LEU+ to HALEU transitions in advanced reactor fuel cycles

ANS Great Lakes Local Section

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Outline

We use Cyclus to model fuel cycles

Cyclus is an open-source agent-based fuel cycle code allowing for detailed facility and transaction modeling [2].

Source: `https://github.com/cyclus/cyclus.github.com/blob/source/source/logos/logo2_transp.png`

Cyclus is being used to tackle big questions in fuel cycle modeling

Making facility models more accurate

OpenMCyclus [1] couples Cyclus with OpenMC to model realtime depletion.

Making transaction models more detailed

There is active work to incorporate realistic purchasing agreements and market models into Cyclus.

Identifying realtime diversion or diversion paths

CNTAUR [3] and Pyre [4] format outputs in IAEA code 10 format and model real time diversion, respectively.

Finding advanced reactor impacts on the fuel cycle

We will talk about that today!

Outline

1. Fuel Cycle Modeling
2. Deployment Schemes
3. LEU+ to HALEU
4. Conclusion

Greedy reactor deployment algorithm

```
Initialize demand
while demand exists do
    Select the largest reactor that does not exceed demand
    Deploy reactors until the next reactor exceeds demand
    Update demand
end while
```

Random reactor deployment algorithm

Initialize demand
while demand exists **do**
    Randomly deploy a reactor that does not exceed demand
    Update demand
end while

Random + greedy reactor deployment algorithm

```
Initialize demand
while demand exists do
    Randomly deploy a reactor
    if demand is exceeded then
        Remove last reactor
        if demand still exists then
            Select the largest reactor that does not exceed demand
            Deploy until the next reactor exceeds demand
            Update demand
        end if
    end if
end while
```

Outline

What if we can't get HALEU to fuel these advanced reactors?

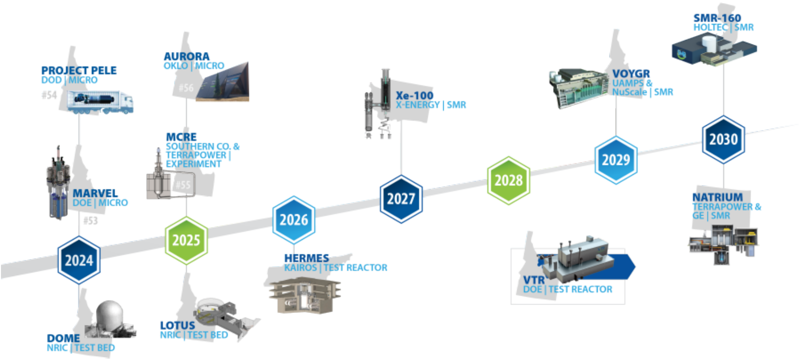


Figure: Source: `inl.gov/nuclear-reactor-sustainment-and-expanded-deployment/`

Could we use LEU+ in the meantime?

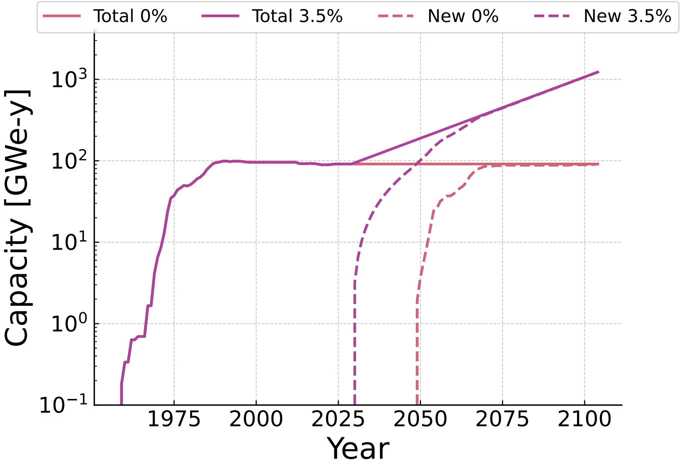
We define the enrichment levels as...

These are a mash-up of economic and regulatory definitions.

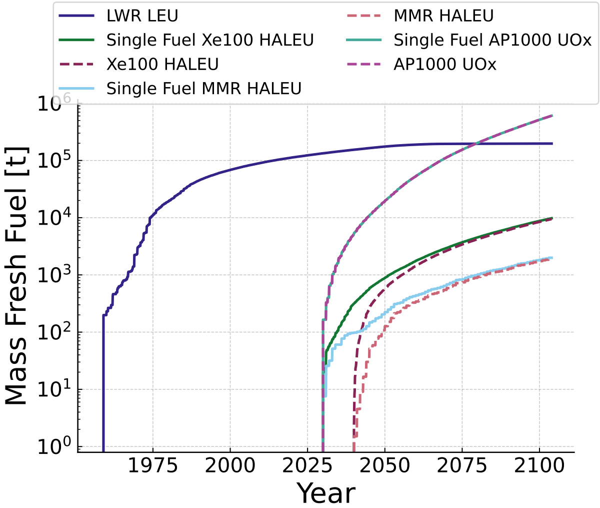
Table: Enrichment levels and their ranges.

Enrichment Level	**Range [% ^{235}U]**
Natural	< 0.711
LEU	0.711-5
LEU+	5-10
HALEU	10-20
HEU	≥ 20

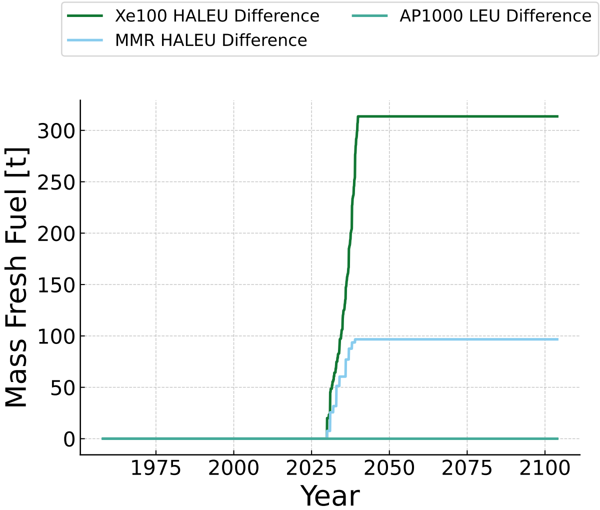
Our demand for energy is going up



Staggering enrichment could give the supply chain time to develop



The difference is on the order of hundreds of tons



Outline

Fuel cycles modeling is useful for enegy planning and safeguards

We have covered a tiny fraction of what fuel cycle modeling can do, but there is so much more to do. In our simple case, we transition from LEU+ to HALEU after 10 years of operation.

- For the Xe100 reactors, we need almost 315 less tons of HALEU.
- For the MMR reactors, we need almost 97 less tons of HALEU.

Next we need to characterize what the cost of this transition would be.

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References I

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