Comparing HALEU Demand Among Advanced Reactor Fuel Cycle Transitions

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Outline

Introduction

Mutliple new reactor designs will require High-Assay Low-Enriched Uranium (HALEU) fuel, which allows for

- Longer cycle times
- Higher burnups

To meet the HALEU demand, the U.S. Department of Energy (DOE) has proposed two methods [2]:

- Recovery and downblending of High-Enriched Uranium (HEU)
- Enrichment of natural uranium

Determining which method to use, or how to combine them, will be based on the material requirements of the reactor(s) deployed.

Objectives

This work simulates multiple transition scenarios to HALEU-fueled reactors and aims to

- Quantify material requirements of the transition to reactors fueled by HALEU
  - Number of reactors deployed
  - Ability to meet energy demand
  - Mass of uranium supplied to reactors
  - Separative Work Unit (SWU) capacity to enrich uranium
- Compare the material requirements of a small reactor with a long cycle time and a medium-sized reactor with on-line refueling
- Identify how each HALEU production method can be used to meet the material requirements

Outline

Methodology

Simulated 5 fuel cycle scenarios in CYCLUS [3]

- **Scenario 1:** Current fleet of Light Water Reactors (LWRs)
- **Scenario 2:** No growth transition to Ultra Safe Nuclear Corporation (USNC) Micro Modular Reactor (MMR)™
- **Scenario 3:** No growth transition to X-energy Xe-100
- **Scenario 4:** 1% growth transition to USNC MMR™
- **Scenario 5:** 1% growth transition to X-energy Xe-100

Table 1: Advanced reactor design specifications

Design Criteria	USNC MMR™	X-Energy Xe-100
Reactor Type	Modular HTGR	Modular HTGR
Power Output (MWe)	10	75
Enrichment (% ^{235}U)	13	15.5
Cycle Length (years)	20	Online Refuel
Fuel Form	TRISO Compacts	TRISO Pebbles
Reactor Lifetime	20 years	60 years

Simulation Details

- Simulations model reactor deployment from 1965-2090
- LWR commission dates are obtained from the IAEA Power Reactor Information System (PRIS) database [1]
- LWRs are assumed to operate for 60 years, unless they were decommissioned by December 2020
- Transitions begin in 2025
- Timestep of one month

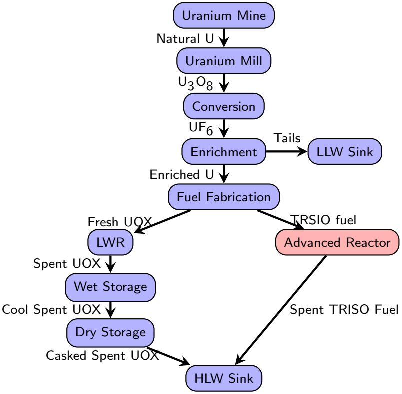


Figure 1: Fuel cycle facilities and material flow between facilities.

Outline

Reactor Deployment

- The last LWR is decommissied in 2076
- In the no growth scenarios (Scenarios 2 and 3) the advanced reactors are deployed starting in June 2038
- In the 1% growth scenarios (Scenarios 4 and 5) the advanced reactors are deployed starting in July 2036
- The maximum number of advanced reactors deployed at one time in Scenarios 2-5 are 5962, 50, 11474, and 51 reactors, respectively

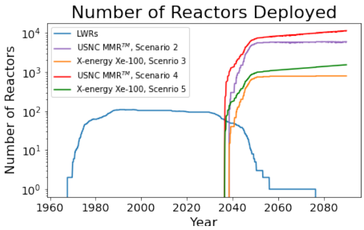
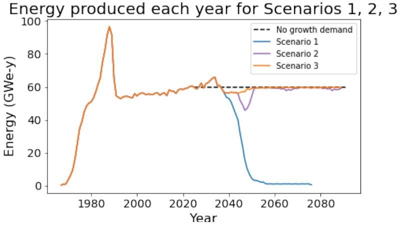


Figure 2: Reactor deployment schedule for LWRs and advanced reactors.

Energy

- Energy produced by LWRs in Scenario 1 in 2025 is 59.613 GWe-y
- Scenarios 2 and 3 do not meet demand between 2038-2053
- Scenario 4 does not meet demand between 2035-2054
- Scenario 5 does not meet demand between 3035-2048
- Noticable deviations from demand in Scenarios 2, 4 when new reactors are deployed secWEV;UW



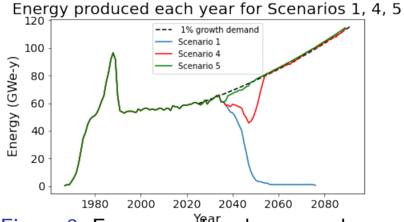
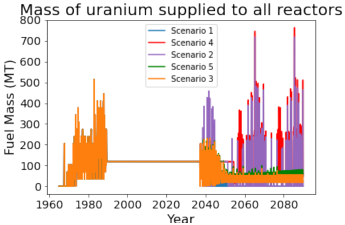


Figure 3: Energy produced per year by all reactors in Scenarios 1-3 (top) and Scenarios 1, 4, 5 (bottom)

Uranium Mass Supply

- All scenarios have the same uranium demands until advanced reactors are deployed
- Large peaks in Scenarios 2 and 4 correspond to the deployment of new reactors
- Less variation with time in the uranium supplied to reactors for Scenarios 3 and 5 than Scenarios 2 and 4
- There is a 6 month delay in when advanced reactors are deployed and fueled in Scenario 4



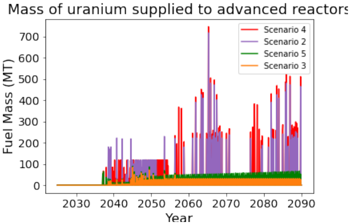


Figure 4: Uranium mass sent to all reactors (top) and only advanced reactors (bottom)

SWU Requirements

- Follows similar pattern to uranium mass
- Scenarios 2 and 4 require the most SWU because of the large mass of urnaium, despite a lower enrichment level for the advanced reactors Scenarios 3 and 5

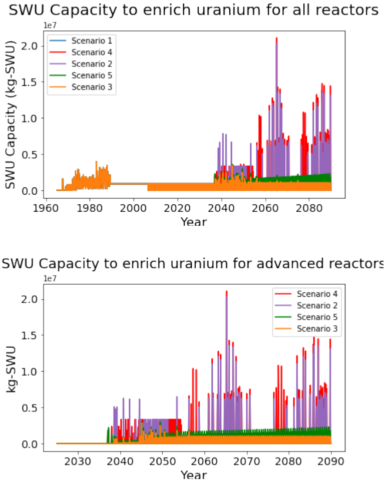


Figure 5: SWU required to produce enriched uranium for all reactors (top) and only advanced reactors (bottom)

Outline

Conclusions

- Simulated 5 fuel cycle scenarios to investigate the material requirements of deploying HALEU-fueled reactors
- Transitions to the X-energy Xe-100 reactor are better able to meet the energy demand of the scenarios
- Transitions to the USNC MMR™ have significantly more material requirements than transitions to the X-energy Xe-100
- Changing to a 1% growth demand model requires advanced reactors to be deployed 2 years earlier

Ongoing Work

- Incorporate LWR license expiration dates
- Increase the amount of time in the scenario, change end date to 2125
- Determine how much HALEU can be produced by downblending HEU

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