LEU+ to HALEU transitions in advanced reactor fuel cycles

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Advanced Reactors and Fuel Cycles

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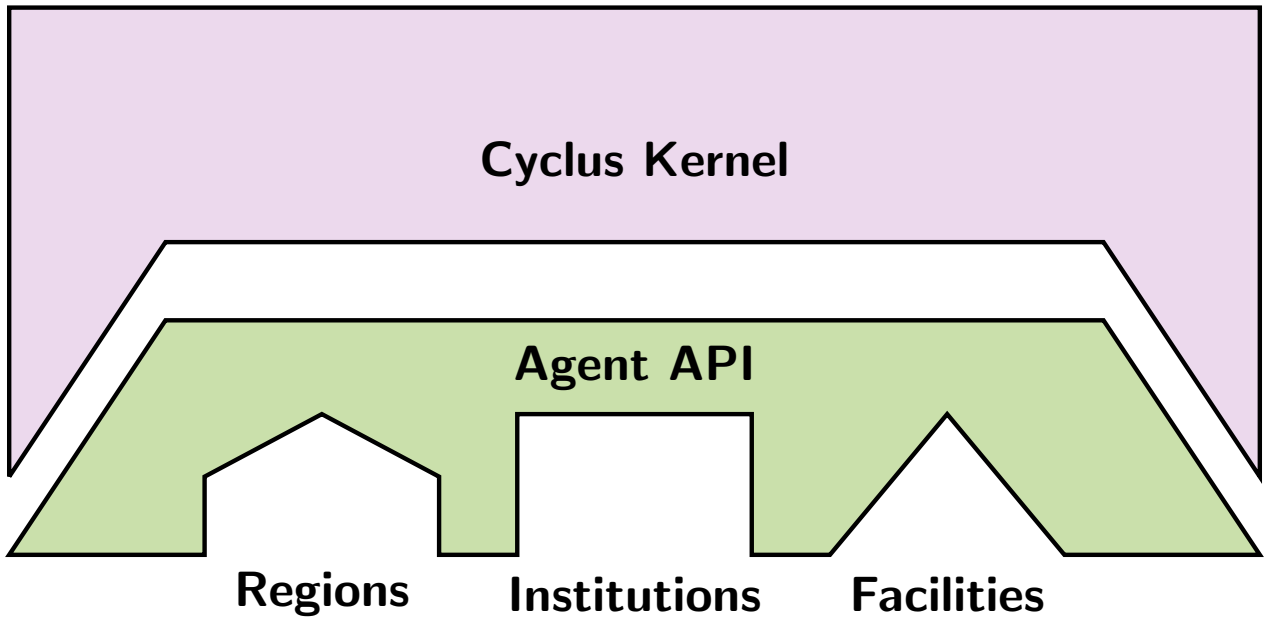
Outline

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].



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.

Nonproliferation and Safeguards.

CNTAUR [3] and Pyre [5] format outputs in IAEA code 10 format and model real time diversion, respectively.

Facility Models.

OpenMCyclus [1] couples Cyclus with OpenMC to model realtime depletion. The Dynamic Power Reactor (DPR) and Trading On-Demand (TOD) reactor, which introduce dynamic parameters and change how the facilities interact with time.

Transition Scenarios.

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

Outline

Greedy reactor deployment algorithm

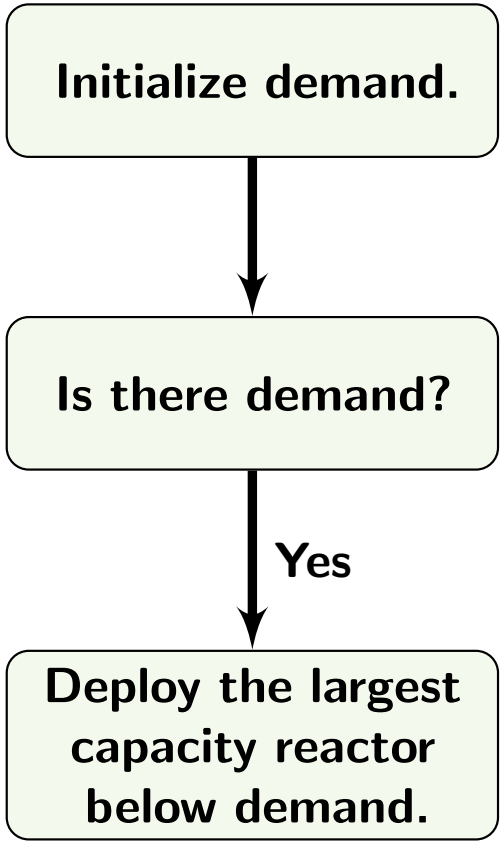


Figure 1: The greedy deployment diagram demonstrates a preference for the larger power capacity reactors, and shows how the scheme could under-deploy if the remaining capacity is less than the size of the smallest reactor.

Greedy reactor deployment algorithm

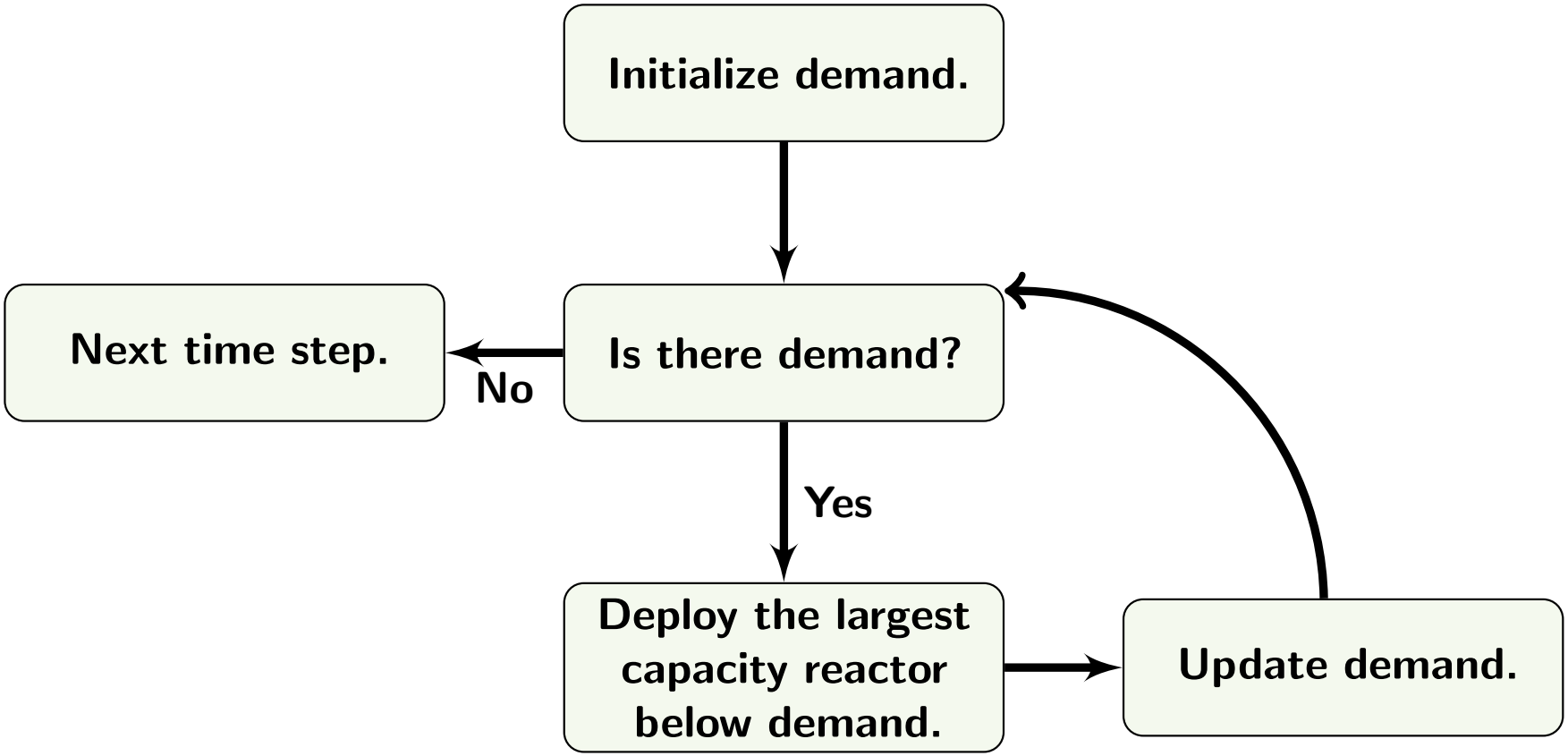


Figure 1: The greedy deployment diagram demonstrates a preference for the larger power capacity reactors, and shows how the scheme could under-deploy if the remaining capacity is less than the size of the smallest reactor.

Random reactor deployment algorithm

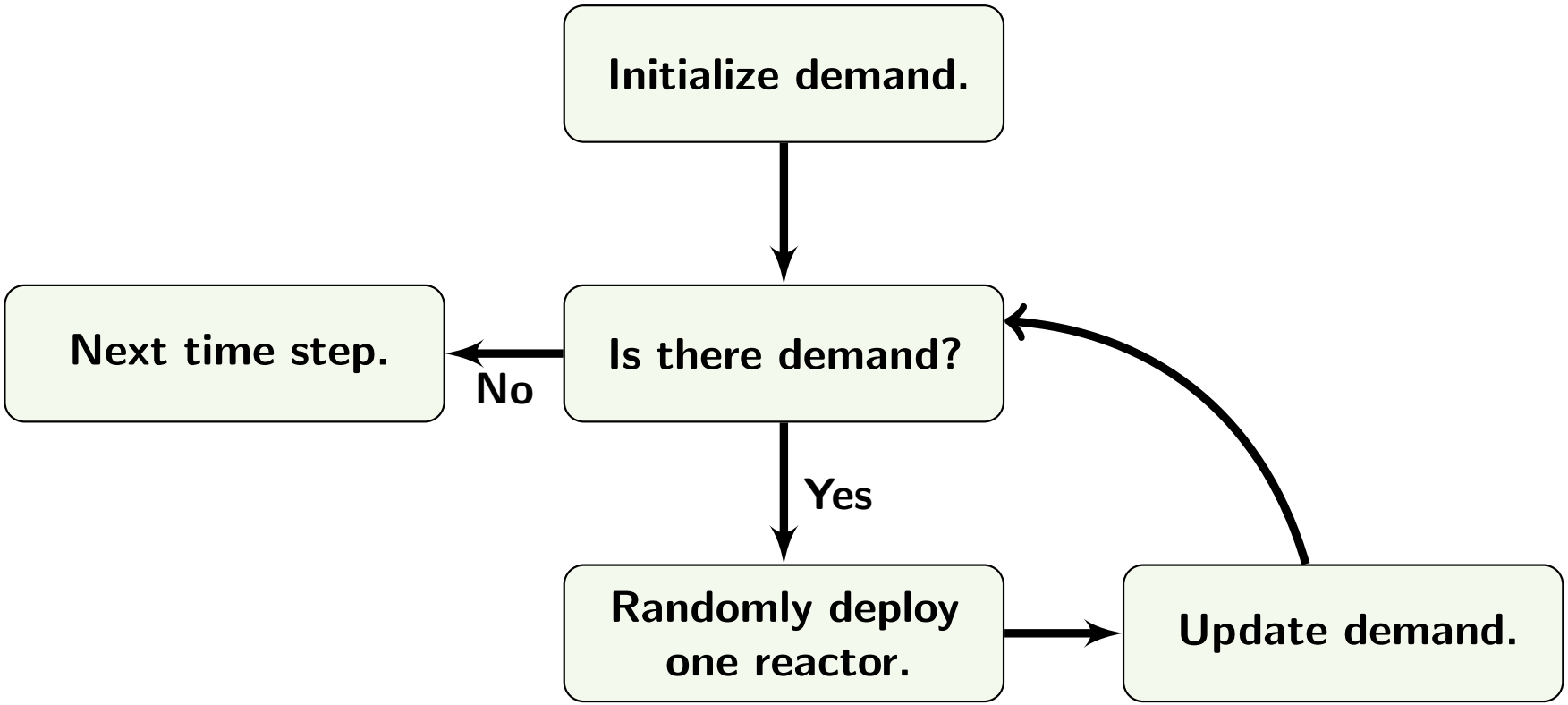


Figure 2: Random reactor deployment diagram. This algorithm randomly deploys reactors until the demand is met. If a reactor is deployed that exceeds the demand, it will simply be removed and the algorithm will try again.

Random + greedy reactor deployment algorithm

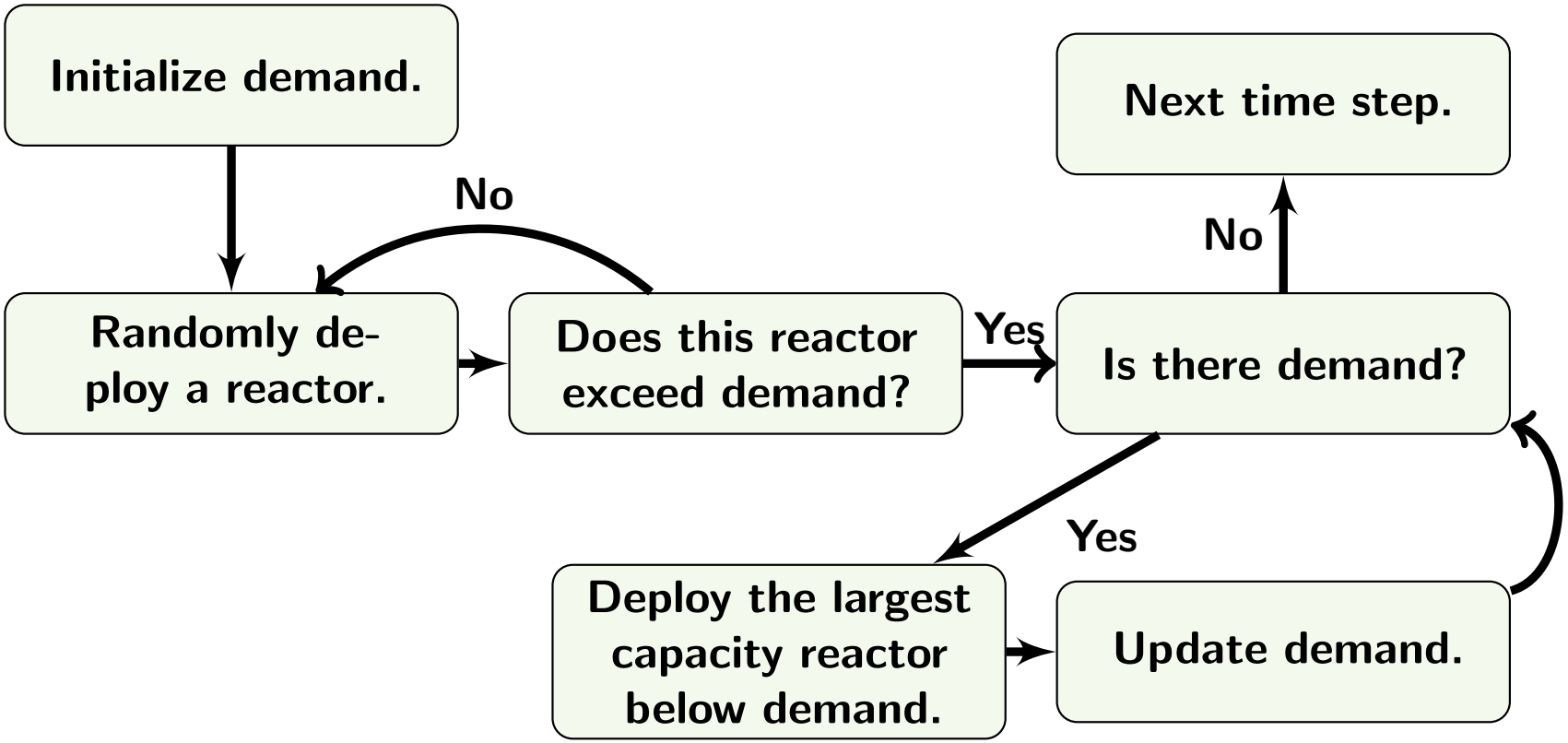


Figure 3: Random + Greedy deployment diagram. This algorithm first attempts to randomly deploy a reactor, and if that reactor exceeds demand, it will remove the last reactor and then use the greedy approach to fill in the remaining demand.

Outline

What are our options if we cannot get HALEU fuel?

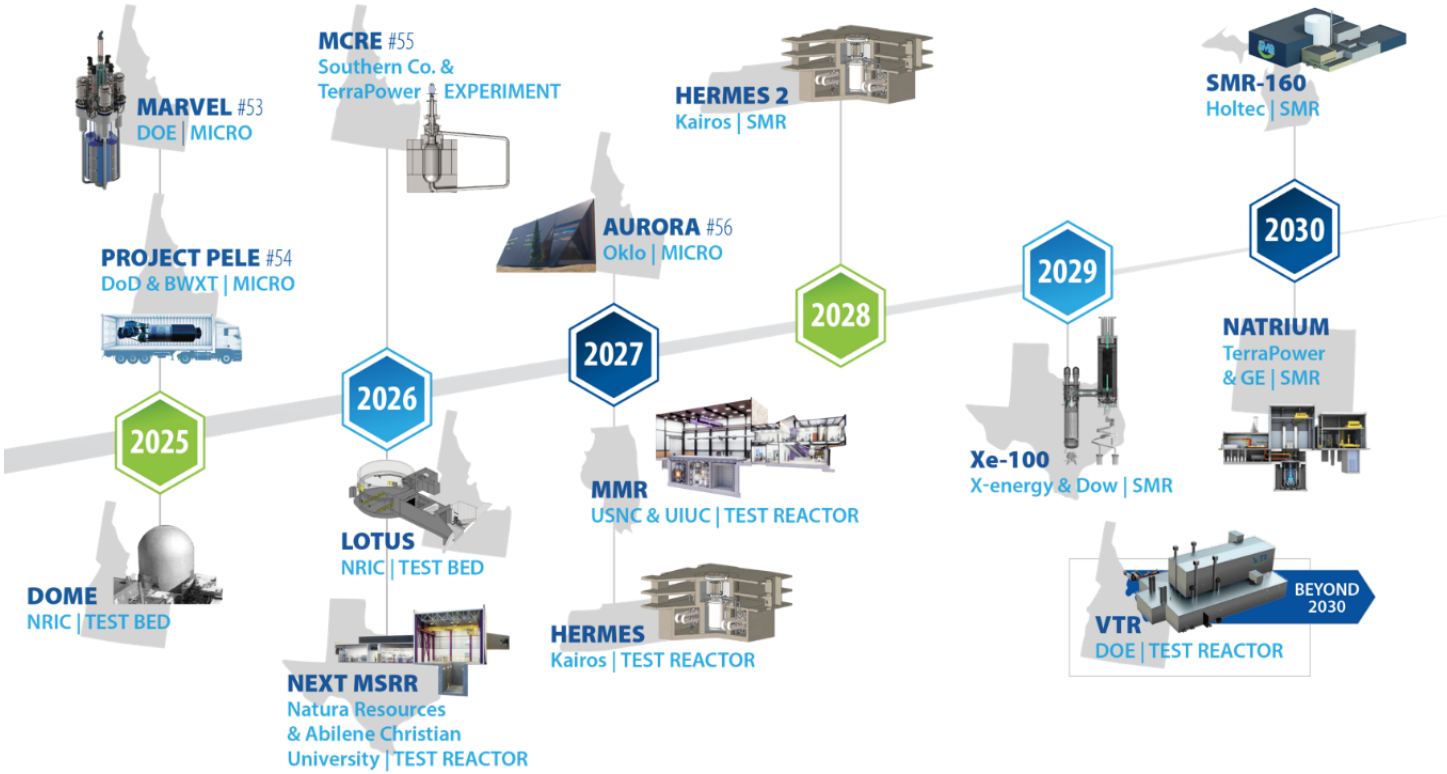


Figure 4: Advanced reactor demonstration and deployment projects [4].

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

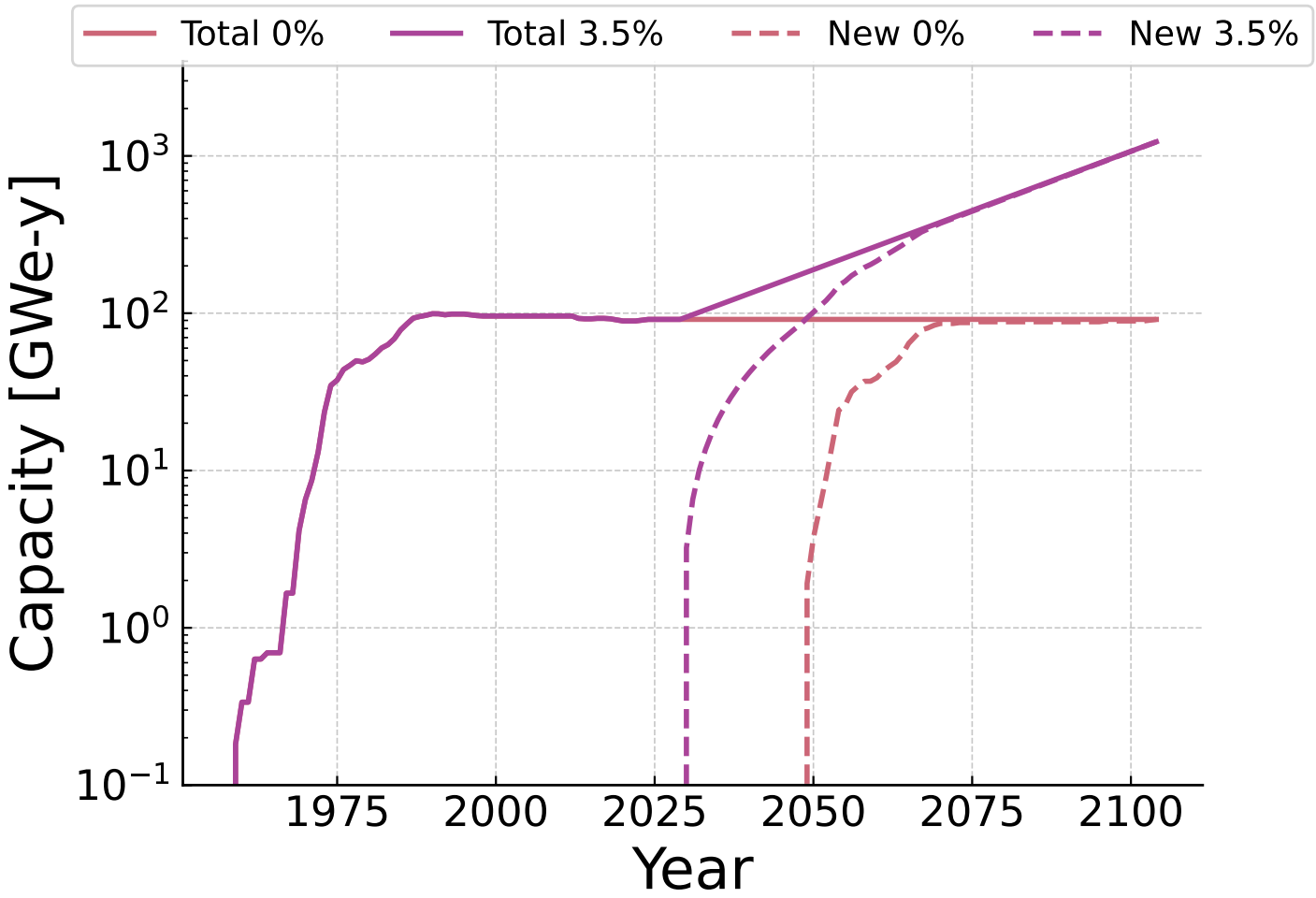
We define the enrichment levels as...

Table 1: Enrichment levels and their ranges.

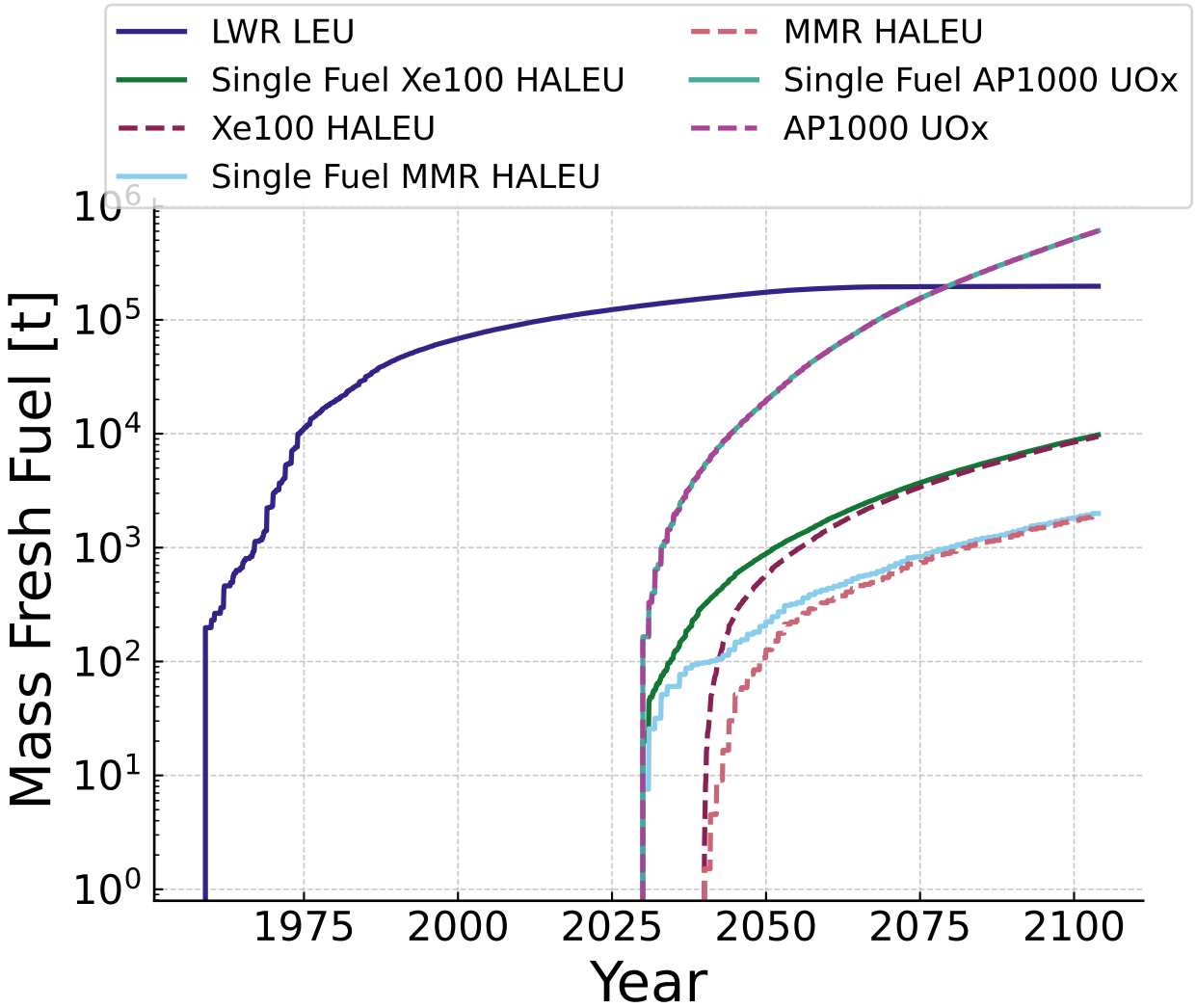
Enrichment Level	**Range [% ^{235}U]**
Natural	< 0.711
LEU	0.711-5
LEU+	5-10
HALEU	10-20
HEU	≥ 20

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

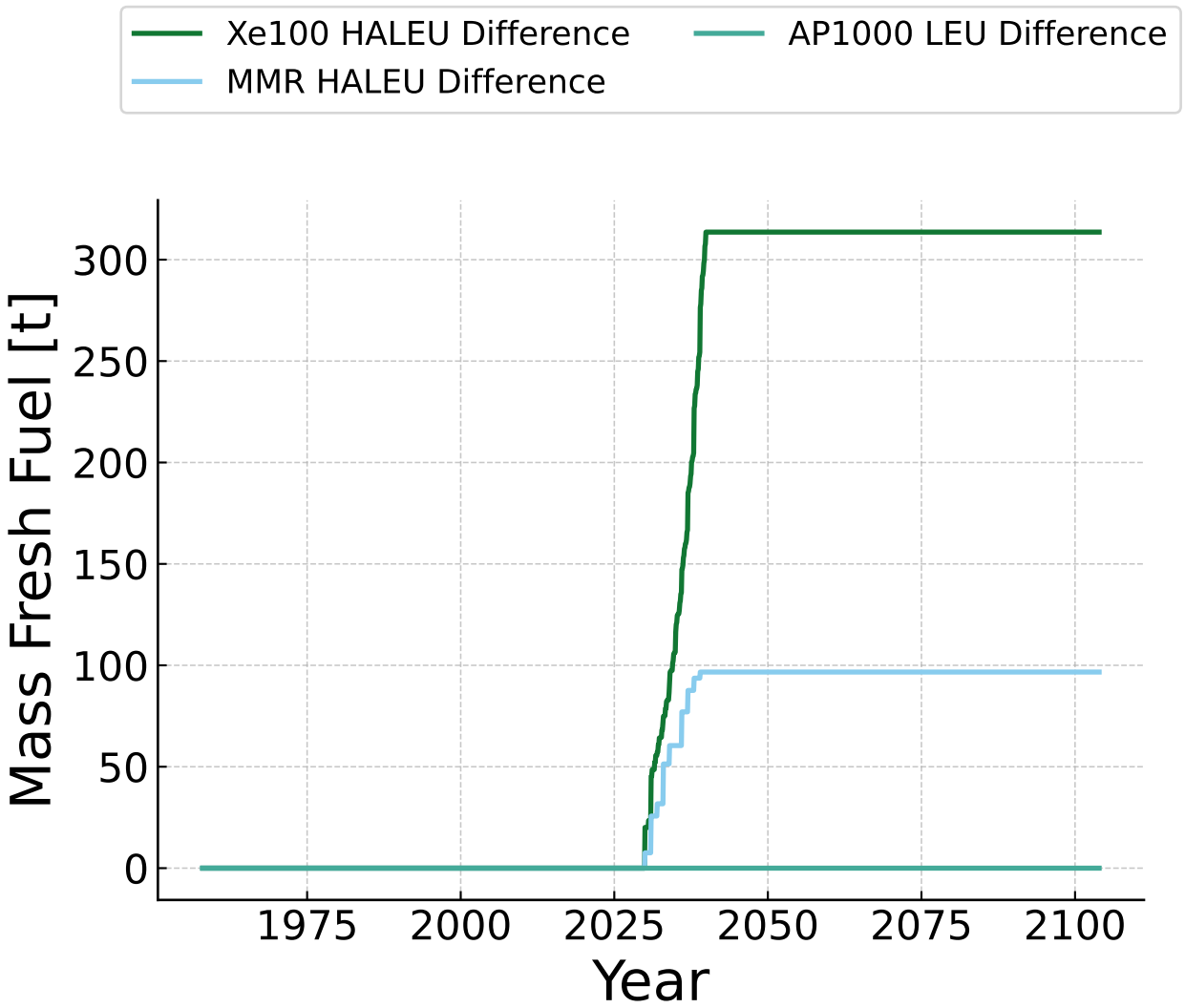
Our demand for energy is going up



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

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