Enrichment Technology in a Nuclear Future

NPRE 412 - Project Proposal

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1 Introduction

Over the coming decades, the International Renewable Energy Agency (IRENA) predicts gross power generation to more than double~~d~~ from 20,204 TWh/yr in 2015 to 41,508 TWh/yr in 2050 [1]. Simultaneously, leaders of the G7 member states (France, the United States, the United Kingdom, Germany, Japan, Italy, and Canada) have dedicated to net-zero carbon emissions by 2050 [2]. To provide the projected power and supplant fossil fuels, which generate 80% of global electricity, we need more nuclear power.

A major constraint on new nuclear is the lack of enrichment capacity. After the Russian invasion of Ukraine, the United States banned the import of uranium products from Russia and Russian companies [3]. Russia accounts for 40% of global uranium enrichment capacity, so the ban dramatically reduced the supply of enriched uranium for the United States and its allies. Luckily, the United States have massive Highly Enriched Uranium (HEU) stockpiles from the Russia Highly Enriched Uranium Purchase Agreement, colloquially referred to as the "Megatons to Megawatts Program." However, other countries are not afforded the same luxury. As developing nations increase electricity generation, more enrichment capacity is required to ensure nuclear reactors are tenable in developing nations.

Ban did not affect allies directly.

Therefore, I will answer enrichment capacity required to satisfy the projected nuclear demand. Although many enrichment methods exists, I will tailor my assessment towards laser enrichment, formally known as Atomic Vapor Laser Isotope Seperation (AVLIS). AVLIS is characterized by single-stage separation and low energy consumption with downsides of high temperatures (2300 °C) causing the uranium vapor to attack almost all other materials [4]. Although development for AVLIS has stalled, I believe enrichment via AVLIS can satisfy the future need for enriched uranium.

2 Current Methods

As of today, ~~centrifugation~~ the enrichment centrifuge is the ~~only~~ primary enrichment method used [5]. However, new domestic enrichment capacity has not been built since 1954. The drought of new US-owned, US-technology uranium enrichment plants was broken with the construction of the American Centrifuge Plant in Piketon, Ohio [6]. Notably the American Centrifuge Plant, like all publicly-known enrichment facilities, uses centrifugal enrichment to extract uranium. Other enrichment methods may be under development, but none have been favored as much as centrifugal enrichment.

3 Analysis Approach

There will be two aspects to my final project. First, I will predict the enrichment capacity required to achieve the goals set during the 2023 G7 Summit held Hiroshima. Second, I will investigate the various enrichment methods with a focus on AVLIS.

Be specific. Are you referring to Sapporo 5?

3.1 Enrichment Capacity Prediction

First, I will predict the required enrichment capacity required for the coming decades. However, I understand predicting energy demands over decades is uncertain. Also, the future uncertainty is amplified by the burgeoning energy industries in many developing countries, which might not have the capital to build nuclear plants. Therefore, I will research more about how the energy will be produced in developing nations. I will also likely assume we will meet the goals set during the 2023 G7 Summit held

in Hiroshima.

By determining the (i) growth in energy demand, (ii) methods of electricity generation in developing nations, and (iii) the predicted role in nuclear power in the future, I will be able to determine the required enrichment capacity to satisfy global demand. When predicting the enrichment capacity, I will determine the demand for enriched uranium over time. Due to Megatons to Megawatts, the United States can increase its nuclear capacity while relying on an existing stockpile of HEU. However, the construction of nuclear power in other countries may be limited by available enrichment capacity. I will account for these factors and more in my final project.

3.2 Enrichment Method Investigation

After predicting the required enrichment capacity, I will determine how each enrichment method will contribute. As previously mentioned, all extant enrichment facilities use centrifugal enrichment. However, I determine if centrifugal enrichment is the most apt method. ?

I will perform an analysis of the enrichment methods with the highest usage potential, like [4]: gaseous diffusion, centrifugal enrichment, separation nozzle, AVLIS. If AVLIS is viable, I will describe the current constraints and limitations of AVLIS. If AVLIS is not viable, I will change my investigation to the next most viable option.

Based on cost? Efficiency?

4 Conclusion

With an growing demand for carbon-free energy and a need to replace fossil fuels, nuclear energy will be instrumental in the coming decades. For nuclear power plants to operate, traditional designs require enriched uranium. However, 40% of global enrichment capacity was supplied by the now-sanctioned Russia. Therefore, other countries need to increase their enrichment capabilities. Therefore, I will predict the required enrichment capabilities for a net-zero carbon world. I will investigate the role of AVLIS in the future of uranium enrichment.

5 References

[1] *Global Energy Transformation*. Tech. rep. 2018.

[2] W. E. Forum. "G7 summit: 3 key takeaways for net zero action, nature and the circular economy". In: *Nature and Biodiversity* (2023).

[3] U. O. of Public Affairs. *Uranium Import Ban*. 2024.

[4] N. Tsoulfanidis. *The Nuclear Fuel Cycle*. American Nuclear Society, 2013.

[5] W. N. Association. "Uranium Enrichment". In: *Nuclear Fuel Cycle* (2024).

[6] W. N. News. *Enrichment operations start at US HALEU plant*. 2023.

1 Proposal

Proposal Score: 90

Criterion	Needs Improvement	Developing	Excellent
Minimum 500 words			X
Maximum 1000 words			X
Two columns			X
Reasonable margins			X
10 pt font or larger			X
State the question you plan to answer			X
Summarize the current state of the art in the literature			X
Motivate the problem, explaining its relevance			X
Describe the approach and methods you will take to answer the question		X	
Propose an outline of the analysis, software, data, and/or conclusions that will be delivered		X	

Table 1: 30% of the proposal grade is based on successful compliance with proposal instructions.

Criterion	Needs Improvement	Developing	Excellent
Relevance			X
Novelty			X
Technical Detail		X	
Analytic Rigor		X	
Verifiability			X
Clarity			X
A Conclusion			X

Table 2: 70% of the proposal grade is based on successful performance with respect to the review criteria.

Criterion	Comments
Relevance	✓
Novelty	✓
Technical Detail	Clarify comparison metric, add tables, figures, and data.
Analytic Rigor	Include equations, software, data to be used.
Verifiability	✓
Clarity	Spell check, proof read.
A Conclusion	✓

Table 3: Scientific report criterion and evaluation.