments or tests are exempt activities per the INL Cultural Resources Management Plan (INL 2016f). With proposed operations conducted within existing facilities, there would be no impacts to paleontological resources.</td><td colspan="2">Construction and Operations:
No impacts on cultural or paleontological resources as modifications or construction would occur in K Area Complex facilities or adjacent to those facilities on previously disturbed land.</td></tr>
<tr><td colspan="5">Infrastructure (Chapter 4, Section 4.7)</td></tr>
<tr><td rowspan="2"></td><td colspan="4">Construction:
Use of existing infrastructure would be at levels well below existing capacities.</td></tr>
<tr><td>Operations:
Use of existing infrastructure within the Fuel Conditioning Facility would be well below existing capacities. Electric demand would be 6,700 megawatt-hours per year and water usage would be 1.5 million gallons per year.</td><td>Operations:
Use of existing infrastructure within FCF, the Fuel Manufacturing Facility and Zero Power Physics Reactor would be well below existing capacities. Electric demand would be 8,300 to 13,300 megawatt-hours per year and water usage would be 0.88 million gallons per year.</td><td>Operations:
Use of existing infrastructure within the K-Reactor Building would be well below existing capacities. Electric demand would be 6,700 megawatt-hours per year and water usage would be 1.5 million gallons per year.</td><td>Operations:
Use of existing infrastructure within K-Reactor Building would be well below existing capacities. Electric demand would be 8,300 to 13,300 megawatt-hours per year and water usage would be 1.4 million gallons per year.</td></tr>
</table>

Resource Area	***Options***			
	INL Feedstock Preparation	***INL Fuel Fabrication***	***SRS Feedstock Preparation***	***SRS Fuel Fabrication*** [a]
Noise and Vibration (Chapter 4, Section 4.8)				
	Construction: Due to the distance, estimated noise and vibration levels at the INL Site boundary (2.9 miles) and closest receptor (5.0 miles) would not be perceptible and would be consistent with ambient levels.		*Construction*: Due to the large distance from the site and receptors, estimated noise and vibration levels at the SRS boundary (5.5 miles) would not be perceptible and would be consistent with ambient levels.	
	Operations: Operational noise and vibration would be contained within the building and not be perceptible at the boundary.			
Waste Management and Spent Nuclear Fuel Management (Chapter 4, Section 4.9)				
	Construction: Existing facilities would be modified and existing equipment reallocated, as necessary, to support both feedstock preparation and fuel fabrication activities. Equipment currently in this space would be relocated for use in other facilities. Small volumes of construction waste, LLW, MLLW, and hazardous and TSCA wastes would generated during the modifications of facilities and the relocation of existing equipment and the installation of the new equipment.			
	Operations (annual impacts): During operations, 170 to 340 cubic meters of LLW, 2 to 4 cubic meters of MLLW, and 1 to 2 cubic meters of hazardous and TSCA wastes would be generated. The characteristics of these wastes would be similar to wastes currently generated by existing activities. These wastes would be managed within the current waste management system and sent offsite for disposal. The proposed action would provide preparation and packaging capabilities for the 200 to 400 cubic meters of TRU waste that would be generated from fuel production; TRU waste would be shipped to the Waste Isolation Pilot Plant for disposal.			
Human Health – Normal Operations (Chapter 4, Section 4.10)				
	Construction: Offsite population No impacts on the public; no radiological releases expected during construction Worker population Work would occur in a clean area of an existing facility so there would be no worker dose. Due to the short duration and small number of workers, less than 1 industrial injury is calculated.	*Construction*: Offsite population No impacts on the public; no radiological releases expected during construction Worker population Dose: 21 person-rem LCFs: 0 (calculated: 1×10^{-2}) Due to the short duration and small number of workers, less than 1 industrial injury is calculated.	*Construction*: Offsite population Same as INL Feedstock Preparation Worker population Dose: 1.3 person-rem LCFs: 0 (calculated: 8×10^{-4}) Industrial accidents: 10 injuries with no fatalities expected.	*Construction*: Offsite population Same as INL Fuel Fabrication Worker population Dose: 0.8 person-rem LCFs: 0 (calculated: 5×10^{-4}) Industrial accidents: 10 injuries with no fatalities expected.
	Operations (annual impacts): Offsite population Dose: 0.012 person-rem LCFs: 0 (calculated: 7×10^{-6}) Maximally exposed individual Dose: 0.0012 millirem LCF risk: 7×10^{-10}	*Operations (annual impacts):* Offsite population Dose: 0.0053 person-rem LCFs: 0 (calculated: 3×10^{-6}) Maximally exposed individual Dose: 0.0016 millirem LCF risk: 1×10^{-9}	*Operations (annual impacts)*: Offsite population Dose: 0.042 person-rem LCFs: 0 (calculated: 2×10^{-5}) Maximally exposed individual Dose: 0.0015 millirem LCF risk: 9×10^{-10}	*Operations (annual impacts)*: Offsite population Dose: 0.020 person-rem LCFs: 0 (calculated: 1×10^{-5}) Maximally exposed individual Dose: 0.00071 millirem LCF risk: 4×10^{-10}

Resource Area	***Options***			
	INL Feedstock Preparation	***INL Fuel Fabrication***	***SRS Feedstock Preparation***	***SRS Fuel Fabrication*** [a]
	Worker population Dose: 51 person-rem LCFs: 0 (calculated: 3×10^{-2}) Industrial accidents: 9 injuries with no fatalities expected.	Worker population Dose: 51 person-rem LCFs: 0 (calculated: 3×10^{-2}) Industrial accidents: 9 injuries with no fatalities expected	Worker population Dose: 51 person-rem LCFs: 0 (calculated: 3×10^{-2}) Industrial accidents: 9 injuries with no fatalities expected.	Worker population Dose: 51 person-rem LCFs: 0 (calculated: 3×10^{-2}) Industrial accidents: 9 injuries with no fatalities expected.
Human Health – Facility Accidents (Chapter 4, Section 4.11)				
	Construction: No impacts on the offsite public, maximally exposed individual, or noninvolved worker. No construction accidents are expected to release radiological or hazardous materials. No impacts on the noninvolved worker. There are no radiological or hazardous material accident scenarios during construction.			
	Operations (annual impacts): Offsite population Probability less than 0.0001/year Dose: 0.034 person-rem LCF risk: 2×10^{-5} Maximally exposed individual Probability less than 0.0001/year Dose: 0.0002 rem LCF risk: 1×10^{-7} Noninvolved worker Probability less than 0.0001/year Dose: 0.00052 rem LCF risk: 3×10^{-7}	*Operations (annual impacts):* Offsite population Probability less than 0.0001/year Dose: 0.13 person-rem LCF risk: 8×10^{-5} Maximally exposed individual Probability less than 0.0001/year Dose: 0.0036 rem LCF risk: 2×10^{-6} Noninvolved worker Probability less than 0.0001/year Dose: 0.048 rem LCF risk: 3×10^{-5}	*Operations (annual impacts):* Offsite population Probability less than 0.0001/year Dose: 0.22 person-rem LCF risk: 1×10^{-4} Maximally exposed individual Probability less than 0.0001/year Dose: 7.9×10^{-5} rem LCF risk: 5×10^{-8} Noninvolved worker Probability less than 0.0001/year Dose: 0.015 rem LCF risk: 9×10^{-6}	*Operations (annual impacts):* Offsite population Probability less than 0.0001/year Dose: 0.81 person-rem LCF risk: 5×10^{-4} Maximally exposed individual Probability less than 0.0001/year Dose: 0.0016 rem LCF risk: 9×10^{-7} Noninvolved worker Probability less than 0.0001/year Dose: 0.18 rem LCF risk: 1×10^{-4}
	Discussion: The risks to the maximally exposed individual and the general population from accidents at the INL Site and SRS are very small, taking into account the very, very low probabilities (less than one in 10,000 per year) and consequences of the accidents. A criticality while melting plutonium metal and adding uranium and zirconium is the bounding operational accident during fuel fabrication; an aqueous/electrorefining accident is bounding during feedstock preparation. Offsite impacts on the public from an accident at SRS are up to six times greater than impacts at the INL Site because the population near SRS is larger and closer to the reactor fuel production facility.			

Resource Area	***Options***			
	INL Feedstock Preparation	***INL Fuel Fabrication***	***SRS Feedstock Preparation***	***SRS Fuel Fabrication*** [a]
Human Health – Transportation Impacts (Chapter 4, Section 4.12)				
	Construction: Shipments: None Accidents: None		*Construction*: Shipments: 2,454 with no radiological impacts Accidents: None	
	Operations (annual impacts): All transportation impacts associated with reactor fuel production are included. No distinction is made between impacts from feedstock preparation and those from fuel fabrication. Radioactive waste shipments: 57 to 285 estimated shipments. Additionally, this option would include 15 VTR fuel shipments annually to ORNL for the ORNL VTR Alternative. Population: Maximum dose: 20 person-rem with no LCFs. Individual doses from operations would be well below DOE and regulatory limits. Worker Population: Maximum dose: 23 person-rem with no LCFs. Individual worker doses from operations would be limited to meet DOE administrative worker dose limits. Accidents: LCFs: None Nonradiological traffic fatalities: Two potential traffic accident fatalities over the life of the project		*Operations (annual impacts):* All transportation impacts associated with reactor fuel production are included. No distinction is made between impacts from feedstock preparation and those from fuel fabrication. Radioactive waste shipments: There would be 57 to 278 estimated shipments. Additionally, this option would include 15 VTR fuel shipments annually to the INL Site or ORNL, for the INL VTR or the ORNL VTR Alternative, respectively. Population: Maximum dose: 32 person-rem with no LCFs. Individual doses from operations would be well below DOE and regulatory limits. Worker Population: Maximum dose: 34 person-rem with no LCFs. Individual worker doses from operations would be limited to meet DOE administrative worker dose limits. Accidents: LCFs: None Nonradiological traffic fatalities: Three potential traffic accident fatalities over the life of the project	
Traffic (Chapter 4, Section 4.13)				
	Construction and Operations: The increase in traffic from both material shipments and workers are not expected to cause a change in existing level of service of offsite roads and no upgrades or improvements to onsite roads are anticipated.			
Socioeconomics (Chapter 4, Section 4.14)				
	Construction: Negligible adverse impact; small and beneficial short-term economic impact associated with construction activities.			
	Operations: The increase in jobs and income would be considered a potential beneficial impact on the local and regional economy. The population influx associated with an in-migrating workforce and their families is considered relatively small and would have no major adverse impacts on the regional in terms of population, employment, income levels, housing, or community services.			
	300 new employees for operations	70 new employees for operations	300 new employees for operations	300 new employees for operations

Resource Area	Options			
	INL Feedstock Preparation	INL Fuel Fabrication	SRS Feedstock Preparation	SRS Fuel Fabrication [a]
Environmental Justice (Chapter 4, Section 4.15)				
	Construction and Operation: No disproportionately high and adverse impacts on minority or low-income populations are expected. Increased health risks to minority or low-income individuals or populations exposed to radiation would be negligible.			

EPA = U.S. Environmental Protection Agency; INL = Idaho National Laboratory; LCF = latent cancer fatality; LLW = low-level radioactive waste; MLLW = mixed low-level radioactive waste; NAAQS = National Ambient Air Quality Standards; SRS = Savannah River Site; TRU = transuranic; TSCA = Toxic Substances Control Act; VTR =Versatile Test Reactor.

[a] If the SRS Fuel Fabrication Option were selected, there would be a fuel fabrication development/demonstration capability established in the Fuel Manufacturing Facility at INL. The impacts of 3-to-4 years INL fuel development effort would approximate those of a single year of fuel fabrication under the INL Fuel Fabrication Option.

Note: Sums and products presented in the table may differ from those calculated from individual entries due to rounding.

Table 2–5. Summary of Combined Environmental Consequences for the Versatile Test Reactor, Feedstock Preparation, and Fuel Fabrication at Idaho National Laboratory

Resource Area	***Construction***	***Operations***
Land Use and Aesthetics (Chapter 4, Section 4.1)		
Land Use	Same as Table 2–3, INL VTR Alternative: There would be minor impacts on land use from the disturbance of approximately 100 acres during construction activities. The VTR complex would occupy approximately 25 acres after construction.	There would be no impact on land use since no additional land would be disturbed.
Aesthetics	Same as Table 2–3, INL VTR Alternative: There would be minimal impacts on aesthetics as newly constructed facilities would not dominate the local landscape and would be similar in design to existing facilities.	Same as Table 2–3, INL VTR Alternative: There would be minimal impacts on aesthetics from operation of the newly constructed facilities that would be similar in design to existing facilities.
Geology and Soils (Chapter 4, Section 4.2)		
	Same as Table 2–3, INL VTR Alternative: Area disturbed would be 100 acres. The total quantities of geologic and soil materials needed during construction would represent small percentages of regionally plentiful resources and are unlikely to adversely impact geology and soil resources.	Same as Table 2–3, INL VTR Alternative: Area occupied would be 25 acres. No additional land disturbance, no additional excavation, and little or no use of geologic and soil materials. Minimal impacts.
Water Resources (Chapter 4, Section 4.3)		
	Water would be drawn from existing wells that access the Snake River Plain Aquifer and treated through the existing Materials and Fuels Complex (MFC) potable water system. The total water estimated to be used is 128 million gallons. Discharges would be made to surface water (which could include the MFC sewage lagoons or other surface discharges such as swales).	Water use is estimated to be 6.8 million gallons per year. Water would be drawn from groundwater and most would be discharged as surface water to the Industrial Waste Pond or active sewage lagoons. About 50,000 gallons of potentially contaminated process water would be sent off site for treatment and disposal.
Air Quality (Chapter 4, Section 4.4)		
	Annual nonradiological emissions from construction of the VTR facilities would be well below the EPA prevention of significant deterioration (PSD) permitting threshold of 250 tons per year for a criteria pollutant. Hazardous air pollutant emissions generated by construction activities would not result in adverse air quality impacts on the public. Construction activities would not generate radiological air emissions.	Annual nonradiological emissions from operation of the VTR facilities would be well below the annual PSD indicator thresholds. Operations activities would generate small quantities of radiological air emissions. See Human Health – Normal Operations below for the estimated impacts from these emissions.

Resource Area	***Construction***	***Operations***
Ecological Resources (Chapter 4, Section 4.5)		
	Same as Table 2–3, INL VTR Alternative: Area disturbed: is about 100 acres. Construction would result in a loss of sagebrush habitat. Losses to sagebrush habitat would be compensated for in accordance to the DOE's 'no net loss of sagebrush habitat' policy on the INL Site under the Candidate Conservation Agreement (CCA) for the sage-grouse. Nesting bird surveys, as indicated in the MBTA permit, would occur prior to any ground disturbance or vegetation removal to confirm the absence of MBTA protected species, as well as sage-grouse, from the proposed project area. A 300-foot buffer would be established around active pygmy rabbit burrow systems to prevent direct impacts. Operational and administrative controls will be evaluated and implemented, if warranted, to reduce the potential for adverse effects to wildlife species and human-wildlife interactions.	Same as Table 2–3, INL VTR Alternative: Area occupied is about 25 acres. Operations would take place in new and existing facilities. No additional land disturbance would occur so there would be no impacts on ecological resources.
Cultural and Paleontological Resources (Chapter 4, Section 4.6)		
	No impacts on significant cultural and paleontological resources would occur from facility construction, land disturbance, and operations.	
Infrastructure (Chapter 4, Section 4.7)		
	Construction electricity usage would be 1,000 megawatt-hours average annual value with annual peak value of 2,000 megawatt-hours. Diesel fuel usage would total 2.3 million gallons. Total water usage would be 128 million gallons.	VTR operations and driver fuel production would use 170,000 megawatt-hours per year of electricity, 4.7 million cubic feet of propane per year, and 6.8 million gallons of water per year.
Noise & Vibration (Chapter 4, Section 4.8)		
Noise	Due to the distance, estimated construction and operations noise levels at the INL Site boundary (2.9 miles) and closest receptor (5.0 miles) would not be perceptible and would be consistent with ambient levels.	
Vibration	Ground-borne vibration due to typical construction and operation activities are expected to be below the threshold of human perception.	
Waste Management and Spent Nuclear Fuel Management (Chapter 4, Section 4.9)		
Waste Management	About 9,900 cubic meters of construction waste would be generated during VTR construction activities. For the Reactor Fuel Production, existing facilities would be modified and existing equipment reallocated, as necessary, to support feedstock preparation and fuel fabrication activities. Equipment currently in this space would be relocated for use in other facilities. Small volumes of construction waste, LLW, MLLW, and hazardous and TSCA wastes would be generated during the modifications of facilities and the relocation of existing equipment and the installation of the new equipment would be minimal.	Annually, about 710 to 880 cubic meters of LLW, 40 to 42 cubic meters of MLLW, 200 to 400 cubic meters of TRU waste, and 8.2 to 9.2 cubic meters of hazardous and TSCA wastes would be generated. The characteristics of most of these wastes would be similar to wastes currently generated from existing activities and would be managed within the current waste management system. The project would provide preparation and packaging capabilities for the 200 to 400 cubic meters of TRU waste that would be generated from fuel production. All wastes would be shipped off site for treatment and/or disposal. Treatment and disposal of these wastes are well within the current capacities of existing offsite facilities.

Resource Area	***Construction***	***Operations***
Spent Nuclear Fuel	*Construction:* No spent nuclear fuel would be generated during construction.	*Operations:* The heavy metal from 45 spent driver fuel assemblies produced annually (66 for the final core offload at the end of the VTR's operational lifetime) would be treated and packaged as spent nuclear fuel and placed on the VTR spent fuel pad pending offsite shipment. The total number of spent fuel assemblies over the lifetime of the project represent about 110 metric tons of heavy metal.
Human Health – Normal Operations (Chapter 4, Section 4.10)		
	Offsite population No population impacts. Maximally exposed individual No maximally exposed individual impacts. Worker population Dose: 32 person-rem LCFs: 0 (calculated: 2×10^{-2}) Industrial accidents: 80 injuries with no fatalities expected.	*Annual impacts:* Offsite population Dose: 0.06 person-rem LCFs: 0 (calculated: 4×10^{-5}) Maximally exposed individual Dose: 0.0096 millirem LCF risk: 6×10^{-9} Worker population Dose: 160 person-rem LCFs: 0 (calculated: 9×10^{-2}) Industrial accidents: 26 injuries with no fatalities expected.
Human Health – Facility Accidents (Chapter 4, Section 4.11)		
	Offsite population No impacts on the offsite public. There are no radiological or hazardous material accident scenarios during construction. Maximally exposed individual No impacts on the maximally exposed individual. There are no radiological or hazardous material accident scenarios during construction. Noninvolved worker No impacts on the noninvolved worker. There are no radiological or hazardous material accident scenarios during construction.	*Annual impacts*: Offsite population Accident probability: less than one in 10,000 per year Dose: 1,400 person-rem LCFs: 1 Maximally exposed individual Accident probability: less than one in 10,000 per year Dose: 0.25 rem LCF risk: 0.0001 Noninvolved worker Accident probability: less than one in 10,000 per year Dose: 160 rem LCF risk: 0.2

Resource Area	Construction	Operations
Human Health – Transportation Impacts (Chapter 4, Section 4.12)		
	Radioactive waste shipments: 18,460 total shipments with no radiological impacts Accidents: One potential traffic accident fatality.	Radioactive waste shipments: 187 to 415 shipments annually. Offsite Population: Maximum dose: 28 person-rem with no LCFs. Individual doses from operations would be well below DOE and regulatory limits. Worker Population: Maximum dose: 30 person-rem with no LCFs. Individual doses from operations would be well below DOE and regulatory limits. Accidents: LCFs: None Nonradiological traffic fatalities: Three potential traffic accident fatalities over the 60-year life of the project
Traffic (Chapter 4, Section 4.13)		
	The average increases in daily traffic during construction are not expected to exceed existing level of service of offsite roads, and no upgrades or improvements to onsite roads are anticipated.	Operations at each facility are expected to result in an increase of about 400 employees. This represents a negligible increase in traffic at each facility (about 5 percent). Operation traffic not expected to exceed existing level of service of offsite roads and no upgrades or improvements to onsite roads are anticipated.
Socioeconomics (Chapter 4, Section 4.14)		
	The increase in jobs and income would have a short-term beneficial impact on the local and regional economy. The population influx associated with an in-migrating workforce and their families is considered relatively small and would have no major adverse impacts on the regional area of influence in terms of population, employment, income levels, housing, or community services.	The increase in 588 jobs would have a beneficial impact on the local and regional economy. The population influx associated with an in-migrating workforce and their families is considered relatively small and would have no major adverse impacts on the regional area of influence in terms of population, housing, or community services.
Environmental Justice (Chapter 4, Section 4.15)		
	No disproportionately high and adverse impacts on minority or low-income populations are expected. Increased risks of minority or low-income individuals or populations exposed to radiation would be negligible.	

EPA = U.S. Environmental Protection Agency; INL = Idaho National Laboratory; LCF = latent cancer fatality; LLW = low-level radioactive waste; MLLW = mixed low-level radioactive waste; TRU = transuranic; TSCA = Toxic Substances Control Act; VTR =Versatile Test Reactor.
Note: Sums and products presented in the table may differ from those calculated from individual entries due to rounding.

2.9.2 Summary and Comparison of Cumulative Impacts

Council on Environmental Quality regulations define cumulative impacts as effects on the environment that result from implementing any of the alternatives when added to other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such actions (40 CFR 1508.7). Cumulative impacts were assessed by combining the effects of activities at the INL Site, ORNL, and SRS for each of the alternatives and options assessed in this VTR EIS with the effects of other past, present, and reasonably foreseeable future actions. Many of these actions occur at different times and locations and may not be truly additive. However, the effects were combined irrespective of the time and location of the impact, to encompass any uncertainties in the projected activities and their effects. This approach produces a conservative estimate of cumulative impacts for the activities considered. **Table 2–6**, presents a summary and comparison of cumulative impacts at the INL Site, ORNL, and SRS. Cumulative impacts for issues of national and global concern (i.e., transportation, ozone depletion, and climate change) are presented below. For the full discussion of cumulative impacts, refer to Chapter 5.

Transportation – The assessment of cumulative transportation impacts for past, present, and reasonably foreseeable future actions concentrates on offsite transportation throughout the nation that would result in potential radiation exposure to the transportation workers and the general population. Cumulative radiological impacts from transportation are estimated using the dose to the workers and the general population, because dose can be directly related to latent cancer fatalities (LCFs) using a cancer risk coefficient.

When combined with past, present, and reasonably foreseeable future nation-wide transportation, the cumulative transportation worker dose was estimated to be about 430,000 person-rem (258 LCFs). The cumulative general population dose was estimated to be about 441,000 person-rem (265 LCFs). For the INL VTR and the ORNL VTR Alternatives evaluated in this EIS, doses to transportation workers and the general population would be less than 2,120 and 2,025 person-rem, respectively. Therefore, transportation worker and population doses from the proposed action would be less than 0.5 percent of the cumulative worker and population doses and would not substantially contribute to cumulative transportation impacts.

Ozone Depletion – The proposed action is not expected to use substantial quantities of ozone-depleting substances as regulated under 40 CFR Part 82, “Protection of Stratospheric Ozone.” Emissions of ozone-depleting substances would be very small and would represent a negligible contribution to the destruction of the Earth’s protective ozone layer.

Climate Change – Greenhouse gas (GHG) emissions from construction and operations at the INL Site, ORNL, and SRS of 65,000, 97,000, and 59,000 metric tons of carbon dioxide equivalents, respectively, would occur over a period of up to 65 years. These emissions would imperceptibly add to U.S. and global GHG emissions, which were estimated to be 6.7 billion metric tons and 36.6 billion metric tons of carbon dioxide equivalents, respectively, in 2018. Therefore, GHGs emitted from the proposed actions at the INL Site, ORNL, and SRS would be a negligible percentage of U.S. and global GHG emissions and would not substantially contribute to future climate change.

Table 2–6. Summary and Comparison of Cumulative Impacts

Resource Area	*INL VTR Alternative (including Reactor Fuel Production Option)*	*ORNL VTR Alternative*	*SRS Reactor Fuel Production Option*
Land Use and Aesthetics	Activities evaluated under the proposed action would disturb 100 acres, or approximately 0.2 percent of the 45,400 acres of currently developed land at the INL Site and approximately 0.02 percent of the 569,600 acres of land available at the INL Site, and would not substantially contribute to cumulative land use impacts. Because construction would disturb only 100 acres, would be located adjacent to industrial area at MFC, and would be geographically separated from most of the other activities at the INL Site, the proposed action would not substantially contribute to cumulative aesthetics impacts.	Activities evaluated under the proposed action would disturb 150 acres, or approximately 1.2 percent of the 12,250 to 12,450 acres of developed land at ORR and approximately 0.5 percent of the 32,867 acres of land available at ORR, and would not substantially contribute to cumulative land use impacts. Because construction would disturb only 150 acres and would be geographically and topographically separated from most of the other activities at ORR, the proposed action would not substantially contribute to cumulative aesthetics impacts.	Modification and operation activities would occur primarily within existing buildings with minimal additional land disturbance. Therefore, impacts of the proposed action on land use and aesthetics would be minimal and would not contribute substantially to cumulative impacts.
Geology and Soils	Based on the information presented above for Land Use, the amount of soil disturbed by the proposed action would be a small percentage of the total soil disturbed at the INL Site and would not substantially contribute to cumulative impacts. The amount of geologic and soils materials used by the proposed action would be 112,000 cubic yards or about 9 percent of the 1,230,000 cubic yards used by other activities at the INL Site.	Based on the information presented above for Land Use, the amount of soil disturbed by the proposed action would be a small percentage of the total soil disturbed at ORR and would not substantially contribute to cumulative impacts. The amount of geologic and soils materials used by the proposed action would be 187,000 cubic yards or approximately 13 percent of the 1,460,000 cubic yards used by other activities at ORR.	Modification and operation activities would occur primarily within existing buildings with minimal additional land disturbance. Therefore, impacts of the proposed action on geology and soils would be minimal and would not contribute substantially to cumulative impacts.
Water Resources	Under the proposed action, no effluent would be discharged directly to natural surface water bodies, and no surface water would be used. Therefore, the proposed action would not contribute to cumulative impacts on surface water. No effluent would be discharged directly to groundwater, and thus the proposed action would not contribute to cumulative impacts on groundwater quality. Groundwater withdrawal for the proposed action, would be less than 1 percent of the 872 million gallons per year cumulative groundwater use at the INL Site, and therefore, would not substantially contribute to cumulative impacts. The other past, present, and reasonably	Under the proposed action, no effluent would be discharged directly to groundwater, and no groundwater would be withdrawn, except shallow groundwater withdrawn during dewatering. Dewatering would be of short duration and localized extent. Therefore, the proposed action would not substantially contribute to cumulative groundwater impacts. Water use would be less than 0.1 percent of the 4.27 billion gallons per year cumulative surface water use at ORR, and would not substantially contribute to cumulative impacts on surface water availability. No contaminated effluent would be discharged directly to surface water	Under the proposed action, modification and operation activities would occur within existing buildings with no additional land disturbance and no effluent discharged directly to surface water or groundwater. Therefore, impacts on surface water and groundwater quality would be minimal and would not contribute to cumulative impacts. No surface water would be used, and thus, the proposed action would not contribute to cumulative impacts from surface water use. Groundwater withdrawal for the proposed action would be less than 1 percent of the 538 to 623 million gallons per year cumulative groundwater

Resource Area	INL VTR Alternative (including Reactor Fuel Production Option)	ORNL VTR Alternative	SRS Reactor Fuel Production Option
	foreseeable future actions would be located across the INL Site and would discharge wastewater to different discharge points. Therefore, there would be little or no cumulative impact of these discharges.	during operation, and thus, the proposed action would not contribute to cumulative impacts on surface water quality.	use at SRS, and therefore would not substantially contribute to cumulative impacts.
Air Quality	The minor increase in offsite air pollutant concentrations produced from construction and operation, in combination with emissions from other past, present, and reasonably foreseeable future actions, would result in air pollutant concentrations that would not exceed the State and national ambient air quality standards. Emissions from construction and operations activities would not substantially contribute to cumulative air quality impacts.		
Ecological Resources	Cumulative impacts on ecological resources would not be substantial because ground disturbance and land clearing for the proposed action and other past, present, and reasonably foreseeable future actions would occur at different locations and times, and appropriate best management practices (such as sagebrush replacement and invasive species management) would be enforced.	The proposed action and other past, present, and reasonably foreseeable future actions would occur at different locations and times, and appropriate best management practices (such as wetland protection) would be enforced. The loss of habitat associated with the proposed action would account for less than 1 percent of the 24,000 acres of forested-hardwood habitat and less than 1 percent of the 4,100 acres of interior forest available at ORR. Even though these impacts to vegetation would generally be considered minor due to the availability of forested-hardwood habitats within ORNL and intermountain regions of Appalachia, ongoing assessments of the ORNL's ecological resources suggest that in-kind mitigation (i.e., protection or enhancement of ecologically-similar resources) could be required due to impacts to vegetation and may entail greater acreage than available elsewhere on ORNL (ORNL 2020d).	Under the proposed action, modification and operation activities would occur primarily within existing buildings with minimal additional land disturbance. Therefore, impacts of the proposed action on ecological resources would be minimal and would not contribute substantially to cumulative impacts.
Cultural and Paleontological Resources	Cumulative impacts on cultural and paleontological resources within the regional area of influence would be negligible because no historic properties or paleontological resources were identified within the area of proposed new construction. The proposed new construction is consistent with the historic industrial character of the area and would not diminish the integrity of setting of any existing historic property within MFC.	Cumulative impacts on cultural and paleontological resources within the regional area of influence would be negligible because of the lack of significant resources within the area of potential effect and due to the necessity of following the NHPA Section 106 process for all activities.	Under the proposed action, modification and operation activities would occur primarily within existing buildings with minimal additional land disturbance. Therefore, impacts of the proposed action on cultural and paleontological resources would be minimal and would not contribute substantially to cumulative impacts.

<table>
<tr><th>Resource Area</th><th>INL VTR Alternative (including Reactor Fuel Production Option)</th><th>ORNL VTR Alternative</th><th>SRS Reactor Fuel Production Option</th></tr>
<tr><td>Infrastructure</td><td>Projected cumulative site activities would annually require 468,000 to 471,000 megawatt-hours of electricity which is below the site capacity of 481,800 megawatt-hours. Annual electricity use for the proposed action would be approximately 170,000 megawatt-hours of electricity, which represents about one third of the 481,800 megawatt-hours of site capacity.

Operation of the proposed action would annually use about 6.8 million gallons of water, which represents a fraction of the 872 million gallons cumulative infrastructure use and an even smaller fraction of the 11.4 billion gallons total site capacity. Therefore, operation activities would not substantially contribute to cumulative water use impacts.</td><td>Projected cumulative site activities would annually require about 1,440,000 to 1,520,000 megawatt-hours of electricity, which is well within the total site-wide capacity of 13,880,000 megawatt-hours.

Cumulative annual water usage would be about 4,270 million gallons, which is well within the site-wide capacity of 11,715 million gallons.

Operation of the proposed action would annually use about 180,000 megawatt-hours of electricity and about 4.4 million gallons of water, which represents a fraction of cumulative infrastructure use and an even smaller fraction of total site capacity. Therefore, operation activities would not substantially contribute to cumulative infrastructure impacts.</td><td>Projected cumulative site activities would annually require about 851,000 to 1,000,000 megawatt-hours of electricity, which is well within the total site-wide capacity of 4,400,000 megawatt-hours.

Cumulative annual water usage would range from about 538 million to 624 million gallons of water, which is well within the site-wide capacity of 2,950 million gallons.

Operation of the proposed action activities would annually use about 13,300 megawatt-hours of electricity and 3.6 million gallons of water, which represents a fraction of the cumulative infrastructure use and an even smaller fraction of total site capacity. Therefore, operation activities would not substantially contribute to cumulative infrastructure impacts.</td></tr>
<tr><td>Noise</td><td>The closest offsite receptor is a home/farm site that is approximately 5.0 miles away. Given the large distance, cumulative noise from construction or operation of projects at MFC and other locations within the INL Site would be indistinguishable from background at the closest offsite noise-sensitive receptor.</td><td>The closest offsite receptors include residential homes more than 1.25 miles to the east and across the Clinch River. Given the large distance, cumulative noise from construction or operation of projects at ORNL would be indistinguishable from background at the closest offsite noise-sensitive receptors.</td><td>Under the proposed action, modification and operation activities would occur within existing buildings with no additional land disturbance. Therefore, impacts of the proposed action on noise would be minimal and would not contribute to cumulative impacts.</td></tr>
<tr><td>Waste Management</td><td colspan="3">The waste management infrastructures at the INL Site, ORNL, and SRS were developed such that they would be able to accommodate the quantities of waste generated by the proposed action. Therefore, cumulative waste generation would be within site capacities. There are existing offsite DOE and commercial waste management facilities with sufficient capacities for the treatment and disposal needs associated with the relatively small volumes of LLW and MLLW wastes that would be generated by the proposed action. Therefore, substantial cumulative impacts on offsite LLW and MLLW treatment and disposal facilities would not be expected.

The Waste Isolation Pilot Plant (WIPP) is currently the only disposal option for TRU waste. WIPP's Land Withdrawal Act total TRU waste volume limit is 175,564 cubic meters. As of the reporting date for the 2019 Annual Transuranic Waste Inventory Report (ATWIR), 67,400 cubic meters of TRU waste were disposed of at the WIPP facility. The alternatives and options evaluated in this EIS would generate an estimated 24,000 cubic meters of TRU waste. TRU waste volume estimates such as those provided in NEPA documents, cannot be used to determine compliance with the WIPP Land Withdrawal Act TRU waste volume capacity limit. These wastes and waste from other actions will be incorporated, as appropriate, into future ATWIR TRU waste inventory estimates. Any GTCC-like waste (e.g., non-defense TRU waste not eligible for disposal at WIPP) generated from the proposed action would be stored at the generator site in accordance with applicable requirements until a disposal capability is available.</td></tr>
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Resource Area	INL VTR Alternative (including Reactor Fuel Production Option)	ORNL VTR Alternative	SRS Reactor Fuel Production Option
Human Health – Normal Operations	The cumulative offsite population dose would be 0.13 person-rem per year with no expected LCFs (calculated value of 8×10^{-5}). Operation of the proposed action would result in a total population dose of 0.061 person-rem per year with no expected LCFs (calculated value of 4×10^{-5}). The proposed action would be 45 percent of the cumulative dose and LCFs. While the proposed action would be a significant portion of the cumulative impact, the absolute value would be low, and, therefore, would not substantially contribute to human health impacts. The cumulative MEI dose would be 1.8 millirem per year with an associated LCF risk of 1×10^{-6}. Operation of the proposed action would result in a total MEI dose of 0.0096 millirem per year with an associated LCF risk of 6×10^{-9}. The proposed action would be 0.05 percent of the cumulative MEI dose and LCFs and, thus, would not substantially contribute to cumulative human health impacts. The cumulative worker dose would be 220 person-rem per year with no expected LCFs (calculated value of 0.1). Operation of the proposed action would result in a total worker dose of 110 person-rem per year with no expected LCFs (calculated value of 0.07). The proposed action would be 51 percent of the cumulative dose and LCFs. The proposed action could result in 4 worker LCFs from 60 years of VTR operation. Some of the worker dose estimate is the result of using conservative dose estimates for some fuel fabrication workers. Additional worker protection could be incorporated into the final design to reduce potential worker doses.	The cumulative offsite population dose would be 94 person-rem per year with no expected LCFs (calculated value of 0.06). Operation of the proposed action would result in a total population dose of 0.58 person-rem per year with no expected LCFs (calculated value of 0.0004). The proposed action would be less than one percent of the cumulative dose and LCFs and therefore, would not substantially contribute to cumulative human health impacts. The cumulative MEI dose for ORR activities would be 3.8 millirem per year with an associated LCF risk of 2×10^{-6}. Operation of the proposed action would result in a total MEI dose of 0.031 millirem per year with an associated LCF risk of 2×10^{-8}. The proposed action would be about one percent of the cumulative MEI dose and LCFs and, thus, would not substantially contribute to cumulative human health impacts. The cumulative worker dose would be 110 person-rem per year with no expected LCFs (calculated value of 0.08). Operation of the proposed action would result in a total worker dose of 44 person-rem per year with no expected LCFs (calculated value of 0.03). The proposed action would be 39 percent of the cumulative dose and LCFs. This could result in 2 worker LCFs from 60 years of VTR operation. Additional worker protection could be incorporated into the final design potentially reducing worker doses.	The cumulative offsite population dose would be 35 person-rem per year with no expected LCFs (calculated value of 0.02). Operation of the proposed action would result in a total population dose of 0.062 person-rem per year with no expected LCFs (calculated value of 4 x 10^{-5}). The proposed action would be 0.2 percent of the cumulative dose and LCFs and, thus, would not substantially contribute to cumulative human health impacts. The cumulative MEI dose from SRS activities would be 0.82 millirem per year with an associated LCF risk of 5×10^{-7}. Operation of the proposed action would result in a total MEI dose of 0.0022 millirem per year with an associated LCF risk of 1×10^{-9}. The proposed action would be about 0.03 percent of the cumulative MEI dose and LCFs and therefore, would not substantially contribute to cumulative human health impacts. The cumulative worker dose would be about 1,000 person-rem per year with 1 expected LCFs (calculated value of 0.6). Operation of the proposed action would result in a total worker dose of 102 person-rem per year with no expected LCFs (calculated value of 0.06). The proposed action would be 10 percent of the cumulative dose and LCFs and therefore, would not substantially contribute to cumulative human health impacts. This could result in 4 worker LCFs from 60 years of VTR operation. Additional worker protection could be incorporated into the final design potentially reducing worker doses.
Traffic	The impacts on traffic from construction and operation activities are anticipated to be negligible to minor. As such, they would not substantially contribute to cumulative traffic impacts.		

Resource Area	***INL VTR Alternative (including Reactor Fuel Production Option)***	***ORNL VTR Alternative***	***SRS Reactor Fuel Production Option***
Socioeconomics	Cumulative employment at INL from present and reasonably foreseeable future actions could reach a peak of about 7,990 persons; this is about 5.1 percent of the 157,400 people employed in the INL Site region in 2018. Activities under the proposed action could produce direct employment of up to a peak of about 1,350 construction workers during the 51-month construction period, nearly 32 percent of the 4,120 cumulative workforce related to construction activities. The 588 operations staff (new workers) under the proposed action would be about 7.4 percent of the 7,990 cumulative workforce related to annual operations and a very small percentage of the about 157,400 people employed in the INL Site region in 2018. Note: That the total operations workforce under the proposed action would actually be close to 820, however, 230 of these workers would be pulled from the existing on-site workforce. The overall contribution to cumulative socioeconomic impacts (e.g., housing, schools, and community services) from the proposed action on the regional area of influence is expected to be small.	Cumulative employment at ORR from past, present, and reasonably foreseeable future actions could reach a peak of about 15,200 persons; this is about 4.7 percent of the 320,327 people employed in the ORR regional area of influence, including ORNL, in 2019. Activities under the proposed action could produce direct employment of up to a peak of 1,598 construction workers during the 51-month construction period, or 30 percent of the 5,380 cumulative workforce (peak) related to construction activities. The 300 operations staff under the proposed action would be about 2 percent of the 15,200 cumulative workforce related to operations and a very small percentage of the about 320,327 people employed in the ORR region in 2019. The overall contribution to cumulative socioeconomic impacts (e.g., housing, schools, and community services) from the proposed action on the regional area of influence is expected to be small.	Cumulative employment at SRS from past, present, and reasonably foreseeable future actions could reach a peak of about 15,600 persons; this is about 6.4 percent of the 243,863 people employed in the SRS regional area of influence in 2019. Activities under the proposed action could produce direct employment of up to a peak of 240 construction workers during the three-year construction period, or 3.2 percent of the 7,430 cumulative workforce (peak) related to construction activities. The 600 operations staff under the proposed action would be about 3.7 percent of the 16,410 cumulative workforce related to operations and a very small percentage of the about 243,863 people employed in the SRS region in 2019. The overall contribution to cumulative socioeconomic impacts (e.g., housing, schools, and community services) from the proposed action on the regional area of influence is expected to be small.
Environmental Justice	Because the doses from the proposed action would be small and there would be no disproportionate high and adverse impacts on minority and low-income populations, the proposed action would not substantially contribute to cumulative environmental justice impacts.		