DOE/EIS-0559
March 2024

DRAFT
Environmental Impact Statement
for Department of Energy Activities in Support of Commercial Production of High-Assay Low-Enriched Uranium (HALEU)

SUMMARY

U.S. Department of Energy
Office of Nuclear Energy

This page left blank intentionally.

Reader's Guide

This Reader's Guide is intended to help readers navigate the Environmental Impact Statement (EIS) and does not on its own provide sufficient information regarding the Proposed Action. This Summary provides a brief overview of the EIS and a summary of impacts, but for full impact analyses, please review the EIS and its Appendices.

Proposed Action Overview

As you read this EIS, keep in mind that under the Proposed Action, the U.S. Department of Energy (DOE) would acquire a particular type of uranium that is not widely produced by the commercial market at this time. Under the Proposed Action, DOE would acquire a limited quantity of high-assay low-enriched uranium (HALEU) to encourage commercial producers to invest in the necessary fuel cycle infrastructure and gear up production to provide the expected amount of HALEU needed for commercial use or demonstration projects.

DOE's ***Proposed Action*** is to acquire, through procurement from commercial sources, HALEU enriched to at least 19.75 and less than 20 weight percent uranium-235 over a 10-year period of performance, and to facilitate the establishment of commercial HALEU fuel production.

Various companies would perform the activities to produce the HALEU that DOE proposes to acquire. In 2023 and early 2024, DOE released Requests for Proposals for companies to consider what needs to be done to provide HALEU to DOE. While the Requests for Proposals support DOE's Proposed Action to acquire HALEU, similar activities are already well established within the existing uranium fuel economy, and a sizable body of information already exists that evaluates the potential environmental consequences of those activities. In this EIS, DOE used that existing information to estimate potential environmental impacts associated with the Proposed Action to acquire HALEU. Note: This EIS uses "impacts" and "environmental consequences" interchangeably.

Associated Activities

DOE has considered the activities of a uranium-based fuel cycle and determined that the production of HALEU would involve the following activities. The process starts with **mining and milling** or in-situ recovery of uranium ore. The uranium ore is **converted** into a form that can be **enriched**. The enriched uranium hexafluoride would then need to be **deconverted** into a form that can be used for fuel fabrication. The various uranium forms would be **stored** until needed for each of these activities. The uranium forms also would need to be **transported** between the different facilities where these activities are performed.

So, the production of HALEU under DOE's Proposed Action would require the following activities:

- Uranium mining and milling
- Uranium conversion
- Uranium enrichment to HALEU
- HALEU deconversion
- HALEU storage
- Transportation of uranium between activity locations

Increasing the concentration of uranium-235 is called **enrichment**, which is one of six activities in the HALEU fuel cycle associated with the Proposed Action.

In addition to the activities above, there are several reasonably foreseeable activities that could result from implementation of the Proposed Action—HALEU could be used for fuel fabrication and used in HALEU-fueled reactors. When no longer usable as an energy source, the HALEU would be managed as spent nuclear fuel. While not specifically a part of the Proposed Action, the impacts from these reasonably foreseeable activities are acknowledged and addressed to the extent practicable in this EIS.

The activities performed under DOE's Proposed Action, if implemented, have a long history of being conducted safely and none are unique to the production of HALEU, having been conducted for other uranium forms and improved over many decades. Extensive environmental analyses have been completed for facilities that perform uranium mining and milling, conversion, enrichment, deconversion, storage, and transportation activities, as well as fuel fabrication, use of uranium fuel in reactors, and spent nuclear fuel management.

Analytical Approach – The Use of Existing NEPA Evaluations and Information

Analytical Approach: Existing NEPA documentation for uranium fuel cycle activities and facilities where those activities have historically taken place was carefully examined to estimate the potential impacts of each of the activities associated with the Proposed Action.

This EIS presents the potential environmental consequences of the Proposed Action (i.e., the impacts from each of those HALEU production, storage, and transportation activities) and discusses the potential impacts of HALEU fuel fabrication, use in reactors, and the resulting spent nuclear fuel management. DOE is in the process of requesting proposals from commercial vendors regarding HALEU procurement and enrichment and deconversion services. Site-specific details will only be available after proposals are received and evaluated in response to the relevant Request for Proposals (RFPs). While this EIS will provide information that could be used to identify impacts from the construction and operation of HALEU fuel cycle facilities, the selection of specific locations and facilities will not be a part of the Record of Decision for this EIS. The decisions to be supported are whether or not to acquire HALEU from commercial sources and to facilitate commercial HALEU fuel production capability.

Sixteen resources are considered in this EIS:

- land use
- visual and scenic resources
- geology and soils
- water resources
- air quality
- ecological resources
- historic and cultural resources
- infrastructure
- noise
- waste management
- public and occupational health – normal operations
- public and occupational health – facility accidents
- traffic
- socioeconomics
- environmental justice
- human health – transportation

One of the main contributing factors to the significance of the environmental impacts is where the facilities are located. To determine the potential environmental consequences, DOE evaluated the existing National Environmental Policy Act (NEPA) documentation for uranium fuel cycle facilities used in the low-enriched uranium (LEU) fuel cycle. Some of the HALEU activities (mining and milling and conversion) are no different from their corresponding LEU fuel cycle activities, using the same processes and having the same feed and product material. Others (enrichment and deconversion) are different but similar. While the feed and product materials differ only in the enrichment of the materials, the processes employed are the same. However, some adjustments need to be implemented to address criticality safety controls for HALEU that are not the same as for LEU and depleted uranium. From an environmental impact perspective, these adjustments are minor.

Therefore, the existing NEPA evaluations for those activities and facilities where those activities take place were carefully examined to extrapolate the potential impacts of each of the activities being evaluated in this HALEU EIS.

Since the Proposed Action is to acquire HALEU from commercial sources, those commercial sources could propose a range of scenarios for producing HALEU. Those scenarios could include the use of existing uranium fuel cycle facilities (also referred to as an **existing** facility or existing site) with modifications and/or expansions, construction and operation of a new facility at an existing industrial site (also referred to as a previously disturbed or **brownfield** site), and/or the construction and operation of a new facility at a previously undisturbed site (also referred to as a **greenfield** site).

Extensive NEPA evaluation documentation exists for environmental consequences of activities similar to those of the Proposed Action.

Existing uranium fuel cycle facilities – Many of the existing facilities that produce LEU and HEU could be modified or expanded to produce HALEU.

Other industrial (brownfield) sites – Operation of HALEU production facilities at other industrial sites likely would result in similar impacts to performing these activities at existing uranium fuel cycle facilities.

Undeveloped (greenfield) sites – Operation of HALEU production facilities on previously undeveloped lands would likely result in similar impacts to performing these activities at an existing uranium fuel cycle facility.

Specific locations and facilities will not be selected in the decision document (i.e., the Record of Decision) for this EIS and ***site-specific impacts will not be addressed in DOE's analysis***. The modification, construction, and operation of uranium fuel cycle facilities would be subject to U.S. Nuclear Regulatory Commission, other Federal agency, or Agreement State licensing, including NEPA review, and potentially other Federal and state permitting. To estimate potential impacts associated with the Proposed Action, this EIS leverages the extensive existing NEPA documentation's impact assessments previously identified for the various fuel cycle activities and presents the relative impacts associated with performing these activities at existing facilities, brownfield sites, or greenfield sites.

This EIS adopts the NRC impact assessment categories from most of the NEPA documents that were used as the basis for the impact analysis:

- **SMALL –** The environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.
- **MODERATE** – The environmental effects are sufficient to alter noticeably, but not destabilize, important attributes of the resource.
- **LARGE** – The environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

Structure and Content of the EIS

This ***Summary*** provides a concise summary of the HALEU EIS, highlighting key information from the EIS, including the purpose and need, the Proposed Action, the analytical approach, and potential environmental consequences of the Proposed Action.

Chapter 1 introduces background information on the need for HALEU and the Proposed Action.

Chapter 2 provides an overview of alternatives evaluated, a description of each HALEU activity, a description of facilities that have historically conducted or are capable of conducting each activity, and a high-level summary of the impacts associated with each activity. Table 2.6-1 in the EIS presents a "quick-reference" comparison of impacts under each HALEU activity associated with placement of HALEU fuel cycle facilities at existing fuel cycle facilities, brownfield sites, and greenfield sites. Impacts are characterized in alignment with the standard ratings used by the U.S. Nuclear Regulatory Commission: SMALL, MODERATE, or LARGE. Chapter 2 also presents a summary of environmental consequences of the Proposed Action and No Action Alternative as well as a brief overview and comparison of cumulative effects.

Chapter 3, Affected Environment and Environmental Consequences, describes the assumptions that DOE used for this analysis, the general analysis methodology for determining impact ratings by utilizing existing NEPA evaluations, and any exceptions to that general methodology. Chapter 3 presents the impacts of constructing and operating HALEU facilities under the Proposed Action by activity and siting scenario (i.e., existing site, brownfield site, greenfield site). This chapter further expands on impacts for resources that decision-makers need to consider because they are characterized as having potential MODERATE and LARGE impact ratings. (Resources characterized with SMALL impacts are addressed in the Appendices.)

Chapter 3 presents potential impacts of constructing and operating a new HALEU facility at existing sites, at brownfield sites, and at greenfield sites, which were extrapolated from and expand on existing NEPA evaluations.

Chapter 4, Cumulative Effects, addresses cumulative effects associated with the Proposed Action. These effects typically consider past, present, and reasonably foreseeable actions. However, as site selection is not a decision to be supported by this EIS, specific regions of influence would be speculative and so in depth, cumulative effects analysis is not possible for most resources. However, some impacts are more specifically discussed in Chapter 4, such as those from radioactive material transportation and spent nuclear fuel management, ozone depletion, and climate change since these impacts would be cumulative across all HALEU activities, are not site dependent, and with regards to ozone depletion and climate change are potentially global in nature.

Appendices contain additional information supporting the main body of the EIS. Appendix A, *Environmental Consequences Supporting Information*, includes details about the activity-specific analysis methodology and precise lists of the existing NEPA documents used to determine potential impacts for each respective HALEU activity. Appendix A also presents further supporting details for resources with potential MODERATE and LARGE impact ratings by discussing those potential impacts that contributed to the impact assessment of MODERATE or LARGE. In Appendix B, *Facility NEPA Documentation*, readers can find a discussion of the extent of existing NEPA coverage available (or not available) for each activity as well as a breakdown of various reference materials by activity and existing facility location. Appendix C, *Federal Register Notices*, presents a copy of the published notice of intent to prepare this EIS.

See Appendix A for a detailed description of the activity-specific analysis methodology and each of the activity-specific NEPA evaluations that helped inform the activity-specific analysis.

TABLE OF CONTENTS

S.1 Introduction **1**
- S.1.1 What is HALEU? 2
- S.1.2 Why Do We Need More HALEU? 3
- S.1.3 Where Do We Get Uranium for Reactor Fuel Now? 3
- S.1.4 How Will We Get What We Need? 5
- S.1.5 DOE and Commercial HALEU Supply 6

S.2 Purpose and Need for Agency Action **7**

S.3 DOE Notice of Intent and Opportunity for Comment **8**

S.4 DOE Requests for Proposals – HALEU Enrichment and Deconversion Services **8**

S.5 Proposed Action and Related Activities **10**

S.6 Decisions to be Supported **11**

S.7 Alternatives Analyzed **11**
- S.7.1 Proposed Action and Related Activities 11
- S.7.2 No Action Alternative 20

S.8 Alternatives Considered and Dismissed from Detailed Analysis **21**
- S.8.1 Use of DOE Stockpiles of HEU 21

S.9 Preferred Alternative **21**

S.10 Summary of Environmental Consequences **21**
- S.10.1 Summary and Comparison of Alternatives 21
- S.10.2 Summary and Comparison of Cumulative Effects 28

S.11 References **31**

List of Figures

Figure S.1-1. Components of the HALEU Supply Chain 2
Figure S.1-2. Uranium Fuel Production Process Overview 4
Figure S.1-3. United States and Foreign Uranium Production 4
Figure S.7-1. Uranium Mines in the United States 13
Figure S.7-2. An In-Situ Recovery Operation 13
Figure S.7-3. Developed Portion of the Metropolis Facility 14
Figure S.7-4. Centrus Centrifuge Demonstration Cascade 16

List of Tables

Table S.2-1. Nuclear Energy Institute Survey Results for Estimated HALEU Demand Through 2035 8
Table S.10-1. Summary of Impacts 25

ACRONYMS AND ABBREVIATIONS

%	percent
ACO	American Centrifuge Operating, LLC
ACP	American Centrifuge Plant
ANR	advanced nuclear reactor
BWXT	BWX Technologies, Inc.
CFR	Code of Federal Regulations
CO_2e	carbon dioxide equivalent
DOE	U.S. Department of Energy
DOE-NE	DOE Office of Nuclear of Energy
EIS	Environmental Impact Statement
ET	Eastern Time
FR	Federal Register
g CO_2e/kWh	grams of carbon dioxide equivalent per kilowatt-hour
GHG	greenhouse gas
HALEU	high-assay low-enriched uranium
HEU	highly enriched uranium
INL	Idaho National Laboratory
ISR	in-situ recovery
kg	kilograms
LCF	latent cancer fatality
LEU	low-enriched uranium
LEU+	uranium enriched 5% up to 10%
LWR	light water reactor
MSR	molten salt reactor
MT	metric tons
MWe	megawatts electric
NEF	National Enrichment Facility
NEI	Nuclear Energy Institute
NEPA	National Environmental Policy Act
NRC	U.S. Nuclear Regulatory Commission
ODS	ozone-depleting substance
rem	roentgen equivalent man
RFP	Requests for Proposal
ROI	region of influence
SC-GHG	social cost of GHG
SNF	spent nuclear fuel
TRISO	tri-structural isotropic
U.S.	United States
U.S.C.	United States Code
U-235	uranium-235
U-238	uranium-238
U_3O_8	triuranium octoxide (i.e., yellowcake, a uranium oxide)
UF_6	uranium hexafluoride
UO_2	uranium dioxide
UO_3	uranium trioxide
UUSA	Urenco USA

S.1 Introduction

The United States (U.S.) Department of Energy (DOE), in accordance with the National Environmental Policy Act (NEPA), has prepared this documentation in support of activities associated with DOE's Proposed Action. DOE's Proposed Action, as discussed in further detail in Section S.5, *Proposed Action and Related Activities*, is to acquire, through procurement from commercial sources, high-assay low-enriched uranium (HALEU)[1] and to facilitate the establishment of commercial HALEU fuel production. The Proposed Action would address Section 2001(a)(2)(D)(v) of the Energy Act of 2020 (Title 42 U.S. Code [U.S.C.] Section 16281; 134 Statute 2454; Public Law 116-260 Division Z). DOE's objective is to establish a temporary domestic demand for HALEU to support the availability of HALEU for civilian domestic commercial use and demonstration projects by engaging with industry and other stakeholders to enter into partnership and incentivize the establishment of a domestic HALEU fuel cycle (i.e., the HALEU supply chain).

Figure S.1-1 presents an overview of various activities that are addressed in this Environmental Impact Statement (EIS). The Proposed Action includes the procurement of uranium, which would entail mining and milling, conversion services, enrichment services, deconversion services, storage, and transportation[2] services. DOE acknowledges that fuel fabrication, advanced reactor operations, and spent nuclear fuel (SNF) storage and disposition, while not specifically part of the Proposed Action, are reasonably foreseeable activities that could result from successful implementation of the Proposed Action. Although they are reasonably foreseeable actions that could follow from DOE's efforts, those activities are not part of the Proposed Action (see Section S.7.1, *Proposed Action and Related Activities*). Further, the specifics of those activities are presently unknown and would be subject to U.S. Nuclear Regulatory Commission (NRC) licensing and analysis. Therefore, this EIS addresses those reasonably foreseeable activities to the extent possible, but a detailed analysis of the impacts[3] of those activities, herein, would be speculative.

This "HALEU EIS" analyzes the range of options that could fulfill DOE's Proposed Action. Site-specific details (such as the location of facilities) and whether activities would result in modifying existing facilities or constructing new facilities are not yet determined and will not be considered as a part of this EIS; the associated Record of Decision will not select specific locations or facilities. For this reason, to analyze a full range of impacts (i.e., to "bound" potential impacts), DOE has analyzed the potential impacts associated with (1) modifications to or expansions of existing uranium fuel cycle facilities, (2) construction and operation of new HALEU facilities at existing industrial facilities/sites (also known as **brownfield sites**), and (3) construction and operation at undeveloped sites (also known as **greenfield sites**). The impact analysis is based on existing NEPA analysis for uranium fuel cycle facilities.[4] The modification, construction, and operation of uranium fuel cycle facilities would be subject to NRC or Agreement State licensing and potentially other Federal and state permitting, including NEPA review.

---

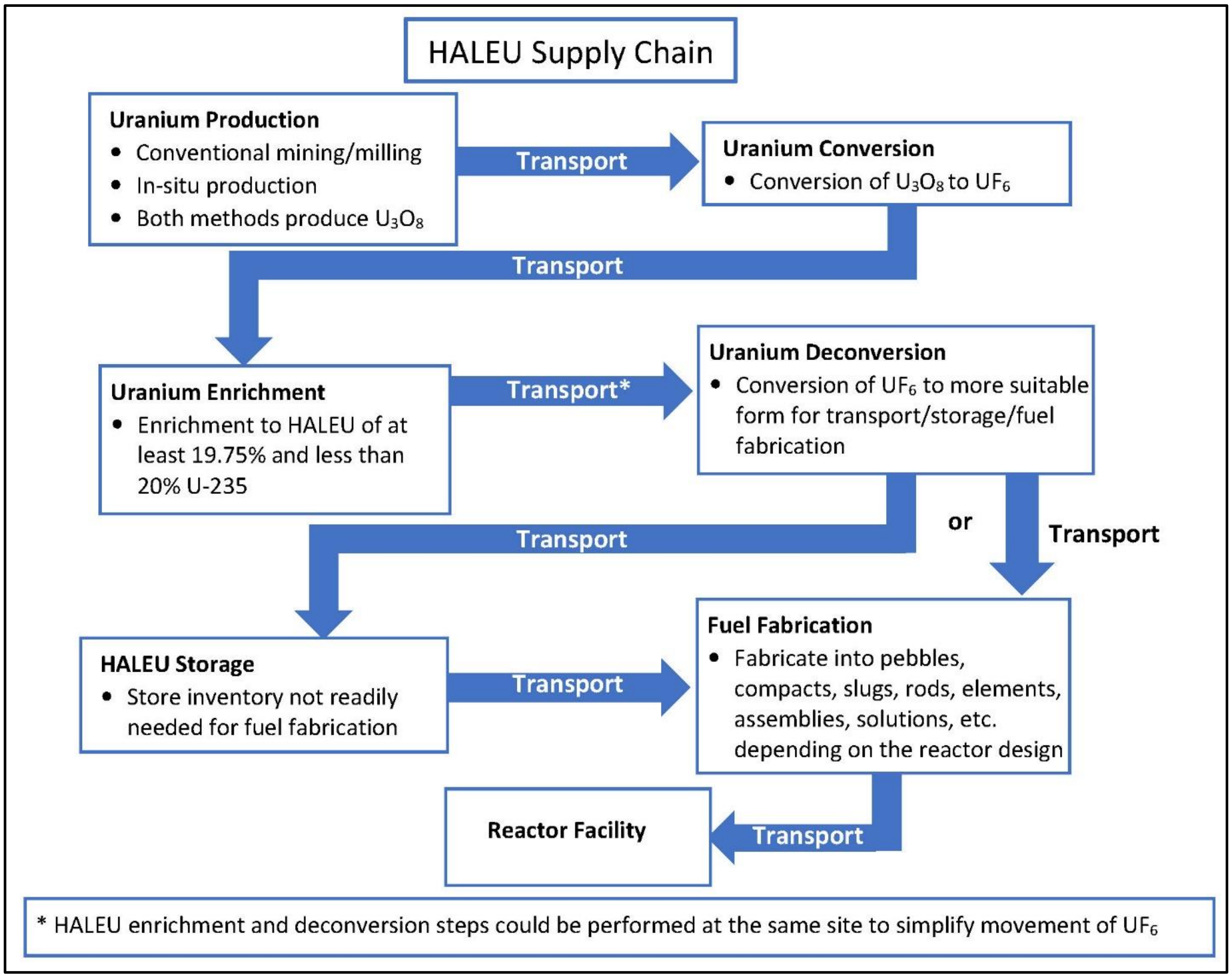
[1] HALEU is "uranium having an assay greater than 5.0 weight percent and less than 20.0 weight percent of the uranium-235 isotope" Section 2001 (d)(4) of the Energy Act of 2020 (42 U.S.C. 16281(d)(4)).

[2] Figure 1.0-1 shows transportation activities between every HALEU fuel cycle facility; however, some HALEU fuel cycle facilities may be co-located, eliminating the need to transport material between those co-located facilities.

[3] "Impacts" and "effects" are used interchangeably in this EIS.

[4] Existing facilities that produce low-enriched uranium (LEU) and highly enriched uranium (HEU) are approved to operate under existing NRC licenses, U.S. Department of Interior permits, and/or applicable Federal, state, and local permits and approvals. NEPA or equivalent evaluations for these facilities were previously performed and considered under those licensing, permitting, and approval action decisions. In this EIS, those NEPA evaluations—the majority of which are EISs and Environmental Assessments prepared by the NRC—are identified for each of the HALEU fuel cycle activities and are used to characterize the potential environmental consequences associated with the Proposed Action.

As further discussed in Section S.4, *DOE Requests for Proposals – HALEU Enrichment and Deconversion Services*, DOE is in the process of requesting proposals from commercial vendors regarding HALEU procurement and enrichment and deconversion services. Site-specific details will only be available after proposals are received in response to the relevant Requests for Proposals (RFPs). If contracts are awarded thereunder, the awardee(s) (Contractor[s]) will be required to apply to and obtain licenses/permits from appropriate regulatory authorities (e.g., the NRC, other Federal agencies, or Agreement States), and these regulatory agencies will be required to comply with applicable NEPA requirements or state equivalents. At that time, DOE expects that site-specific environmental analysis would be conducted by the relevant regulatory agency.



Key: % = percent; HALEU = high-assay low-enriched uranium; U_3O_8 = triuranium octoxide; UF_6 = uranium hexafluoride

Figure S.1-1. Components of the HALEU Supply Chain

S.1.1 What is HALEU?

Low-enriched uranium (LEU) is enriched less than 20 percent (%) uranium-235 ("U-235")[5]—the main fissile isotope that produces energy during a chain reaction (DOE, 2020a). HALEU is ''uranium having an assay

[5] Existing commercial light water reactors (LWRs) typically operate using LEU fuel enriched to 5% or less.

greater than 5.0 weight percent[6] and less than 20.0 weight percent of the uranium-235 isotope'' (Section 2001 (d)(4) of the Energy Act of 2020 [42 U.S.C. 16281(d)(4)]). Under the Proposed Action, DOE seeks to acquire HALEU enriched to at least 19.75 and less than 20 weight percent U-235.

In the United States, HALEU is currently made, in limited quantities, by blending down highly enriched uranium (HEU) (enriched to 20% or greater) (DOE, 2020a) with natural uranium or lower-enriched uranium (i.e., "downblending").[7]

S.1.2 Why Do We Need More HALEU?

The current U.S. commercial power reactor fuel cycle is based on LEU enriched to less than 5%, but many advanced reactor designs require HALEU (NEI, 2020; DOE, 2020b). Although some advanced reactor technologies are currently under development, there is no domestic commercial source of HALEU available to fuel them. The lack of such a source could impede both the demonstration of these technologies and the development of future advanced reactor technologies. Using HALEU fuel would allow advanced reactor designers to create smaller reactors that get more power with less fuel than the current fleet of reactors. HALEU would also allow developers to optimize their systems for longer life cores and other increased efficiencies (DOE, 2020a). A sufficient domestic commercial capability to produce HALEU through enrichment of natural uranium or LEU does not exist in the United States.

The Energy Act of 2020 directs DOE to establish and carry out, through DOE Office of Nuclear Energy (DOE-NE), a program to support the availability of HALEU for civilian domestic research, development, demonstration, and commercial use and make such HALEU available to members of a DOE HALEU consortium by January 1, 2026 (Section 2001(a)(1); (2)(H) of the Energy Act of 2020 [42 U.S.C. 16281(a)(1); (2)(H)]).[8]

S.1.3 Where Do We Get Uranium for Reactor Fuel Now?

The primary ore mineral of uranium is uraninite or pitchblende (NRC, 2009), though a range of other uranium minerals are found in particular ore deposits (EIA, 2020). As described on the U.S. Energy Information Administration website,[9] after the uranium ore is mined,[10] it goes through a milling process that extracts uranium from the ore, producing uranium oxides (yellowcake) (primarily triuranium octoxide

---

[6] The terms "weight percent" and "percent" (when used in reference to enrichment) are synonymous and used interchangeably in this document.

[7] Idaho National Laboratory (INL) is working to produce up to 10 metric tons (MT) of HALEU from SNF using electrochemical processing in the near term to support current testing and demonstration projects (DOE-ID, 2019).

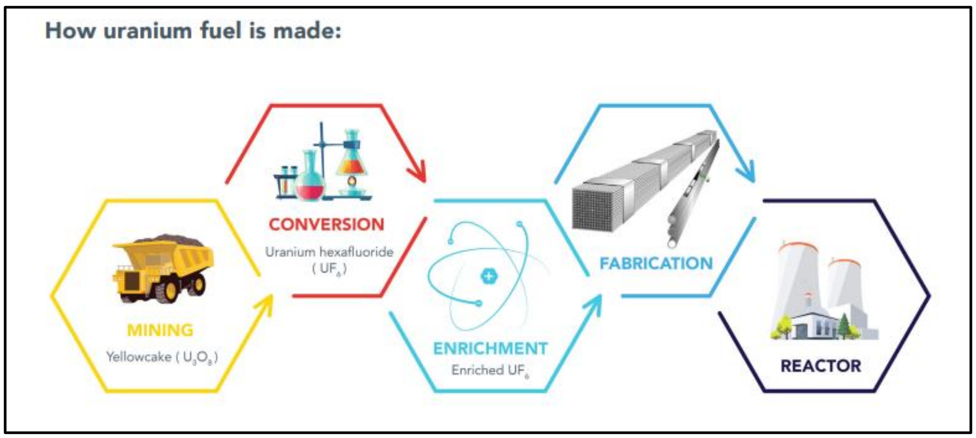
[8] DOE's activities to address Section 2001(a) of the Energy Act of 2020 are generally referred to as the HALEU Availability Program. The HALEU Availability Program includes several elements, such as conducting biennial surveys of industry stakeholders to estimate the amount of HALEU needed for domestic commercial use for the subsequent 5 years, establishing a consortium of entities involved in the nuclear fuel cycle to support the availability of HALEU (including providing survey information and purchasing HALEU made available by the Secretary for commercial use), acquiring or providing HALEU from a stockpile of uranium owned by the Department, or using enrichment technology to supply members of the consortium with HALEU for commercial use or demonstration projects. The focus of this EIS is DOE's Proposed Action, which addresses Section 2001(a)(2)(D)(v).

[9] https://www.eia.gov/todayinenergy/detail.php?id=44416

[10] As an alternative to surface and subsurface mining, the in-situ recovery (ISR) process can be used to recover uranium from low-grade ores or deeper deposits that are not economically recoverable by conventional mining and milling techniques. In the ISR process, a leaching agent, such as oxygen with sodium carbonate, is added to native groundwater and injected through wells into the subsurface ore body to mobilize the uranium. The leach solution containing the mobilized uranium is pumped from there to the surface processing plant, and then ion exchange separates the uranium from the solution. After additional purification and drying, the resultant product, a mixture of uranium oxides also known as "yellowcake," is placed in 55-gallon drums prior to shipment off-site for further processing.

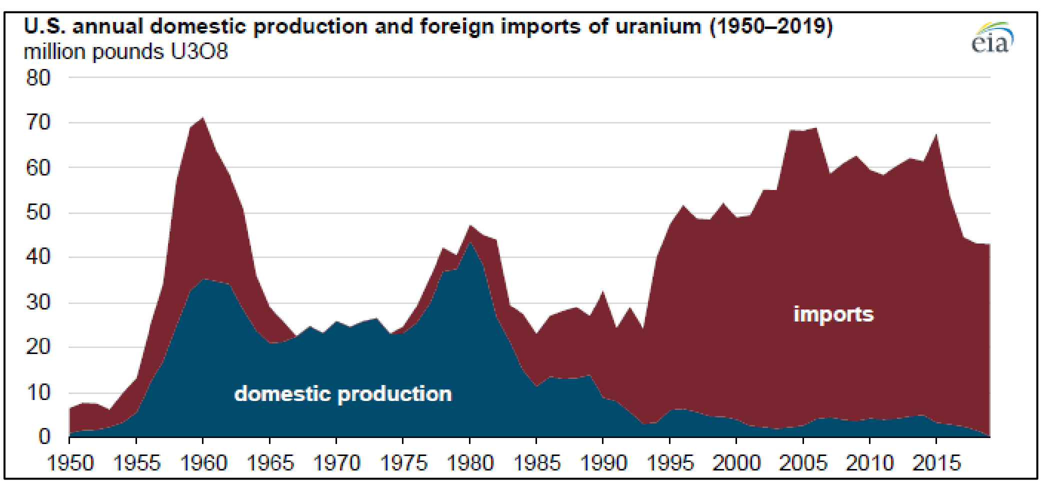
[U_3O_8] but containing other oxides such as uranium dioxide [UO_2] and uranium trioxide [UO_3]). Although the original ore contains as little as 0.02% uranium, yellowcake, primarily consisting of U_3O_8, is usually more than 80% uranium. The U_3O_8 is then processed at conversion, enrichment, and fuel fabrication facilities, where reactor fuel is fabricated for use in commercial nuclear reactors (Figure S.1-2).

In the late 1940s and early 1950s, the United States introduced incentives and trade policies encouraging the growth of domestic uranium production. After these policies ended in the 1980s, domestic production began to decline. Other countries, such as Canada and Australia, have more accessible, high-quality uranium deposits, allowing them to produce U_3O_8 at a lower cost than the United States. As shown in Figure S.1-3, since 1990, purchased imports of U_3O_8 have exceeded domestic U_3O_8 production each year. In 2019, U.S. commercial nuclear power reactor operators purchased a total of 48.3 million pounds of U_3O_8. Foreign imports of U_3O_8 supply the majority of fuel to U.S. commercial nuclear reactors, and 42.6 million pounds, or 88% of the total U_3O_8 purchased, was imported in 2019. The United States produced 174,000 pounds of U_3O_8 in 2019, 89% less than in 2018 and the lowest amount produced since the U.S. Energy Information Administration data series began in 1949.



Source: DOE (2020b)

Figure S.1-2. Uranium Fuel Production Process Overview



Source: (EIA, 2020)

Figure S.1-3. United States and Foreign Uranium Production

Canada, which has large, high-quality uranium reserves, has historically been the largest source of U.S. uranium imports. In 2019, Canada remained the largest source of imported uranium supplied to U.S. civilian nuclear power plants, followed by Kazakhstan, Australia, and Russia. Subsidies for uranium producers in Kazakhstan have led to increases in the country's uranium exports, including those to the United States.

S.1.4 How Will We Get What We Need?

There are limited options for the acquisition of HALEU. Currently, HALEU is available (in limited quantities) domestically through downblending of DOE stockpiles of HEU. Domestic production through the enrichment of LEU is limited to less than a metric tons (MT) following the demonstration of HALEU enrichment at the American Centrifuge Plant (ACP). The only source of foreign HALEU is from a state-owned Russian nuclear energy company. Future supplies, from a domestic source, sufficient to meet the projected needs of the commercial nuclear power industry[11] would require the development of a U.S.-based HALEU fuel cycle economy (Regalbuto M. C., 2020). But as indicated by many commercial entities that responded to DOE's *Request for Information (RFI) Regarding Planning for Establishment of a Program to Support the Availability of High-Assay Low-Enriched Uranium (HALEU) for Civilian Domestic Research, Development, Demonstration, and Commercial Use* (86 *Federal Register* [FR] 71055; December 14, 2021), there is a potential timing/coordination/cost issue with developing domestic commercial HALEU enrichment capability.

To address this issue, an initial public/private partnership, as proposed, is intended to accelerate development of a sustainable commercial HALEU supply capability. If successful, this partnership could provide the incentive for the private sector to incrementally expand the capacity in a modular fashion as a sustainable market develops.

Capital costs for enrichment activities at various levels are key to the deployment of a HALEU supply chain. A factor in the capital costs is the physical security requirements for possession of that portion of HALEU enriched to above 10% U-235. About 90% of the separative work[12] required to enrich natural uranium from 0.711% to 19.75% U-235 is utilized in the 0.711% to 10% enrichment range. Enrichments above 5% and below 10% (often referred to as LEU+) can be attained in the same enrichment facilities used for enriching natural uranium up to 5% enrichment. This can be done in an NRC Category III facility.[13] Uranium enriched in U-235 at 10% but less than 20% must be conducted in an NRC Category II facility, which requires significant capital investments to license, build, secure, and operate. Deconversion, storage, and fuel fabrication of HALEU enriched to 10% or higher must also be conducted in an NRC Category II facility.

---

[11] DOE estimates that by 2035 50 MT per year of HALEU would be required to support commercial use, with the demand increasing to about 500 MT per year by 2050 (INL, 2021).

[12] Separative work is the work required to separate a stream of an element (feed material) into a product stream (enriched in one isotope of the element) and a waste stream (depleted in one isotope of the element). For uranium, the feed material is natural uranium; U-235-enriched stream is the product. The waste stream consists of depleted uranium, which has a higher content of uranium-238 (U-238) and a lower content of U-235 than natural uranium. The standard unit of separative work is the separative work unit.

[13] The NRC classifies special nuclear materials and the facilities that possess them into three categories based upon the materials' potential for use in nuclear weapons, or their "strategic significance." The NRC's physical security requirements differ by category, from least stringent for Category III facilities to most stringent for Category I facilities. An NRC Category III facility (low strategic significance) includes facilities containing uranium at enrichments of less than 10 weight percent U-235. An NRC Category II facility (moderate strategic significance) includes facilities containing uranium at enrichments from 10 weight percent to less than 20 weight percent U-235. An NRC Category I facility (strategic special nuclear materials) includes facilities containing uranium at enrichments equal to or greater than 20 weight percent U-235.

S.1.5 DOE and Commercial HALEU Supply

DOE HALEU Supply

The potential near-term supply of HALEU will be from processing DOE materials at DOE facilities. These activities are estimated to produce HALEU as follows:

- Up to 10 MT of HALEU[14] produced from Experimental Breeder Reactor-II fuel at the Idaho National Laboratory (INL)
- Approximately 2.5 MT of HALEU produced from existing HEU uranyl nitrate solution in storage at H-Canyon at the Savannah River Site
- Up to 2.4 MT of HALEU produced by BWX Technologies (BWXT)[15] using HEU from Y-12 National Security Complex

These DOE capabilities could supply up to a total of 14.9 MT of HALEU. There may be other DOE inventories that could provide some additional HALEU for advanced reactor developers, but this would not stimulate commercial development of a domestic HALEU production capability nor meet near-term HALEU needs and, therefore, is not analyzed in the HALEU EIS.

Commercial HALEU Supply

There is currently an insufficient domestic commercial capability to produce HALEU. Technically, portions of the HALEU fuel cycle could use existing LEU fuel cycle facilities (mines and mills, uranium conversion facility, LEU enrichment facilities); however, DOE does not want the commercialization of the HALEU fuel cycle to negatively impact the existing baseline uranium production capacity currently supporting the U.S. domestic nuclear industry. Also, within the existing fuel cycle infrastructure, there are HALEU production gaps that would need to be filled. Enrichment of LEU to HALEU enrichment levels by a commercial entity is currently limited to the ACP, run by American Centrifuge Operating, LLC (ACO), a subsidiary of Centrus Energy Corp. ACO began construction of centrifuges in Piketon, Ohio, in 2019 under contract with DOE. On November 7, 2023, ACO marked a major milestone by delivering 20 kilograms (kg) HALEU to DOE. ACP has a capacity of 900 kg per year starting in 2024. Additionally, the ability to deconvert the uranium hexafluoride (UF_6) to a form suitable for fuel fabrication does not exist domestically for HALEU material. Only limited capabilities to fabricate HALEU fuel have been demonstrated. BWXT in Lynchburg, Virginia, has demonstrated the capability to downblend HEU to fabricate HALEU fuel. Limited HALEU fuel fabrication capability has been demonstrated, although TRISO-X, a subsidiary of X-Energy, LLC, has applied for an NRC license to fabricate tri-structural isotropic (TRISO)-based HALEU fuel at a facility to be built in Oak Ridge, Tennessee. In and of themselves, these capabilities are insufficient to support establishment of a domestic commercial HALEU fuel cycle or to provide the amount of HALEU needed in the near future. Further, the only existing enrichment facility in the United States other than ACP is the National Enrichment Facility (NEF) owned by Urenco USA (UUSA), formerly "URENCO (LES)," located in Eunice, New Mexico. NEF is an NRC Category III facility, licensed to possess LEU, not an NRC Category II facility, licensed to possess HALEU.

The first three steps in the commercial HALEU fuel cycle are the same as what currently occurs in the LEU fuel cycle. This includes enrichment up to LEU (i.e., less than 5%). Enrichments below 10% (LEU+)[16] could

[14] Five MT is to be provided to Oklo Inc. (Oklo) for use in the Aurora reactor.

[15] BWXT is NRC licensed.

[16] Some enrichment at levels above 5% but below 10% (often referred to as LEU+) would be for advanced fuels for LWRs. Production of LEU+ for LWRs is not within the scope of this analysis and would be separately conducted by NRC-licensed commercial facilities.

occur in an NRC Category III facility. Enrichments in the 10% to 19.75% range (HALEU) would need to be performed in an NRC Category II facility. The enrichment facility in Piketon, Ohio, is the only NRC-licensed Category II facility; Nuclear Fuel Services/BWXT in Erwin, Tennessee, and BWXT in Lynchburg, Virginia, are the only NRC-licensed Category I facilities (able to possess HEU).

S.2 Purpose and Need for Agency Action

One of the aspects of a clean energy future is sustainment and expanded development of safe and affordable nuclear power. One key element of that goal is the availability of fuel to power advanced reactors. The Energy Act of 2020 directs DOE "to establish and carry . . . out a program to support the availability of HA-LEU for civilian domestic research, development, demonstration, and commercial use." DOE is committed to support the development and deployment of the HALEU fuel cycle and to acquire and provide HALEU as authorized by Congress in Section 2001 of the Energy Act of 2020. Further, Section 3131 of the recently enacted National Defense Authorization Act for Fiscal Year 2024 (Nuclear Fuel Security Act of 2023), among other things, seeks to expeditiously increase domestic production of HALEU to meet the needs of advanced nuclear reactor developers and the consortium established under Section 2001(a) of the Energy Act of 2020.

There is currently insufficient private incentive to invest in commercial HALEU production due to the current market base. There is also insufficient incentive to invest in the necessary commercial deployment of advanced reactors, because the domestic HALEU fuel cycle does not exist. This concern is a consistent theme in the industry responses to DOE's *Request for Information (RFI) Regarding Planning for Establishment of a Program to Support the Availability of High-Assay Low-Enriched Uranium (HALEU) for Civilian Domestic Research, Development, Demonstration, and Commercial Use* (86 FR 71058). These responders emphasized the importance of the HALEU consortium that is called for in the Energy Act of 2020 and that DOE established on December 7, 2022 (87 FR 75048). Responders also emphasized the opportunity for DOE to be an agent for stability (both in assuring HALEU availability and market price certainty) during the initial phase of HALEU fuel production.

DOE predicts that by the mid-2020s, approximately 22 MT of uranium will be needed for initial core loadings to support reactor demonstrations and DOE test and research reactors that were converted from HEU fuel with a high-fidelity HALEU (up to 19.75 weight percent U-235 enrichment) demand of between 8 and 12 MT of HALEU annually for the next 10 years (Regalbuto M. C., 2022). HALEU demand for commercial use is projected to increase to over 50 MT per year of HALEU by 2035 and over 500 MT of HALEU per year by 2050 (INL, 2021).

Table S.2-1 shows the results of an industry survey taken by the Nuclear Energy Institute (NEI) in 2021. The NEI surveyed advanced reactor developers and fuel designers that plan to utilize HALEU, to identify their estimated annual needs through 2035. This survey estimated industry requirements, driven by a more aggressive estimate of advanced reactor construction, increasing at a more rapid pace than the DOE estimates to over 600 MT of HALEU at between 10.9% and 19.75% enrichment per year by 2035.

Both DOE and industry groups have recognized that DOE action is needed to facilitate the development of the necessary infrastructure, to support near-term research and demonstration needs, and to support the U.S. commercial nuclear industry. (Regalbuto M. C., 2022; NEI, 2022). The NEI recognized that the main challenge to establishing a commercial HALEU-based reactor economy is the upfront capital investment required to establish the enrichment capability to produce quantities of HALEU suitable for fabrication into the fuel needed for the various types of advanced nuclear reactor designs (NEI, 2022).

Table S.2-1. Nuclear Energy Institute Survey Results for Estimated HALEU Demand Through 2035

Year [(a)]	*Total MT/yr* [(b)]	*Cumulative MT*	*Year* [(a)]	*Total MT/yr* [(b)]	*Cumulative MT*	*Year* [(a)]	*Total MT/yr* [(b)]	*Cumulative MT*
2022	1.8	1.8	2027	78.7	204.1	2031	252.3	954.0
2023	7.7	9.5	2028	130.8	334.9	2032	375.3	1,392.2
2024	18.0	27.5	2029	151.7	486.6	2033	454.2	1,783.4
2025	25.8	53.3	2030	215.0	701.6	2034	527.1	2,310.5
2026	72.1	125.4				2035	613.8	2,924.3

Source: (NEI, 2021)

Key: % = percent; HALEU = high-assay low-enriched uranium; MT = metric tons; MT/yr = metric tons per year; NEI = Nuclear Energy Institute; U-235 = uranium-235

Notes:

[a] This represents the year the material is needed is for fuel fabrication. Insertion in the reactor and reactor operations would occur in a later year.

[b] Material needs listed include enrichments between 10.9% and 19.75% U-235 and do not include utilities that are considering enrichments between 5% and 10%.

S.3 DOE Notice of Intent and Opportunity for Comment

On June 5, 2023, DOE-NE published a Notice of Intent in the *Federal Register* (88 FR 36573) to prepare an EIS for HALEU activities in support of commercial production of HALEU fuel (the “HALEU EIS”). Publication of the Notice of Intent initiated a 45-day scoping period.

DOE-NE hosted three consecutive virtual scoping meetings at 6:00 p.m. Eastern Time (ET), 8:00 p.m. ET, and 10:00 p.m. ET on June 21, 2023. The purpose of these meetings was both to allow the public to familiarize themselves with the Proposed Action, the EIS, and the NEPA process, as well as provide opportunities to submit comments on the scope of the Draft EIS.

During the scoping period, DOE received 43 comment documents, in which 282 comments were identified. DOE also received 1,675 comment documents, mostly identical, submitted through www.regulations.gov. From those 1,675 comment documents, 29 individual comments were identified. DOE reviewed the individual comments to help DOE further identify concerns and potential issues to be considered in the EIS.

DOE is offering opportunities for public review and comment, including public hearings, on this Draft HALEU EIS. Public involvement opportunities and public hearing information will be announced in newspapers in communities with historical ties to uranium fuel cycle activities and in other communications with stakeholders. Comments received during the public comment period will be evaluated in preparing the Final HALEU EIS. Comments received after the close of the public comment period will be considered to the extent practicable. DOE plans to publish the Final HALEU EIS in 2024. DOE will issue a Record of Decision no sooner than 30 days after publication, in the *Federal Register*, of the Notice of Availability of the Final HALEU EIS.

S.4 DOE Requests for Proposals – HALEU Enrichment and Deconversion Services

On June 5, 2023, the DOE Idaho Operations Office published for comment two Draft RFPs for (1) HALEU enrichment capability in the United States (DOE, 2023a) and (2) U.S. capabilities in HALEU deconversion to oxide, metal, or other forms (DOE, 2023b).

Under the *Draft Request for Proposals for High-Assay Low-Enriched Uranium (HALEU) – Enrichment Services* (the “Draft Enrichment RFP”) (DOE, 2023a), DOE solicited comments from industry regarding

DOE's proposal to acquire, through procurement from commercial sources, HALEU UF_6 enriched to a minimum of 19.75 and less than 20 weight percent U-235 as soon as possible to secure a more robust, longer-term HALEU production capability. DOE received comments on the Draft RFPs in July 2023 and published the Enrichment RFP in January 2024 (DOE, 2024). Under the January 2024 Enrichment RFP, which identifies a 10-year period of performance, enrichment may be performed in one or more steps and locations per awardee. Enrichment of uranium up to less than 5% in the U-235 isotope may be performed either within the continental United States or in an allied or partner nation. All enrichment to greater-than-or-equal-to 5% and less than 20% must be performed in the continental United States, and HALEU (in the form of UF_6) storage must occur at a physical location within the continental United States.[17] DOE may enter into multiple agreements as a result of the Enrichment RFP.[18]

While the Enrichment RFP does not include the exact parameters that were extrapolated from the Draft Enrichment RFP (e.g., 145 MT of HALEU per procurement, 6 years of facility operations), DOE considers the assumption of 6 years of facility operations reasonable and applicable for the purposes of analysis in this EIS due to the estimated timeline for the design, licensing, and readiness activities required prior to the start of enrichment operations. The Enrichment RFP no longer specifies a total amount of material as the award will be for an Indefinite Delivery/Indefinite Quantity contract, however, DOE estimates that a maximum of 290 MT HALEU will be needed to establish a temporary domestic demand for HALEU to stimulate a diverse, domestic commercial supply that would ultimately lead to a competitive HALEU market.

The *Request for Proposals for High-Assay Low-Enriched Uranium (HALEU) – Deconversion Acquisition* (the "Deconversion RFP") was published in November 2023 (DOE, 2023c). Under the Deconversion RFP, DOE seeks to acquire domestic HALEU deconversion services for the HALEU UF_6 and storage until future fuel fabrication. This RFP also requires that all deconversion and subsequent storage activities must occur at a physical location within the continental United States.

The Deconversion RFP seeks to acquire deconversion and related services to convert the acquired, enriched UF_6 to forms such as metal and oxide. The Deconversion RFP identified a potential 10-year duration for deconversion activities. Before facility operation could begin, facility design and preparation/submittal of applications for permits and licenses must be performed, including environmental report production, and regulatory review and approval.

This information forms the basis of the quantity of HALEU and the duration of facility operations evaluated in this EIS.

Due to the parallel nature of the development of this EIS and the DOE acquisition efforts for HALEU enrichment and deconversion, no specific sites have yet been identified for evaluation in this EIS. Therefore, this EIS uses existing or proposed fuel cycle facilities and their associated NEPA documents as the basis for evaluating representative impacts for the potential fuel cycle facilities. The scope of the Draft EIS is based on the services sought in the Enrichment RFP and Deconversion RFP, and related activities. This scope is expected to be bounding; however, if incoming proposals suggest changes outside of the scope, DOE will address such changes in the Final EIS or in a supplemental NEPA review, as applicable.

[17] Acquisition of UF_6 would be the responsibility of the commercial entity. Uranium and conversion services, while preferably sourced from U.S. mines and conversion facilities, could be sourced from foreign sources.

[18] As clarified during the scoping meetings, DOE envisions the possibility of multiple awards that could total up to 290 MT of HALEU.

S.5 Proposed Action and Related Activities

HALEU can exist in many forms. Those considered in this EIS are triuranium octoxide (U_3O_8) uranium hexafluoride (UF_6), uranium metal, and uranium dioxide (UO_2). When addressing the amount of HALEU considered under the Proposed Action, unless specifically identified as existing in another form, the quantities are those of HALEU in metallic form (i.e., 50 MT of HALEU and 290 MT of HALEU refers to MT of HALEU in metallic form).

The Proposed Action is to acquire, through procurement from commercial sources, HALEU enriched to at least 19.75 and less than 20 weight percent U-235 over a 10-year period of performance, and to facilitate the establishment of commercial HALEU fuel production. The Proposed Action addresses Section 2001(a)(2)(D)(v) of the Energy Act of 2020 for the acquisition of HALEU produced by a commercial entity using enrichment technology and making it available for commercial use or demonstration projects. Given the variety of HALEU applications, the initial capability is intended to be flexible and able to accommodate the following:

- Enrichments of U-235 to greater than 5 and less than 20 weight percent
- Production of up to 290 MT of HALEU
- Modular HALEU fuel cycle facility design concepts to accommodate future growth
- Deconversion of UF_6 to forms suitable for production of a variety of uranium fuels, to include oxides and metal

This EIS will address the following activities facilitating the commercialization of HALEU fuel production and acquisition of up to 290 MT[19] of HALEU:

- Extraction and recovery of uranium ore (from domestic and/or foreign sources)
- Conversion of the uranium ore into UF_6
- Enrichment (possibly in up to three steps)
    - Enrichment to LEU to no more than 5 weight percent U-235
    - Enrichment to HALEU greater than 5 and less than 10 weight percent U-235
    - Enrichment to HALEU from 10 to less than 20 weight percent U-235 in an NRC Category II facility
- Deconversion of the UF_6 to uranium dioxide, metal, and potentially other forms in an NRC Category II facility
- Storage in an NRC Category II facility
- DOE acquisition of HALEU
- Transportation of uranium/HALEU between facilities

In addition to the activities above, there are several reasonably foreseeable activities that could result from implementation of the Proposed Action. They include the following:

- Fuel fabrication for a variety of fuel types in an NRC Category II facility
- Reactor (demonstration and test, power, isotope production) operation
- Spent fuel storage and disposition

[19] Based on the DOE RFPs discussed in Section S.4, *DOE Requests for Proposals – HALEU Enrichment and Deconversion Services*, this EIS assumes a 6-year period of HALEU production resulting in 290 MT of HALEU total across multiple awards (i.e., rounding to approximately 50 MT of HALEU per year).

While not specifically a part of the Proposed Action, the impacts from these reasonably foreseeable activities are acknowledged and addressed to the extent practicable in this EIS. Many of the specifics associated with these activities are subject to factors beyond the scope of the Proposed Action. The fuel requirements for advanced reactors would be dependent not only upon which reactor designs are ultimately licensed and operated, but also to what extent the commercial operation of advanced reactors is successful. This in turn impacts both the type and number of fuel fabrication facilities needed and the ultimate disposal of HALEU fuel. Therefore, a detailed assessment of the impacts of these activities would be speculative and is not included in the EIS.

S.6 Decisions to be Supported

Briefly, this EIS provides information in support of a decision as to whether to (1) facilitate the establishment of commercial HALEU fuel production capability and (2) acquire (through procurement of enrichment and deconversion services), from commercial sources, up to 290 MT of HALEU enriched to at least 19.75 and less than 20 weight percent U-235 over a 10-year period of performance.

While this EIS will provide information that could be used to identify impacts from the construction and operation of HALEU fuel cycle facilities, the selection of specific locations and facilities will not be a part of the Record of Decision for this EIS. The decisions to be supported are whether or not to acquire HALEU from commercial sources and to facilitate commercial HALEU fuel production capability.

S.7 Alternatives Analyzed

S.7.1 Proposed Action and Related Activities

The Proposed Action is to acquire, through procurement from commercial sources, HALEU enriched to at least 19.75 and less than 20 weight percent U-235 over a 10-year period of performance and to facilitate the establishment of commercial HALEU fuel production. The Proposed Action addresses Section 2001(a)(2)(D)(v) of the Energy Act of 2020 for the acquisition of HALEU produced by a commercial entity using enrichment technology and making it available for commercial use or demonstration projects.

Given the variety of HALEU applications, the initial capability is intended to be flexible and able to accommodate the following:

- Enrichments of U-235 to greater than 5 and less than 20 weight percent
- Production of up to a total of 290 MT of HALEU
- Modular HALEU fuel cycle facility design concepts to accommodate future growth
- Deconversion of UF_6 to forms suitable for production of a variety of uranium fuels, to include oxides and metal

For a more detailed description of the Proposed Action and related activities, see Section S.5, *Proposed Action and Related Activities*.

S.7.1.1 Uranium Mining and Milling

The production of 50 MT of HALEU fuel per year[20] would require mining operations to produce about 2,500 MT of U_3O_8 (commonly referred to as yellowcake) either through conventional mining and milling or through in-situ recovery (ISR). If conventional mining techniques are used, this would require the mining of about 2.6 MT of uranium-bearing ores with a uranium content of 0.1%. To encourage the use of a domestic supply of uranium for the commercialization of the HALEU fuel cycle, DOE has identified domestically sourced uranium from existing capacity as the preferred option for acquiring uranium (yellowcake). However, uranium could be imported,[21] as most supplies of uranium currently are.

U.S. uranium mines are primarily located in a region from the Texas Gulf Coast to the U.S. West Coast and the Canadian border. Historically, the majority of mining activity was in Colorado, New Mexico, Arizona, Utah, and Wyoming (Figure S.7-1). Currently, very little uranium is mined in the United States; about 8 MT were mined in 2020, down from 227 MT in 2018 (Nuclear Energy Agency and International Atomic Energy Agency, 2023, p. 75 Table 1.17).

To encourage the use of a domestic supply of uranium in support of the commercialization of the HALEU fuel cycle, the Enrichment RFP (Solicitation No. 89243223RNE000031, *Purchase of High-Assay Low-Enriched Uranium (HALEU) – Enrichment*) identified domestic supplies of uranium as the preferred source, and North American supplies as the next preferred source, although other foreign sources (allied or partner nations) could be utilized. The Enrichment RFP also identified existing mining capacity as preferred. While not required, it is anticipated that mines selected would have existing operational licenses. Having existing licenses would facilitate or shorten the startup period for the start or resumption of uranium mining activities.

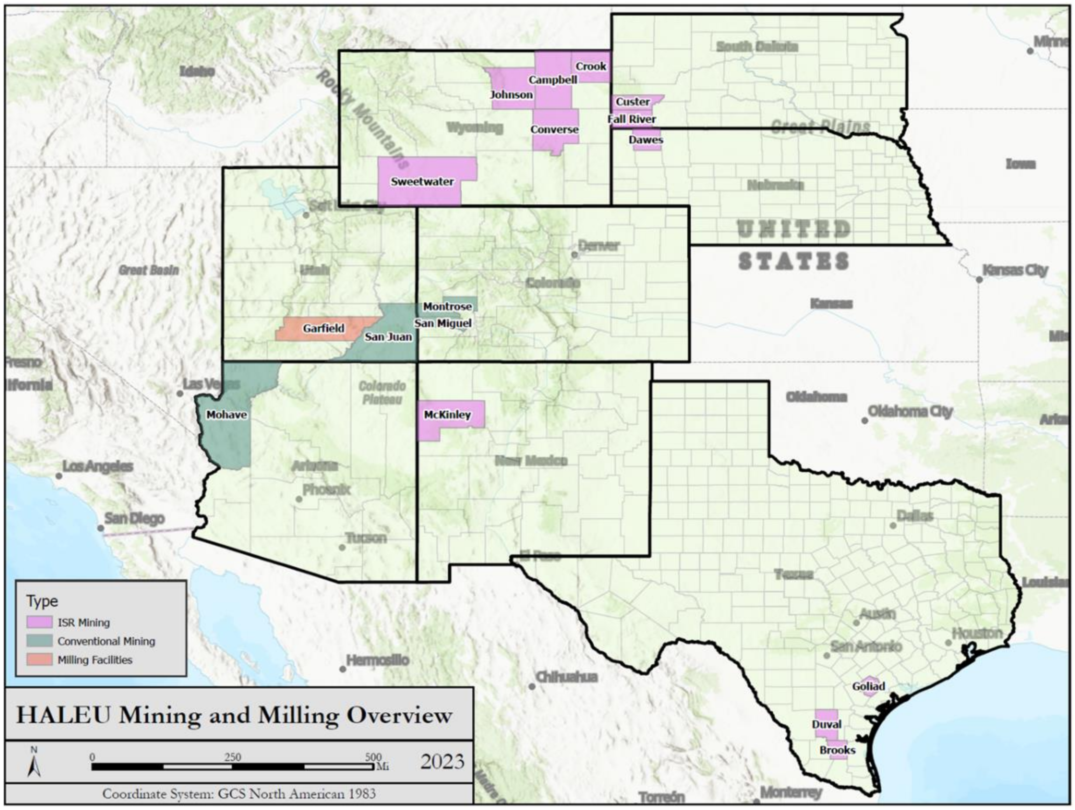
The majority of the uranium milling processing facilities receive coarse uranium-bearing ore or ore slurries excavated by conventional underground or above-ground mining techniques. Crushed uranium-bearing ore or slurry is hauled to a nearby, often co-located, mill where it is crushed and undergoes a chemical process to remove the uranium. The uranium is concentrated to produce a material called "yellowcake."

A commercial ISR facility consists of both an underground and a surface infrastructure (see Figure S.7-2). The underground infrastructure includes injection and production wells drilled to the uranium mineralization zone, monitoring wells drilled to the surrounding ore body aquifer and to the adjacent overlying and underlying aquifers, and perhaps deep injection wells to dispose of liquid wastes (NRC, 2009).

ISR facilities also include a surface infrastructure that supports uranium processing. The surface facilities can include a central uranium processing facility, header houses to control flow to and from the well fields, satellite facilities that house ion-exchange columns and reverse osmosis equipment for groundwater restoration, and ancillary buildings that house administrative and support personnel. Surface impoundments, such as solar evaporation ponds, may be constructed to manage liquid effluents from the central processing plant and the groundwater restoration circuit. The surface extent of a full-scale (i.e., commercial) ISR facility encompasses about 2,500 to 16,000 acres and includes a central processing facility and supporting surface infrastructure for one or more well fields (sometimes called mine units). However, the total amount of land disturbed by such infrastructure and ongoing activities at any one time is much smaller, and only a small portion around surface facilities is fenced to limit access (NRC, 2009).

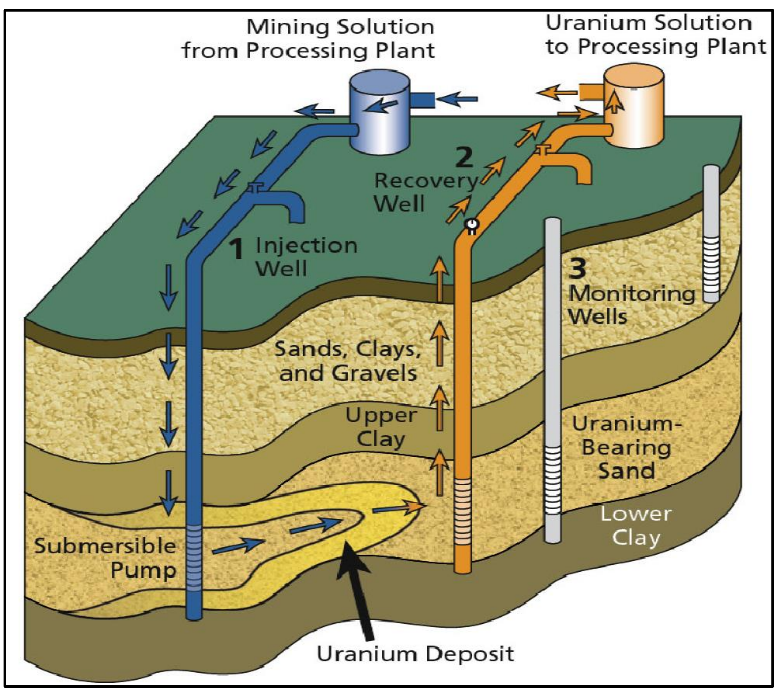
[20] As previously discussed, this EIS assumes a 10-year period of performance, and a 6-year period of HALEU production resulting in 290 MT HALEU total across multiple awards (i.e., rounding to approximately 50 MT of HALEU per year).

[21] Preferably from a North American source.



Key: GCS = geographic coordinate system; HALEU = high-assay low-enriched uranium; ISR = in-situ recovery

Figure S.7-1. Uranium Mines in the United States



Source: NRC (2011)

Figure S.7-2. An In-Situ Recovery Operation

S.7.1.2 Conversion of U_3O_8 to UF_6

The production of 50 MT of HALEU fuel per year[22] would require the conversion of about 2,500 MT of U_3O_3 (yellowcake) into about 3,100 MT of UF_6.

Under the Proposed Action, conversion could occur at either any existing conversion facility or at a new facility. The Enrichment RFP (DOE, 2024) identified U.S. conversion services as preferred, with North American services next preferred, and foreign-provided services (allied or partner nations) also allowed. There is one NRC-licensed conversion facility in the United States: the Honeywell International Metropolis Works Uranium Conversion Facility (the "Metropolis facility") near Metropolis, Illinois. In April 2023, the plant resumed operations after over 5 years in a ready-idle (not operating but easily restarted) mode. Honeywell announced in 2021 its plans to reopen the facility in early 2023.[23] The Metropolis facility has licensed capacity to produce up to 15,000 MT of UF_6. The requirements for HALEU commercialization would be about 20% of the plant's capacity.

The Metropolis facility is about 1,000 acres and borders the Ohio River, just northeast of the city limits of Metropolis, Illinois. Of the 1,000 acres, the processing facility is contained within a 59-acre fenced restricted area. The developed portion of the Metropolis facility (Figure S.7-3) contains the primary process buildings—the Feed Materials Building and associated pads, potassium hydroxide muds building, wet processing/sodium removal building, and the sampling plant—and about a dozen support facilities (NRC, 2019, pp. 2-1).

Source: NRC (2019, pp. 3-32)

Figure S.7-3. Developed Portion of the Metropolis Facility

The developed portion of the Metropolis facility has the appearance of a typical industrial complex. The area includes industrial or warehouse-type buildings. Most of the buildings are low, with the Feed Materials Building being the tallest, at six stories. Several of the structures have exhaust stacks with pollution control equipment. In addition to the buildings, the area includes open-air storage areas,

---

[22] As previously discussed, this EIS assumes a 10-year period of performance and a 6-year period of HALEU production resulting in 290 MT of HALEU total across multiple awards (i.e., rounding to approximately 50 MT of HALEU per year).

[23] In early 2023, DOE awarded ConverDyn (the marketing arm for the Metropolis Works Plant) a $14 million award for conversion services supporting the domestic uranium reserve. This award is separate from the Proposed Action.

settling ponds, and parking lots. The protected area is enclosed in a double chain-link fence (NRC, 2019, pp. 3-31).

S.7.1.3 Uranium Enrichment to HALEU

The production of 50 MT of HALEU per year[24] would require the enrichment of about 3,100 MT of natural uranium (in the form of UF_6) into about 75 MT of HALEU as UF_6 and would generate approximately 2,900 MT of depleted[25] UF_6. The Enrichment RFP required that enrichment of uranium to greater than or equal to 5% and less than 20% in the U-235 isotope occur in the continental United States (DOE, 2024). The RFP does allow enrichment to less than 5% to occur at foreign (allied or partner nations) locations. Several options are available to support the domestic, commercial production of HALEU enriched to at least 19.75 and less than 20 weight percent U-235:

- Construction of new enrichment facilities capable of using natural uranium as feed and producing HALEU enriched to at least 19.75 and less than 20 weight percent U-235
- Modification of existing enrichment facilities that currently produce LEU
- Use of existing enrichment facilities to produce LEU (of up to but less than 10% U-235) and augmentation of the existing facilities with new facilities to enrich the LEU to HALEU

There are two primary means of enrichment. The more technologically mature means is gas centrifuge enrichment, and the other is laser enrichment. Gas centrifuge enrichment is the current process by which commercial enrichment is being performed in the United States. A centrifuge consists of a large rotating cylinder (rotor) and piping to feed UF_6 gas into the centrifuge and then withdraw enriched and depleted UF_6 gas streams. The rotor spins at a high rate of speed inside a protective casing, which maintains a vacuum around the rotor. The centrifugal force produced by the spinning rotor creates radial separation, in which the heavier uranium-238 (U-238) hexafluoride molecules concentrate near the rotor wall and the lighter U-235 hexafluoride molecules collect closer to the axis of the rotor (USEC, 2004). In addition to the radial separation of isotopes, separation along the vertical axis (axial) is also induced in response to a thermal gradient along the length of the rotor. The hotter gas stream rises, while the relatively cooler gas stream flows downward.

The combination of radial and axial separation results in a relatively large assay change between the top and bottom of the centrifuge. Enriched UF_6 is extracted by a scoop at the top of the centrifuge while depleted material is removed from a scoop at the bottom.

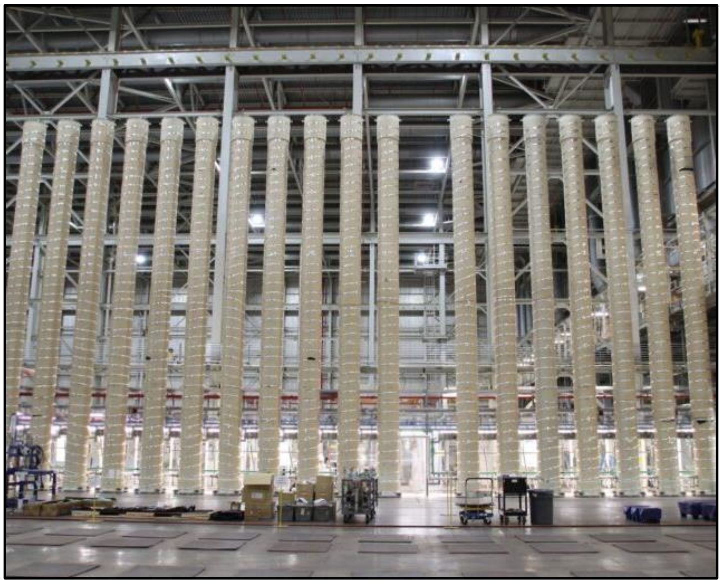
A single centrifuge, while more efficient than older enrichment technologies, cannot enrich natural uranium to HALEU (or even to current commercial light water reactor [LWR] enrichments of less than 5%) and cannot process the volume of material needed to enrich signifiant quantities of uranium. Therefore, the centrifuges are combined in both series and parallel in what is called a cascade. The cascade allows for processing more uranium and allows for the extraction of uranium enriched to different levels at any point during the enrichment process.

Uranium enrichment to LEU (3% to 5%) is currently occurring at Urenco (currently Urenco USA, or UUSA), with LEU+ (uranium enriched to between 5% and 10%) enrichment planned. DOE currently has a contract with ACO for production of up to 900 kg HALEU in 2024 using the 16-centrifuge demonstration cascade

[24] As previously discussed, this EIS assumes a 6-year period of HALEU production resulting in 290 MT of HALEU total across multiple awards (i.e., rounding to approximately 50 MT of HALEU per year).

[25] Depleted uranium consists of uranium with less than the naturally occurring percentage of the U-235 isotope, which is less than 0.7% U-235.

in, Piketon, Ohio (Figure S.7-4).[26] On November 7, 2023, Centrus announced the first delivery of HALEU to DOE (Centrus Energy Corp, 2023a).



Source: Centrus Energy Corp (2023b)

Figure S.7-4. Centrus Centrifuge Demonstration Cascade

Separately, GE-Hitachi had planned a laser enrichment facility for its complex in Wilmington, North Carolina, which would have been a first-of-a-kind facility for the United States. In this enrichment process, laser-emitted light is selectively absorbed by U-235 and not U-238. The absorbed energy ionizes (removes an electron from) the U-235, allowing it to be separated from the non-ionized U-238. As with centrifuge enrichment, a single laser does not enrich the uranium to product levels (both LEU and HALEU) in a single step, and the lasers are arranged in cascades to generate the desired enrichment at production-level quantities. A license was granted by the NRC in 2009, but the facility was not constructed and this license has been terminated.

Although the location of enrichment is not limited to existing facilities/locations, together these three facilities represent the range of possible options under the Proposed Action, from converting an existing facility to building a completely new facility.

S.7.1.4 HALEU Deconversion

The production of 50 MT of HALEU fuel per year[27] would require the conversion of about 75.7 MT of HALEU as UF_6 into a form suitable for fabrication into reactor fuel. This could be 50 MT of uranium metal, 57 MT of UO_2, or an equivalent amount in another chemical form.[28] DOE may choose to enter into multiple deconversion contracts under the Proposed Action. The deconversion facilities need not be of

[26] NEPA documentation for the demonstration effort has been prepared (NRC, 2021a). The demonstration effort is not a part of the Proposed Action.

[27] As previously discussed, this EIS assumes a 6-year period of HALEU production resulting in 290 MT of HALEU total across multiple awards (i.e., for analysis purposes rounding to approximately 50 MT of HALEU per year).

[28] It is possible that not all of the HALEU in the form of UF_6 would be processed through the deconversion facility. Some may be sent directly to fuel fabricators for conversion into their preferred form. The values used here represent the maximum throughput for the deconversion facility to support the production of 290 MT of HALEU and DOE estimates of 50 MT of HALEU per year over a 6-year period of deconversion operations. It is anticipated that multiple facilities would be used to deconvert the full amount of HALEU addressed in the Proposed Action.

the same size (capacity) as the enrichment facilities. Advanced reactor designs may utilize HALEU in different forms. UO_2 is the form currently used by commercial LWRs and may be used in some advanced reactors. TRISO fuel, a uranium/oxide/carbide fuel, is being considered for, among others, many liquid metal reactors. Molten salt reactors (MSRs) use fuel in the form of a molten fluoride or chloride salt.

Deconversion of the HALEU from UF_6 into a form suitable for storage or to be provided to fuel fabricators could include conversion into any of the forms identified above, including uranium metal. All of these processes are chemical conversions. Although deconversion into either a uranium metal or UO_2 has been assumed for this EIS, the form of HALEU to be stored or provided to fuel fabricators is not ripe for decision.

Deconversion currently is performed at several LEU fuel fabrication facilities. In the LEU fuel cycle, the LEU in the form of UF_6 is shipped directly to the LEU fuel manufacturers. But because existing deconversion capabilities at these fuel fabrication facilities are designed for LEU and not HALEU, without modification, these facilities would not be amenable to HALEU deconversion.

Since there is no deconversion facility capable of handling at least 19.75% HALEU in the United States, facilities would need to be constructed or existing facilities modified. Under the Proposed Action, possible locations could include one that is co-located with the enrichment facility, co-located with a fuel fabrication facility, located at another industrial site, or independently located at a greenfield site (i.e., a previously undeveloped site). The facility would have to be an NRC Category II facility, with security features meeting NRC requirements for the possession of uranium enriched to between 10% and less than 20%. Security could be provided for the facility itself or for the site where the facility is located (e.g., at a site with appropriate existing security).

The resulting products would then be packaged in HALEU-certified containers for storage and stored by the awardee(s) until there is a need to ship it to the fuel fabricator.

S.7.1.5 HALEU Storage

The Proposed Action includes storage in a facility (or facilities) to store the full amount to be acquired by DOE under the Proposed Action. Therefore, storage facilities sufficient to meet the maximum amount under the Proposed Action would require a storage capacity of up to 290 MT of HALEU enriched to at least 19.75 and less than 20% U-235. The most likely forms for the HALEU to be stored would be following enrichment and in the form of UF_6[29] (total quantity of material of 440 MT) or following deconversion as uranium metal (290 MT) or uranium dioxide (340 MT). No specific location for the storage facility (or facilities) is proposed. They could be co-located with the enrichment facilities or the deconversion facilities, which may be co-located with an enrichment facility or a fuel fabrication facility or independently located. A storage facility could reside within an existing building if co-located. However, as a conservative approach, the Proposed Action analysis assumes the construction and operation of a new HALEU storage facility at one of these locations.

The design would be required to meet NRC criteria for the storage of HALEU (such as seismic capability, tornado protection, etc.) and would include the necessary environmental controls to protect staff and the environment. The storage facility would be an NRC Category II facility, with security features meeting NRC requirements for the possession of uranium enriched to between 10% and less than 20%.

Operations at the storage facility would be limited to (1) receipt and shipment of HALEU containers by truck, (2) handling of HALEU containers with industrial equipment such as forklifts, and (3) monitoring and

[29] Commercial entities providing enrichment services are required to propose the capability to store UF_6 as part of the proposals in response to the Enrichment RFP.

inspection of stored HALEU containers. Security could be provided for the facility itself or by existing security of the site location.

S.7.1.6 HALEU Transportation

The Proposed Action consists of activities that would be performed at many different facilities across the United States. Although some of the facilities for multiple steps in the fuel cycle could be co-located,[30] no specific facilities have been identified under the Proposed Action, and therefore transportation of the radioactive materials used in the HALEU fuel cycle could involve the transportation of materials between up to seven sites. The EIS assumes, for analytical and bounding purposes, the following potential transportation scenarios:

- Up to 15 million MT (2.6 million MT annually) of uranium-bearing ore from conventional mines to milling facilities
- Up to 14,000 MT (2,500 MT annually) of yellowcake from either mills, ISR facilities, or foreign sources to the Metropolis or new conversion facility[31]
- Up to 18,000 MT (3,100 MT annually) of UF_6 from the Metropolis facility, new conversion facility, or foreign sources to LEU enrichment facilities
- Up to 1,800 MT (310 MT annually) of 5% LEU from LEU enrichment facilities to HALEU enrichment facilities
- Up to 440 MT (75 MT annually) of enriched UF_6 from the HALEU enrichment facilities to the deconversion/storage facility (or facilities)
- Up to 330 MT (56 MT annually) of deconverted HALEU, in the form of UO_2, from the deconversion/storage facilities to fuel fabrication facilities

Transportation of these materials would be carried out in the same manner as that currently done in support of the LEU fuel cycle, by truck using type A packaging. This type of packaging must withstand the conditions of normal transportation without the loss or dispersal of the radioactive contents. DOE is engaged with the commercial sector to develop transportation and storage casks specifically designed and certified for HALEU. That effort is not a part of the Proposed Action.

S.7.1.7 Related Post-Proposed Action Activities

It is reasonable to assume that the HALEU acquired under the Proposed Action would ultimately be used, although exactly where and by whom cannot be determined at this time. The steps associated with the use of the HALEU would be fabrication into fuel at a fuel fabrication facility (either a new facility or modified existing facility), use in a HALEU-fueled advanced reactor, and storage and disposal of the SNF. Although these are reasonably foreseeable actions resulting from implementation of the Proposed Action, many of the specifics are unknown. Therefore, a detailed analysis of the impacts of these activities would be speculative. These activities are discussed to the extent possible in the following sections.

Fuel Fabrication

Fuel fabrication is the last step in the process of turning natural uranium into nuclear fuel. Nuclear reactor fuel is specifically designed for particular types of reactors.

[30] For example, enrichment, deconversion, and storage facilities could all be co-located. Co-location would reduce the amount of material transported between sites.

[31] The analysis of the Proposed Action assumes that the natural uranium would be domestically mined. The Enrichment RFP identifies domestically sourced uranium as the preferred option but allows for foreign sources to be used, preferably from other North American mines.

Fuel fabrication facilities would convert the acquired HALEU into fuel for advanced nuclear reactor (ANRs). Advanced reactors have been proposed that utilize several different fuels designs, requiring fuels to be manufactured in different shapes/forms and chemical compositions. Advanced reactors could require forms such as pebbles, rods, or particles and varying chemical compositions, such as metallic, molten salt, TRISO particle fuel (uranium/oxygen/carbon fuel kernel), uranium nitride, and advanced ceramic (oxide, carbide) fuel. Given that each of the nuclear fuels are fabricated using techniques specific to the fuel shape and composition, it is unlikely that the same fuel fabrication facility would produce multiple fuel types.

Facilities could be sited anywhere in the United States as long as the facility meets NRC siting requirements. Because of their participation in the LEU fuel cycle, current fuel fabricators and possibly the fuel fabrication sites are likely candidates for new HALEU fuel fabrication facilities. Other likely candidates include the reactor vendors themselves, possibly building new facilities that would produce fuel specifically designed for their advanced reactor designs.

Fuel fabrication sites and potential reactor vendor-affiliated candidate sites include, but are not limited to, the following:

- The Nuclear Fuel Services facility in Erwin, Tennessee, and the BWXT facility in Lynchburg, Virginia (both NRC Category I facilities)
- The currently operating LEU facilities (all NRC Category III facilities) that would require modification or new fabrication capabilities:
    - The Framatome fuel fabrication facility in Richland, Washington
    - The Global Nuclear Fuel – Americas fuel fabrication facility in Wilmington, North Carolina
    - The Westinghouse Electric Company fuel fabrication facility in Columbia, South Carolina
- Reactor vendors expressing interest in HALEU fuel fabrication:
    - X-Energy in Oak Ridge, Tennessee, plans to produce HALEU TRISO.
    - Global Nuclear Fuel – Americas and Terra Power are in pre-application discussions with the NRC about producing HALEU fuel for the Natrium™ reactor.
    - Ultra Safe Nuclear Corporation plans to produce TRISO fuel in Oak Ridge, Tennessee.

HALEU-Fueled Reactors

The expected consequence of a viable commercial HALEU production capability would include the construction and operation of multiple ANRs fueled with HALEU fuel. The reactors could include research and development, test, demonstration, and commercial power reactors. Determining the number of reactors, locations, and exact types of facilities would be speculative at this time.

Multiple technologies are under development that vary with respect to the fuel form used. Examples include small modular reactors, which would likely generate between 20 and 300 megawatts electric (MWe), microreactors that would generate less than 20 megawatts thermal, and larger reactors generating more than 300 MWe.

New HALEU-fueled commercial and research reactors would require NRC licenses and the required NRC NEPA documentation. A brief description of potential types of advanced reactors is provided hereafter (McDowell & Goodman, 2021), with some projects that are at various stages of the NRC licensing process:

- High-temperature gas-cooled reactors refer to graphite-moderated, typically helium-cooled systems that could use TRISO fuel.

- Fluoride salt-cooled high-temperature reactors refer to a hybrid design that uses pebble fuel elements (like pebble bed high-temperature gas-cooled reactors) and a fluoride salt coolant (like salt-cooled MSRs).
- MSRs come in several varieties. Some designs use molten fluoride salt, while others use chloride salts as the coolant. Some designs have stationary fuel rods or plates, while others have moving fuel pebbles or fissile material dissolved within the flowing coolant.
- Liquid metal-cooled reactors are an advanced type of nuclear reactor in which the primary coolant is a liquid metal. Liquid metal-cooled reactors are classified based on the liquid metal coolant used, such as sodium, lead-bismuth eutectic alloy, and lead-bismuth.
- Heat pipe reactors typically consist of a solid block core with the fuel in holes inside the solid block. Heat pipes are built into the block in a lattice configuration and remove the heat from the block as the liquid in the heat pipe is vaporized.
- Integral pressurized water reactors are an advancement upon historical pressurized water reactor designs that use coolant and fuels similar to existing LWRs but have the primary coolant circuit components placed within the reactor pressure vessel.

HALEU Spent Nuclear Fuel Storage and Disposition

Interim HALEU SNF storage at any of the reactor sites is possible. The ultimate disposition of SNF is dependent upon the licensing (no facility is currently in the licensing process) of a permanent repository.

HALEU spent fuel storage at the reactor site can utilize spent fuel pools (fuel assemblies stored under water in structures integrated with the reactor building) or dry cask storage. Currently, most LWR SNF is stored on-site in spent fuel storage pools. Storage sites that are away from the reactor site may also be an option for temporary storage of SNF. Such facilities could be very similar to the at-reactor dry cask storage facilities, only larger. These facilities could be used to store SNF from a single reactor or, in the case of a consolidated storage facility, for multiple reactors at a single location.

Ultimately, SNF is to be disposed of at a permanent repository. In a geologic repository, the SNF would be irretrievably stored underground in sealed tunnels. A geological repository uses engineered barrier systems and a portion of the site's natural geology, hydrology, and geochemical systems to isolate the SNF from the environment for long periods of time. While there have been efforts to design and build a geologic repository, the United States does not have an NRC-licensed permanent repository.

S.7.2 No Action Alternative

The No Action Alternative is the status quo, where no sufficient domestic commercial supply of HALEU is available; DOE would not undertake actions to address Section 2001(a)(2)(D)(v) of the 2020 Energy Act. Development of a domestic commercial supply of HALEU would be left to industry, or industry would remain reliant on foreign supplies of HALEU.

Without DOE funding, the development of HALEU production capacity and acquisition of up to 290 MT of HALEU for use in reactors in the United States would be uncertain and speculative. Potential scenarios could range from (1) no significant HALEU production ever materializing, with most reactor designs and reactors continuing to rely on LEU- and LEU+-based fuel that can be produced in existing facilities and other forms of energy production (e.g., fossil fuels, wind, solar, etc.); and (2) significant HALEU production eventually developing, either domestically or internationally, as a result of commercial domestic and/or foreign investment.

S.8 Alternatives Considered and Dismissed from Detailed Analysis

S.8.1 Use of DOE Stockpiles of HEU

DOE has limited capability to produce HALEU by downblending existing surplus stockpiles of HEU. This has been done in limited quantities, sometimes using commercial facilities.[32] (These facilities are operated for purposes other than downblending HEU to HALEU. Downblending can be performed by temporarily repurposing existing facility capabilities.) DOE could produce a total of nearly 15 MT of HALEU using this method. However, the needs would rapidly outpace the capacity of downblended HALEU. Further, downblending HEU to produce HALEU would not encourage the development of the commercial capability needed to foster a HALEU fuel cycle, the stated purpose and need for the Proposed Action.

S.9 Preferred Alternative

The Preferred Alternative is the Proposed Action, to acquire, through procurement from commercial sources, HALEU enriched to at least 19.75 and less than 20 weight percent U-235 over a 10-year period of performance and to facilitate the establishment of commercial HALEU fuel production. The No Action Alternative would not implement the Proposed Action, leaving industry reliant on foreign supplies of HALEU and domestic commercial supply at a status quo, and would be contrary to Congressional direction under Section 2001 of the Energy Act of 2020.

S.10 Summary of Environmental Consequences

S.10.1 Summary and Comparison of Alternatives

This EIS adopts the NRC impact assessment categories from most of the NEPA documents that were used as the basis for the impact analysis:

- **SMALL –** The environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.
- **MODERATE** – The environmental effects are sufficient to alter noticeably, but not destabilize, important attributes of the resource.
- **LARGE** – The environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

This EIS describes the potential environmental consequences associated with implementation of the Proposed Action. The presentation of potential environmental consequences in this document summarizes and incorporates by reference the findings contained in previously issued NEPA evaluation documents.[33]

In the Record of Decision for this EIS, DOE expects to make a decision on whether to move forward with the Proposed Action. The Record of Decision will not select specific locations or facilities. For this reason, and to bound impacts, DOE has analyzed construction and operation of new HALEU facilities at existing uranium fuel cycle facilities, other industrial (brownfield) sites, and at undeveloped (greenfield) sites.

Existing facilities that produce LEU and HEU are approved to operate under existing NRC licenses, U.S. Department of Interior permits, and/or applicable Federal, state, and local permits and approvals. NEPA or equivalent evaluations for these facilities were previously performed and considered under those

[32] These activities are addressed by separate existing or pending NEPA documentation.

[33] Use of the available NEPA documentation for licensed fuel cycle facilities in no way is intended to indicate a preference for the use of these facilities in commercializing the HALEU fuel cycle. They provide information on the kind and significance of impacts that could be incurred through the use of any existing or new facility.

licensing, permitting, and approval action decisions. Those NEPA evaluations—the majority of which are EISs and Environmental Assessments prepared by the NRC—were identified for each of the HALEU fuel cycle activities and were used to characterize the potential environmental consequences associated with the Proposed Action.

Appendix B, *Facility NEPA Documentation*, of the HALEU EIS provides a direct link to the summarized and incorporated-by-reference NEPA evaluation documents. EIS Section 3.1, *Uranium Mining and Milling*, through EIS Section 3.7, *Related Post-Proposed Action Activities*, present the potential environmental consequences of HALEU production associated with each resource area under each HALEU-related activity.

Sixteen resources are considered in this EIS:

- land use
- visual and scenic resources
- geology and soils
- water resources
- air quality
- ecological resources
- historic and cultural resources
- infrastructure
- noise
- waste management
- public and occupational health – normal operations
- public and occupational health – facility accidents
- traffic
- socioeconomics
- environmental justice
- human health – transportation

The environmental consequences in previously issued NEPA evaluations were used in the following manner to address (1) the potential use of **existing** uranium fuel cycle facilities (modified or expanded for HALEU activities), (2) construction and operation of new HALEU facilities at previously developed industrial sites (**brownfield** sites), and (3) the construction and operation of new HALEU facilities at undeveloped sites (**greenfield** sites). This approach was designed to cover the range of potential environmental consequences given the uncertainty regarding the specific facilities and locations that might be used to produce HALEU.

1. ***Existing facilities*** – LEU fuel cycle facilities perform the same activities (i.e., uranium mining and milling and uranium conversion) or very similar activities (e.g., enrichment, deconversion, and storage) that HALEU fuel cycle facilities would be expected to perform. Evaluation of individual LEU fuel cycle facilities' existing NEPA documents indicated that the required capacities of a HALEU facility would be less than those corresponding LEU fuel cycle facilities that have been previously evaluated (Leidos, 2023). It is logical to infer that the potential environmental consequences of constructing and operating HALEU-related facilities would be similar to or less impactful than those existing LEU facilities. Therefore, the potential environmental consequences of construction and operation of a HALEU-related facility were developed for this HALEU EIS from the environmental impacts analyses presented in the LEU facilities' existing NEPA documents. The resulting determination of potential impacts associated with existing sites is presented in EIS Chapter 3, *Affected Environment and Environmental Consequences*. (Further details regarding the basis for the determination of Proposed Action impact assessments are provided in Appendix A, *Environmental Consequences Supporting Information*, which include lists of specific NEPA documents and respective impact indicators [acreages, gallons per day of operational water use, etc.] that were evaluated for each respective activity and resource.)

2. ***Brownfield sites*** – Applying similar logic, the estimated potential environmental consequences for constructing and operating a new HALEU facility on an existing industrial site (a brownfield site) were extrapolated based on the potential environmental consequences associated with construction and operation of fuel cycle facilities as presented in existing NEPA documentation. Subject matter experts for the respective resources leveraged their education, working knowledge, experience, and professional judgement to extrapolate the potential environmental consequences associated with the Proposed Action and post-Proposed Action activities using respective impact

indicators, analyses, and impact assessment ratings for existing facilities in previous NEPA analysis. The resulting determination of potential impacts associated with brownfield sites is presented in EIS Chapter 3, *Affected Environment and Environmental Consequences*.

3. ***Greenfield sites*** – As with the brownfield site evaluation, subject matter experts applied information from previous NEPA analysis for the construction and operation of existing facilities to estimate the relative difference in potential impacts of building a new facility on a site that had not been previously developed versus a brownfield or existing site. The resulting determination of potential impacts associated with greenfield sites is also presented in EIS Chapter 3, *Affected Environment and Environmental Consequences*.

This section summarizes the potential impacts of the Proposed Action as defined in EIS Section 2.1, *Proposed Action and Related Activities*, and for the No Action Alternative as defined in EIS Section 2.2, *No Action Alternative*.

S.10.1.1 Proposed Action

The Proposed Action assumes that HALEU fuel cycle activities, including mining and milling, uranium conversion and enrichment, and HALEU deconversion and storage, would occur at multiple locations, with transportation of radiological material between these locations. Related HALEU fuel cycle activities (HALEU fuel fabrication, HALEU use in advanced reactors, SNF storage and disposition) would also occur at multiple locations.

In general, constructing and operating modified or new HALEU fuel cycle facilities at **existing facilities** results in estimated potential environmental consequences that range from mostly SMALL to MODERATE.[34] Most MODERATE consequences are associated with construction activities and not the HALEU operations or production-related processes.

Overall, constructing and operating all-new HALEU fuel cycle facilities at previously developed industrial sites (**brownfield sites**) or previously undeveloped locations (**greenfield sites**) also could result in estimated potential environmental consequences that range from SMALL to MODERATE. The MODERATE consequences are associated with the uncertainties of the specific characteristics (particularly the presence of ecological and historic and cultural resources) of the site relative to construction and not the HALEU operations or production-related processes. Construction activities are usually transient in nature and mitigations would be expected to be incorporated, as appropriate, to minimize potential consequences, as part of the required regulatory licensing, permitting, and associated NEPA or equivalent evaluation processes. Therefore, potential environmental consequences would likely range from SMALL to MODERATE, and LARGE potential environmental consequences are not anticipated after mitigation.

The Enrichment RFP allows for the use of foreign-mined yellowcake, UF_6 produced at a foreign conversion facility, and LEU of less than 5% in U-235 produced at a foreign enrichment facility. The degree to which domestic environmental impacts of the Proposed Action would be reduced by use of these foreign capabilities depends upon the extent to which material is supplied from foreign sources. A complete

[34] To assist when referring to the existing NEPA evaluations/source documents, this EIS uses the same impacts assessment terminology from the source NEPA evaluations to the extent possible. For reference, the NRC generally defines environmental consequences as (1) SMALL: The environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource; (2) MODERATE: The environmental effects are sufficient to alter noticeably, but not destabilize, important attributes of the resource; or (3) LARGE: The environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource. Therefore, DOE has generally adopted the NRC's environmental consequences definitions for this EIS, with a few exceptions for NEPA evaluations that were prepared by other agencies. Those exceptions are noted where applicable.

reliance on foreign yellowcake (eliminating the use of domestic mining and milling capabilities) would eliminate any domestic environmental impacts associated with these activities. Similarly, a complete reliance of foreign UF_6 (eliminating both domestic mining and milling and domestic conversion) would eliminate any domestic environmental impacts associated with these activities. Finally, the reliance on foreign UF_6 enriched to less than 5% would also reduce, but not eliminate, the impacts from domestic enrichment activities.

The transportation analysis considered the use of foreign conversion capabilities and concluded that there was little difference in domestic impacts between transporting UF_6 from the Metropolis facility or foreign conversion facilities to the enrichment facilities. While not specifically analyzed, impacts from the shipment of enriched UF_6 from foreign suppliers should not adversely affect transportation impacts. Impacts of shipping UF_6 from one domestic enrichment facility to another domestic facility was evaluated in this EIS. Additionally, use of foreign UF_6 reduces or eliminates domestic transportation impacts from the shipment of yellowcake to a conversion facility.

A partial use of foreign capabilities would have a commensurate reduction in domestic impacts. The more yellowcake imported results in fewer domestic mines and lower capacity demands on domestic milling operations. The impacts from conversion are not as noticeable since a single conversion facility could convert yellowcake into a sufficient amount of UF_6 to support the Proposed Action. If only some of the yellowcake were to be imported, many of the impacts from operation of a U.S. conversion facility would not be different (e.g., impacts to resources such as land use, geology and soils, ecological resources, historic and cultural resources). Others may be reduced commensurate with the amount of material imported.

The most notable reduction in impacts from using foreign sources of uranium would be the reduction of the domestic impacts of mining uranium. Impacts associated with mining can range from SMALL to LARGE, and impacts in each resource area are very dependent upon the type of mine (conventional mine and mill or ISR facility), the number of mines, and the location of the mines (site-specific differences are largely responsible for the large range of impacts associated with mining activities).

Table S.10-1 summarizes the potential impacts of the Proposed Action for each activity.[35] The table provides impact assessments for siting of HALEU fuel cycle facilities at existing facilities, brownfield sites, and greenfield sites. In general, siting HALEU facilities at existing uranium fuel cycle sites results in the lowest impact assessments. They are developed sites, with much of the infrastructure, operational controls, and other elements needed to support HALEU operations already in place. For HALEU fuel cycle facilities at developed industrial sites (i.e., brownfield sites) that are not part of the existing uranium fuel cycle, the information in the table addresses only those resource areas that may have higher impact assessments than would be expected at the fuel cycle facility sites (e.g., if traffic is assessed as having SMALL impacts for existing fuel cycle facilities and that assessment would not change for a brownfield site, then traffic is not discussed under the brownfield column). For siting new HALEU fuel cycle facilities at undeveloped (greenfield) sites, the table addresses only those resource areas that may have higher impact assessments than would be expected at the developed sites. When impacts across types of sites are identical, the entries have been combined into a single entry across multiple columns. Impacts information on each of the 16 resources analyzed under the Proposed Action and post-Proposed Action activities (fuel fabrication, reactor operations, and SNF management) is presented in EIS Section 2.6, Summary of Environmental Consequences of the Proposed Action and No Action Alternatives, EIS Section 2.6.1, Proposed Action, as well as EIS Chapter 3, Affected Environment and Environmental Consequences, and Appendix A, Environmental Consequences Supporting Information.

[35] Impacts for all activities are those associated with the production and use of 290 MT of HALEU.

Table S.10-1. Summary of Impacts

Activity	*Located at Existing Uranium Fuel Cycle Facility*	*Located at Other Non-Uranium Fuel Cycle Facility Industrial Site*	*Located on Previously Undisturbed Land*
All HALEU Activities	Overall, the potential environmental consequences are SMALL for most resource areas for most HALEU activities. Exceptions tend to be related to site-specific conditions and transient construction impacts and not to HALEU facility operations.	Overall, the potential environmental consequences are generally SMALL to MODERATE for resource areas. MODERATE impacts are generally associated with construction, which are transient in nature and not operations related. Mitigations could be identified as appropriate to minimize impacts.	Overall, the potential environmental consequences are generally SMALL to MODERATE for resource areas and the MODERATE impacts are generally associated with construction, which are transient in nature and related to site-specific uncertainties, not operations. Mitigations would be expected to be identified as appropriate to minimize impacts and would likely limit impacts to MODERATE.
Uranium Mining and Milling [(a)]	Impacts to some resource areas are SMALL, but larger (MODERATE to LARGE) impacts for resource areas at specific mines are possible. Due to the rural settings of most mines, development and operations have the potential for SMALL to MODERATE impacts on traffic. Development of mines also has the potential for SMALL to MODERATE impacts on ecological resources, and historic and cultural resources and SMALL to MODERATE (existing facilities) or LARGE (industrial or undisturbed sites) impacts on socioeconomics, though with proper management these impacts may be mitigated. The impacts to some resource areas differ depending upon the mine type. In-situ recovery facilities have potentially SMALL to MODERATE impacts to land use, visual resources, noise, and accidents and SMALL to LARGE impacts on water use. Conventional mines show the potential for up to MODERATE impacts for geology and soils. One proposed conventional mine also shows potential for disproportionate and adverse effects on communities with environmental justice concerns. These impacts would be expected to be SMALL to MODERATE. The MODERATE and LARGE potential environmental consequences are generally associated with site-specific conditions and temporary land-disturbing activities. Mitigation measures are expected to be identified as appropriate to minimize impacts and would likely reduce LARGE impacts to MODERATE.		
Uranium Conversion [(a)]	Overall, the potential environmental consequences are SMALL for all resource areas.	Additional MODERATE impacts may also be seen in the area of socioeconomics because of construction. Impacts would be predominately associated with construction activities and should be amenable to mitigation.	Additional MODERATE impacts may also be seen in the areas of ecological resources and historic and cultural resources. Impacts would be predominately associated with construction activities and should be amenable to mitigation.
Uranium Enrichment	For an existing site or other industrial site, impacts are generally SMALL for most resources. Impacts to ecological resources, water resources, and impacts driven in part by the local population have the potential for MODERATE (traffic and environmental justice) to LARGE (socioeconomics) impacts, particularly on regions with smaller populations.		At a greenfield site, additional MODERATE impacts may also be seen in historic and cultural resources, infrastructure, and noise. Impacts would be predominately associated with

Table S.10-1. Summary of Impacts

Activity	*Located at Existing Uranium Fuel Cycle Facility*	*Located at Other Non-Uranium Fuel Cycle Facility Industrial Site*	*Located on Previously Undisturbed Land*
			construction activities and should be amenable to mitigation.
HALEU Deconversion	Overall, the potential environmental consequences are SMALL for all resource areas, except socioeconomics, which may have MODERATE impacts if the in-migration of workers is larger than expected (fewer local workers employed).		MODERATE impacts may also be seen as a result of construction in the areas of ecological resources and historic and cultural resources. Impacts would be predominately associated with construction activities and should be amenable to mitigation.
HALEU Storage	Construction and operation of a HALEU storage facility would disturb approximately 1 acre, there would be no routine emissions of hazardous or radioactive materials, and the facility would be operated by only a few employees; therefore, the impacts of construction and operation of such a facility would likely be SMALL for all resource areas regardless of the location.		Due to site-specific conditions at a greenfield site, there could be potentially MODERATE impacts to historic and cultural resources and ecological resources. Impacts would be predominately associated with construction activities and should be amenable to mitigation.
Transportation [(b)]	The radiological impacts from low levels of radiation emitted during incident-free transportation and from the accidental release of radioactive materials and the nonradiological impacts from accident fatalities resulting from the physical forces of the accident are SMALL for all transportation activities between HALEU fuel cycle facilities.		
HALEU Fuel Fabrication Facility	Overall, the potential environmental consequences are SMALL for land use, air quality, ecological resources, infrastructure, noise, waste management, and public and occupational health – normal operations. SMALL to MODERATE impacts were identified for visual resources, geology and soils, water resources, , historic and cultural resources, public and occupational health – accidents, traffic, socioeconomics, and environmental justice. All but public and occupational health – accidents are related to construction and site-specific conditions but not fuel fabrication facility operations. Mitigative actions would be expected to be identified during site-specific environmental analyses.		Potentially MODERATE impacts to ecological resources could result from construction at a greenfield site. Mitigative actions would be expected to be identified during site-specific environmental analyses.

Table S.10-1. Summary of Impacts

Activity	*Located at Existing Uranium Fuel Cycle Facility*	*Located at Other Non-Uranium Fuel Cycle Facility Industrial Site*	*Located on Previously Undisturbed Land*
HALEU Use in Reactors	Impacts for use of HALEU in advanced reactors was evaluated for a generic site. Therefore, no distinctions are made between impacts for the three site categories applied to the Proposed Action activities. The NRC in its evaluation of the impacts of advanced reactor construction and operation (NRC, 2021b) deferred impact assessments for some resource areas to site-specific analysis. The NRC identified the impacts as undetermined due to the site-specific nature of those impacts that could not be assessed generically. Impacts in the resource areas of water resources, ecological resources, historic and cultural resources, and public and operational health – accidents were given this designation. The analysis of environmental justice impacts was also deferred to a site-specific analysis.		
HALEU SNF Storage and Disposition	At-reactor storage of HALEU SNF would have SMALL impacts for most resource areas. Because the reactor sites are unknown, there is the potential for MODERATE impacts from nonradioactive waste management and LARGE impacts on ecological resources (special status species and habitat) and historic and cultural resources. The HALEU SNF generated by activities related to the Proposed Action would not substantially add to the overall impacts of managing the nation's inventory of SNF.		

Key: HALEU = high-assay low-enriched uranium; NRC = U.S. Nuclear Regulatory Commission; SNF = spent nuclear fuel

Notes:

[a] Impacts are assessed based on all uranium being mined in the United States. Use of foreign-mined uranium ore or uranium hexafluoride (as allowed in the Enrichment RFP) would reduce domestic impacts proportionally to the amount of foreign material used.

[b] The transportation impacts identified in this table relate to human health impacts. Other impacts are addressed elsewhere (emissions are part of the air quality assessment for the other activities and climate change [greenhouse gas emissions] in the cumulative impacts assessment in Section S.10.2, *Summary and Comparison of Cumulative Effects*).

S.10.1.2 No Action Alternative

Under the No Action Alternative, DOE would not address the activities in Section 2001(a)(2)(D)(v) of the 2020 Energy Act. DOE would not acquire, through procurement from commercial sources, up to 290 MT of HALEU or facilitate the establishment of commercial HALEU fuel production. Without implementation of the Proposed Action, the development of HALEU production capacity and the future use of HALEU in reactors in the United States would be uncertain and speculative. Potential scenarios could range from no significant HALEU production ever materializing, with most reactors continuing to rely on LEU-based fuel that can be produced in existing facilities, to significant HALEU production developing as a result of commercial and/or foreign investment unaided by DOE.

Under the scenario where no significant HALEU production materializes, there would be no immediate change to the status quo. Existing electrical generation capacity would continue to operate. Traditional electricity generation sources, including LWRs, hydropower, solar, wind, and fossil-fueled plants, would continue to be relied on to supply our nation's energy demand and energy security.

This could have adverse impacts on meeting greenhouse gas (GHG) reduction goals[36]. The full-lifecycle GHG emissions of coal and natural-gas-power generation sources are substantially higher than for nuclear power. For instance, coal generates 820 grams (g) of carbon dioxide equivalent (CO_2e) per kilowatt-hour (g CO_2e/kWh) of electricity, while natural gas produces 490 g CO_2e/kWh. In contrast, nuclear power produces 12 g CO_2e/kWh (Schlömer et al., 2014). Therefore, using coal or natural gas to generate electricity would result in higher GHG emissions. Those higher GHG emissions from non-nuclear power could contribute to a greater rate of climate change. Substituting hydro and solar for a portion of the power-generating capacity would mitigate, but not eliminate, these higher emissions, as they produce lifecycle emissions at 24 g CO_2e/kWh and 41 g CO_2e/kWh, respectively (Schlömer et al., 2014).

If significant HALEU production and use were to eventually develop as a result of commercial and/or foreign investment unaided by DOE, the impacts of that production would be expected to be similar to the impacts evaluated in this EIS for a similar level of HALEU production and use.

S.10.2 Summary and Comparison of Cumulative Effects

The Council on Environmental Quality defines cumulative effects as "effects on the environment that result from the incremental effects of the action when added to the effects of other past, present, and reasonably foreseeable actions, regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 Code of Federal Regulations [CFR] 1508.1(g)(3)). This section summarizes the more detailed cumulative effects analyses presented in EIS Chapter 4, *Cumulative Effects*.

Cumulative effects are typically evaluated by combining the effects of a proposed action with the effects of other past, present, and reasonably foreseeable actions[37] in the region of influence (ROI).[38] These other actions include on-site and off-site projects conducted by Federal, state, and local governments; the private sector; or individuals that are within the ROIs of a proposed action.

[36] The White House National Climate Task Force has leadership responsibility to implement President Biden's climate change goals including up to a 52% reduction in GHG emissions by 2030 and reaching 100% clean (carbon-free) electricity by 2035.

[37] Reasonably foreseeable, as defined in 40 CFR 1508.1(aa), "means sufficiently likely to occur such that a person of ordinary prudence would take it into account in reaching a decision."

[38] The ROI is the geographic area over which past, present, and reasonably foreseeable actions could contribute to cumulative impacts and is dependent on the type of resource analyzed.

The HALEU activities described in EIS Chapter 2, Section 2.1, *Proposed Action and Related Activities*, are likely to be geographically separated and have different ROIs. Therefore, the impacts at one location would not generally be cumulative with the impacts at another location.

Many of the activities evaluated in this HALEU EIS have existing NEPA documentation for LEU operations that are either directly applicable or similar to the potential HALEU activity. Most, but not all, of those NEPA documents contain cumulative impacts analyses for the specific facilities and locations (see the activity-specific sections of Appendix A, *Environmental Consequences Supporting Information,* as well as Appendix B, *Facility NEPA Documentation*). Generally, these assessments mirrored the impacts associated with the activity being analyzed in the document. Resource areas with SMALL impacts from the proposed activity tended to have SMALL cumulative impacts. Similarly, resource areas with MODERATE or LARGE impacts did as well. However, while generally true, it is not possible to extrapolate that analysis to sites where no cumulative effects analysis has been performed. Because of the large number of activities and potential facilities evaluated in this HALEU EIS and the uncertainty of the numbers and locations of facilities, a cumulative effects analysis for most activities under the Proposed Action in this HALEU EIS would be speculative and not amenable to detailed analysis. DOE expects that new or modified HALEU production facilities that would be licensed and subject to additional NEPA or equivalent state evaluation would include consideration of cumulative impacts by the NRC, an Agreement State, or other Federal agencies.

S.10.2.1 Nationwide and Global Cumulative Effects

There are some effects that are relatively independent of the location of the facilities needed to implement the Proposed Action and the associated activities. SNF would be created by the use of up to 290 MT of HALEU in reactor fuel. This fuel would contribute to the existing SNF inventory from operating commercial LWRs. GHG generation is also a function of the materials used (principally the burning of fossil fuels) and not where the materials are used. Transportation impacts (GHGs emitted) are dependent upon the quantity of material being shipped and the distances this material is shipped. The location of facilities does impact the miles traveled, which impacts the quantity of GHGs generated. However, the same assumptions used in the transportation health impact analysis would provide a conservative estimate of GHG generation. The generation of ozone-depleting materials is a function of the types of activities and materials used, not location. The following sections discuss these impacts.[39]

Cumulative Effects of HALEU Spent Nuclear Fuel Storage and Disposition

As described in Section S.7.1.7, *Related Post-Proposed Action Activities,* HALEU SNF on-site storage is assumed to occur at the reactor that generates the SNF. Off-site storage and disposition is assumed to occur at the facilities used for consolidated storage and disposition of the much larger quantity of existing commercial power-reactor SNF. The total HALEU SNF generated by the HALEU Proposed Action would contain up to 290 MT of HALEU (DOE, 2021, p. 2). Therefore, the HALEU SNF generated over multiple years of reactor operation would not substantially contribute to cumulative impacts of managing the nation's inventory of SNF.

Cumulative Effects of Transportation

As described in Section S.7.1.6, *HALEU Transportation*, HALEU activities would require the transportation of radioactive materials between the facilities associated with HALEU production. The impacts of transportation of these materials are presented in EIS Section 3.6, *Transportation*.

[39] For GHG impacts, no comparison is made between the GHG generated by the Proposed Action plus associated activities and annual U.S. or global GHG emissions. As with most projects, due to the size of annual global and U.S. GHG emissions, such a comparison does not provide any significant insight.

The assessment of cumulative transportation impacts of transportation throughout the United States could result in potential radiation exposure to transportation workers and the general population. Cumulative radiological impacts from transportation are estimated using the dose to the workers and general population because dose can be directly related to latent cancer fatalities (LCFs) using a cancer risk coefficient.

The total number of LCFs (among the workers and the general population) estimated to result from all radioactive material transportation over the period between 1943 and 2090 is about 523, or an average of about 4 LCFs per year, from exposures of about 6,000 person-roentgen equivalent man (rem) per year[40] (DOE, 2022). The total worker and public dose from transportation activities associated with the Proposed Action would be about 100 person-rem with an expected LCF of 0.06 for the entire duration of the effort. Over the 6 years of plant operations during the HALEU commercialization effort, over 3.5 million people are projected to die from cancer, based on National Center for Health Statistics data. The annual number of cancer deaths in the United States in 2019 was about 599,600 (CDC, 2021). The transportation-related LCFs would be indistinguishable from the natural fluctuation in the total annual death rate from cancer.

Global Cumulative Effects

Ozone Depletion

Construction and operation activities associated with the Proposed Action and related activities are expected to be accomplished using materials and equipment that would be compliant with applicable ozone-depleting substance (ODS) laws and regulations including 40 CFR 82, Protection of Stratospheric Ozone. For example, these regulations no longer allow the use of certain ozone-depleting propellants in commercial spray cans and ozone-depleting fluids previously used in air conditioning and refrigeration systems. Because of these restrictions on the use of ODSs, the Proposed Action is not expected to use substantial quantities of ODSs. Therefore, emissions of ODSs would be expected to be very small and would represent a negligible contribution to the destruction of Earth's protective ozone layer.

Greenhouse Gases and Climate Change

Recent scientific evidence indicates a correlation between increasing global temperatures over the past century and the worldwide proliferation of GHGs emitted by mankind. Climate change associated with this global warming is predicted to produce negative environmental, economic, and social consequences across the globe (USGCRP, 2018; IPCC, 2023).

The direct environmental effect of GHG emissions is an increase in global temperatures, which indirectly causes numerous environmental and social effects. Therefore, the ROI and potential effects of GHG emissions from the Proposed Action are by nature global and cumulative. Given the global nature of climate change and the current state of the science, it is not possible to directly link the emissions quantified for local actions to any specific climatological change or resulting environmental impact. Nonetheless, GHG emissions resulting from the Proposed Action are quantified in this EIS for use as indicators of their potential cumulative contributions to climate change effects and for making reasoned choices among alternatives.

It is unknown at this time where the various HALEU commercialization activities would take place across the United States. Therefore, to provide a bounding analysis of potential GHG emissions that could occur from the effort, the analysis developed low- and high-emission scenarios that consider ranges of miles driven by trucks that transport materials for the effort. Emissions from all activities (construction, operation, and

[40] Total LCFs are calculated assuming 0.0006 LCFs per person-rem of exposure.

transport of materials) over the period of performance would add 774,000 to 2.9 million MT of CO_2e emissions to global GHG emissions.

Offsetting the CO_2e emissions from the Proposed Action and related activities would be the expected reduction of CO_2e emissions if the power produced were from reactors fueled by 290 MT of HALEU instead of power produced by existing electrical power generation sources within regions across the United States. The total electrical power that could be generated by advanced reactors with the use of HALEU fuel produced under the Proposed Action is estimated to be roughly 50 gigawatt-years or 438 million megawatt-hours. Total CO_2e emitted from the generation of roughly 438 million megawatt-hours by existing electrical power generation sources could range from a low of 48.2 million MT to a high of 328.5 million MT, depending upon the mix of current generation capabilities assumed. These estimates reveal that electrical power generated by HALEU-fueled ANRs would result in between 47.4 million and 326 million MT lower CO_2e emissions, compared to power generated from the combination of existing non-nuclear sources.

The social cost of GHG (SC-GHG) emissions is the monetary value (in U.S. dollars) of the net harm to society associated with adding GHG emissions to the atmosphere (IWG, 2021). In principle, it includes the value of all climate change impacts, including (but not limited to) changes in net agricultural productivity, human health effects, property damage from increased natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. The estimated SC-GHG for the effort would range from $13 million to $491 million. However, as presented above, power generated by the fuel created and used as a result of the Proposed Action associated activities could displace power generated from higher emitting sources and therefore, offset the SC-GHG and result in a cumulative benefit to climate change.

S.11 References

CDC. (2021). *Deaths: Final Data for 2019.* Centers for Disease Control and Prevention, National Center for Health Statistic, National Vital Statistics System. National Vital Statistics Reports, Vol. 70, No. 8. Retrieved from https://www.cdc.gov/nchs/data/nvsr/nvsr70/nvsr70-08-508.pdf. July 26.

Centrus Energy Corp. (2023a). *Centrus Makes First HALEU Delivery to U.S. Department of Energy*. Retrieved December 28, 2023, from https://www.centrusenergy.com/news/centrus-makes-first-haleu-delivery-to-u-s-department-of-energy/. November 7.

Centrus Energy Corp. (2023b). *Centrus Completes Construction and Initial Testing of Haleu Demonstration Cascade, Expects to Begin Production by End of 2023*. Retrieved from https://www.centrusenergy.com/news/centrus-completes-construction-and-initial-testing-of-haleu-demonstration-cascade-expects-to-begin-production-by-end-of-2023/. February 9.

DOE. (2020a). *What is High-Assay Low-Enriched Uranium (HALEU)?* Retrieved July 1, 2022, from U.S. Department of Energy, Office of Nuclear Energy: https://www.energy.gov/ne/articles/what-high-assay-low-enriched-uranium-haleu. April 7.

DOE. (2020b). *Restoring America's Competitive Nuclear Advantage: A strategy to assure U.S. national security.* U.S. Department of Energy. Retrieved from https://www.energy.gov/sites/default/files/2020/04/f74/Restoring%20America%27s%20Competitive%20Nuclear%20Advantage_1.pdf.

DOE. (2021). *Spent Nuclear Fuel and Reprocessing Waste Inventory: Spent Fuel and Waste Disposition.* Prepared for U.S. Department of Energy Office of Nuclear Energy.

DOE. (2022). *Final Versatile Test Reactor Environmental Impact Statement.* U.S. Department of Energy Office of Nuclear Energy. DOE/EIS-0542. Retrieved from https://www.energy.gov/nepa/articles/doeeis-0542-final-environmental-impact-statement.

DOE. (2023a). *Draft Solicitation No. 89243223RNE000031, High-Assay Low-Enriched Uranium (HALEU) Enrichment Acquisition – Indefinite Delivery/Indefinite Quantity (ID/IQ) Request for Proposals.* U.S. Department of Energy. June 5, 2023.

DOE. (2023b). *Draft Solicitation No. 89243223RNE000033 – Purchase of High-Assay Low-Enriched Uranium (HALEU) – Deconversion Services.* U.S. Department of Energy. June 5.

DOE. (2023c). *Solicitation No. 89243223RNE000033, High-Assay Low-Enriched Uranium (HALEU) Deconversion Acquisition – Indefinite Delivery/Indefinite Quantity (ID/IQ) Request for Proposals.* U.S. Department of Energy. November 28, 2023.

DOE. (2024). *Solicitation No. 89243223RNE000031, High-Assay Low-Enriched Uranium (HALEU) Enrichment Acquisition – Indefinite Delivery/Indefinite Quantity (ID/IQ) Request for Proposals.* U.S. Department of Energy. January 9, 2024.

DOE-ID. (2019). *Environmental Assessment for Use of DOE-Owned High-Assay Low-Enriched Uranium Stored at Idaho National Laboratory.* U.S. Department of Energy, Idaho Operations Office. DOE/EA-2087. Retrieved from https://www.energy.gov/sites/default/files/2019/01/f58/EA-2087-HALEU-2019-01.pdf.

EIA. (2020). *2020 Independent Statistics and Analysis*. Retrieved from U.S. Energy Information Administration: https://www.eia.gov/todayinenergy/detail.php?id=44416.

INL. (2021). *Estimated HALEU Requirements for Advanced Reactors to Support a Net-Zero Emissions Economy by 2050.* Idaho National Laboratory. INL/EXT-21-64913.

IPCC. (2023). *Climate Change 2023: Synthesis Report.* Geneva, Switzerland. Retrieved from https://www.ipcc.ch/report/ar6/syr/

IWG. (2021). *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates Under Executive Order 13990.* Washington, D.C.: Interagency Working Group. Retrieved from https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf. February.

Leidos. (2023). *Technical Report in Support of the Environmental Impact Statement for DOE Activities in Support of Commercialization of High-Assay Low-Enriched Uranium Fuel Production.* Prepared by Leidos for U.S. Department of Energy Idaho Operations.

McDowell, B. K., & Goodman, D. (2021). *Advanced Nuclear Reactor Plant Parameter Envelope and Guidance.* National Reactor Innovation Center, . Richland, WA: Pacific Northwest National Laboratory. February 18.

NEI. (2020). *Updated Need for High-Assay Low Enriched Uranium.* Letter from Nuclear Energy Institute (NEI) President/CEO Maria Korsnick to the Dan Brouillette, Secretary of Energy, U.S. Department of Energy, dated July 23.

NEI. (2021). Updated Need for High-Assay Low Enriched Uranium. Washington DC: Letter from NEI president Maria Korsnick to The Honorable Jennifer Granholm, Secretary of Energy. December 20.

NEI. (2022). *White Paper, Establishing a High Assay Low Enriched Uranium Infrastructure for Advanced Reactors.* Nuclear Energy Institute, January. doi:https://www.nei.org/CorporateSite/media/filefolder/resources/reports-and-briefs/NEI-White-Paper-Establishing-a-High-Assay-Low-Enriched-Uranium-Infrastructure-for-Advanced-Reactors-Jan-2022.pdf.

NRC. (2009). *Generic Environmental Impact Statement for In-Situ Leach Uranium Milling Facilities, NUREG-1910.* U.S. Nuclear Regulatory Commission Office of Federal and State Materials and Environmental Management Programs and the Wyoming Department of Environmental Quality Land Quality Division. Retrieved from https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1910/index.html.

NRC. (2011). *Fact Sheet on Uranium Recovery*. Retrieved from U.S. Nuclear Regulatory Commission: https://www.nrc.gov/reading-rm/doc-collections/fact-sheets/fs-uranium-recovery.html. September.

NRC. (2019). *Environmental Assessment for the Proposed Renewal of Source Material License SUB–526 Metropolis Works Uranium Conversion Facility (Massac County, Illinois). Honeywell International, Docket No. 040-03392.* U.S. Nuclear Regulatory Commission. Retrieved from https://www.nrc.gov/docs/ML1927/ML19273A012.pdf.

NRC. (2021a). *Environmental Assessment for the Proposed Amendment of U.S. Nuclear Regulatory Commission License Number SNM-2011 for the American Centrifuge in Piketon, Ohio.* Washington DC: U.S. Nuclear Regulatory Commission.

NRC. (2021b). *Draft Generic Environmental Impact Statement for Advanced Nuclear Reactors (ANRs), NUREG-2249.* U.S. Nuclear Regulatory Commission Office of Nuclear Material Safety and Safeguards. Retrieved from https://www.nrc.gov/docs/ML2122/ML21222A055.pdf.

Nuclear Energy Agency and International Atomic Energy Agency. (2023). *Uranium 2022 Resources, Production and Demand.* Organization for Economic Co-operation and Development OECD.

Regalbuto, M. C. (2020). *High-Assay Low Enriched Uranium Demand and Deployment Options: HALEU Workshop Report June 2020.* M.C. Regalbuto, Director, Nuclear Fuel Cycle Strategy, U.S. Department of Energy, INL/EXT-21-61768, Revision 3a.

Regalbuto, M. C. (2022). *Integrated Fuel Cycle Solutions HALEU Update.* Monica Regalbuto, Idaho National Laboratory, Idaho Falls, ID, May 24.

Schlömer et al. (2014). Schlömer, S., Bruckner, T., Fulton, L., Hertwich, E., McKinnon, A., Perczyk, D., ... & Wiser, R. Annex III: Technology-specific cost and performance parameters. In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1329-1356). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.).

USEC. (2004). *Environmental Report for the American Centrifuge Plant in Piketon, Ohio.* Bethesda Md.

USGCRP. (2018). *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Vol. II.* Washington, D.C.: U.S. Global Change Research Program. Retrieved from https://nca2018.globalchange.gov/.

This page left blank intentionally.