LEU+ to HALEU transitions in advanced reactor fuel cycles

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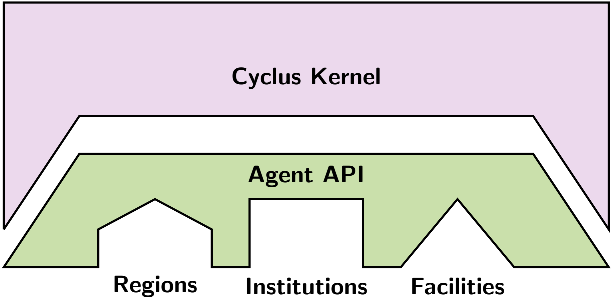
Outline

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].



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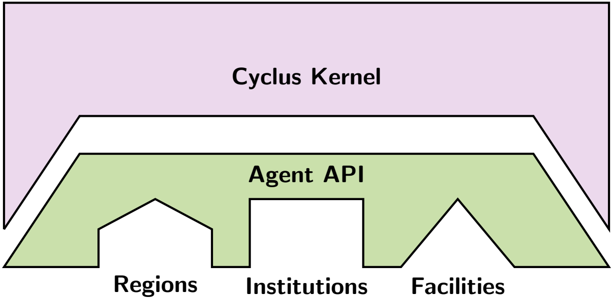

The CYCLUS ecosystem has many *archetypes*, or generic facility models, (like the CYCAMORE Reactor) that can be used to model different fuel cycle facilities.

CYCLUS is being used to tackle big questions.

Transaction Models.

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

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Transition Scenarios.

We will talk about this in the context of advanced reactors.

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 are our options if we can't get HALEU fuel?

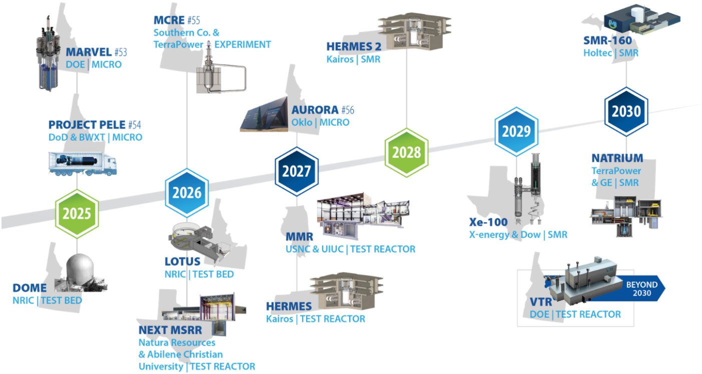


Figure: Advanced reactor demonstration and deployment projects [4].

Could we use low-enriched uranium plus (LEU+) while HALEU supply chains develop?

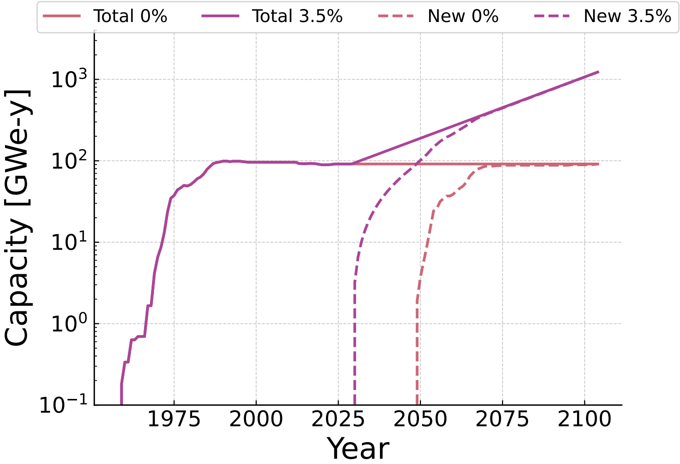
We define the enrichment levels as...

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

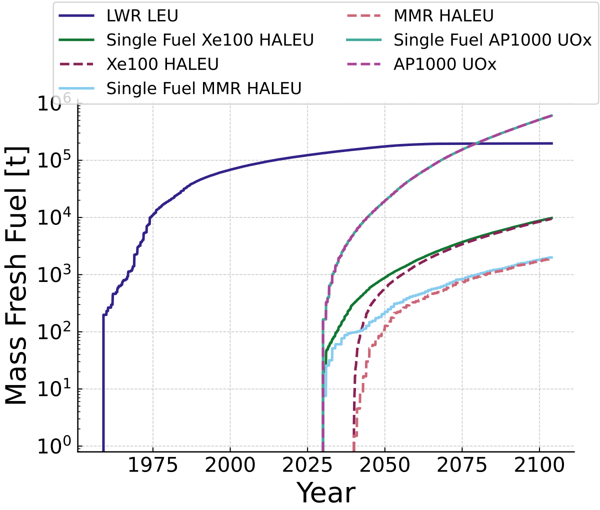
Table: Enrichment levels and their ranges.

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

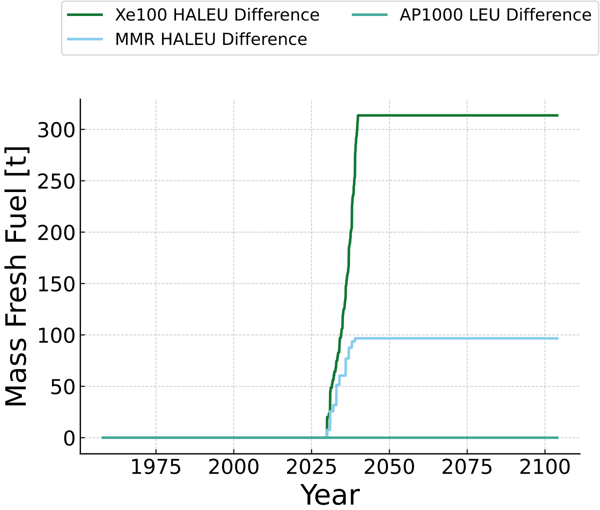
Our demand for energy is going up



Staggering enrichment could give the supply chain time to develop



The difference is on the order of hundreds of tons



Outline

This transition is an upperbound on the amount of HALEU we could defer.

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.

Acknowledgement

This research was performed, in part, using funding received from the DOE Office of Nuclear Energy's Nuclear Energy University Program (Project 23-29656 DE-NE0009390) 'Illuminating Emerging Supply Chain and Waste Management Challenges'.
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