LEU+ to HALEU transitions in advanced reactor fuel cycles

ANS Great Lakes Local Section

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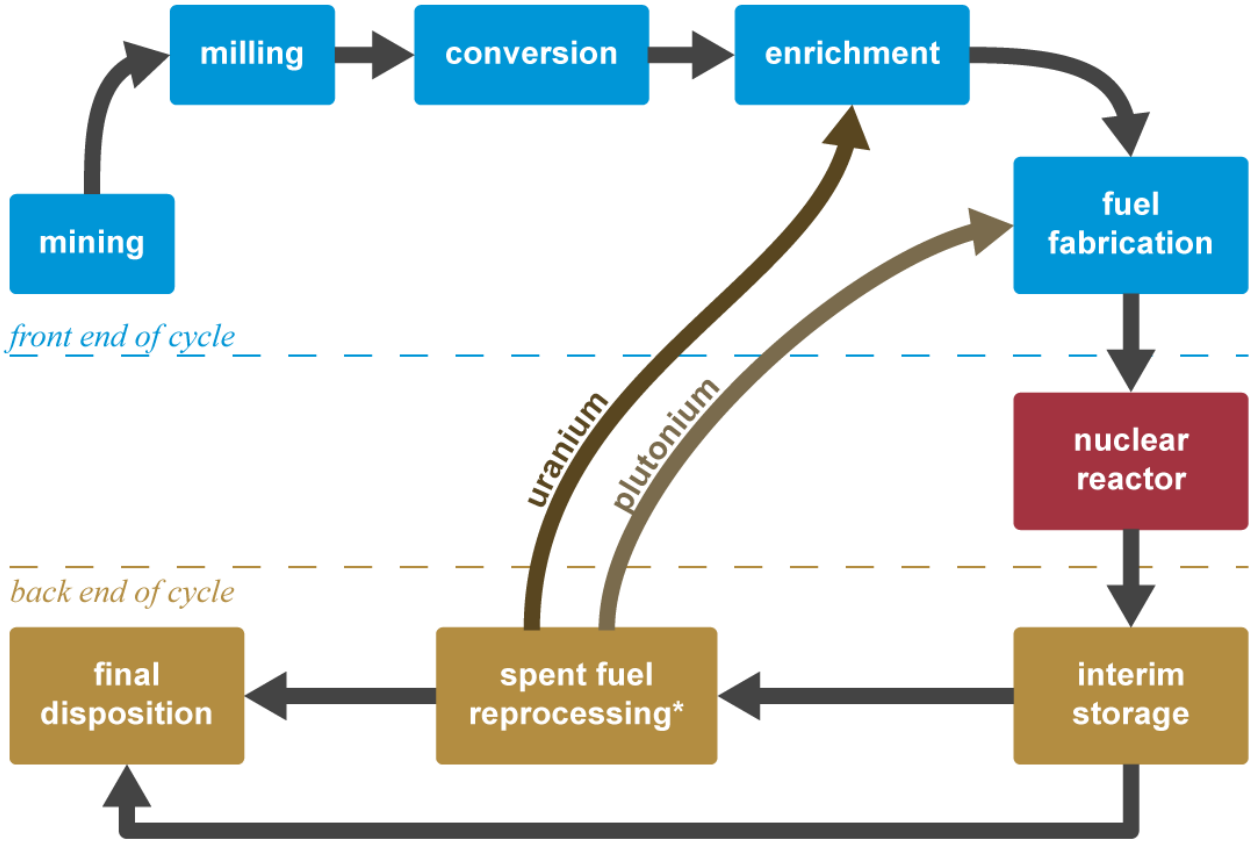
Outline

Generally, fuel cycles have these steps



**Spent fuel reprocessing* is omitted from the cycle in most countries, including the United States.

Source: Penn State Univ. Radiation Science and Engineering Center (public domain)*

Not all fuel cycles are made equal, and we want options

Concerns about economics, waste generation, proliferation risk, and sustainability motivate the need for fuel cycle options. With metrics like:

- natural resource utilization,
- waste mass/volume,
- special material quantities,
- separative work units,
- and energy production,

we can begin to evaluate the tradeoffs between fuel cycle options.

Outline

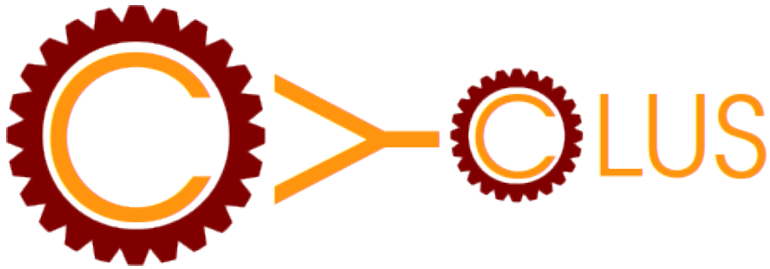
Big questions in fuel cycle modeling

Increased computational power and advanced reactors mean more detailed fuel cycle modeling.

- How can we make facility models more accurate?
- How can we make transaction models more detailed?
- Can we implement nuclear fuel cycle codes to identify realtime diversion or diversion paths?
- When do advanced reactor technologies change key metrics we use to evaluate fuel cycles?

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

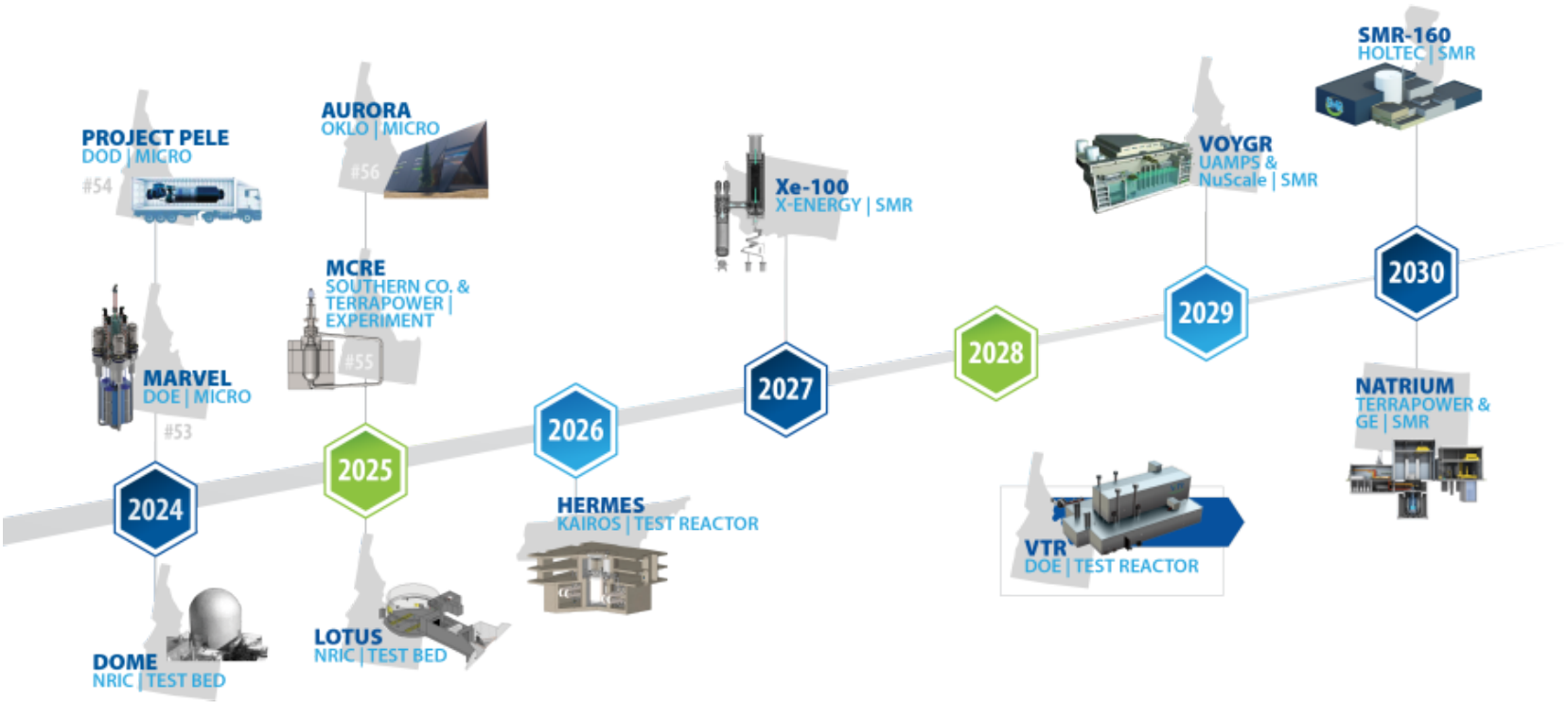
CNTAUR [3] and Pyre [4] format outputs in IAEA code 10 format and model real time diversion, respectively.

Finding advanced reactor impacts on the fuel cycle

We will talk a little about that today!

Outline

A mildly provocative question



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

What if we can't get HALEU to fuel these advanced reactors? Could we use LEU+ in the meantime?

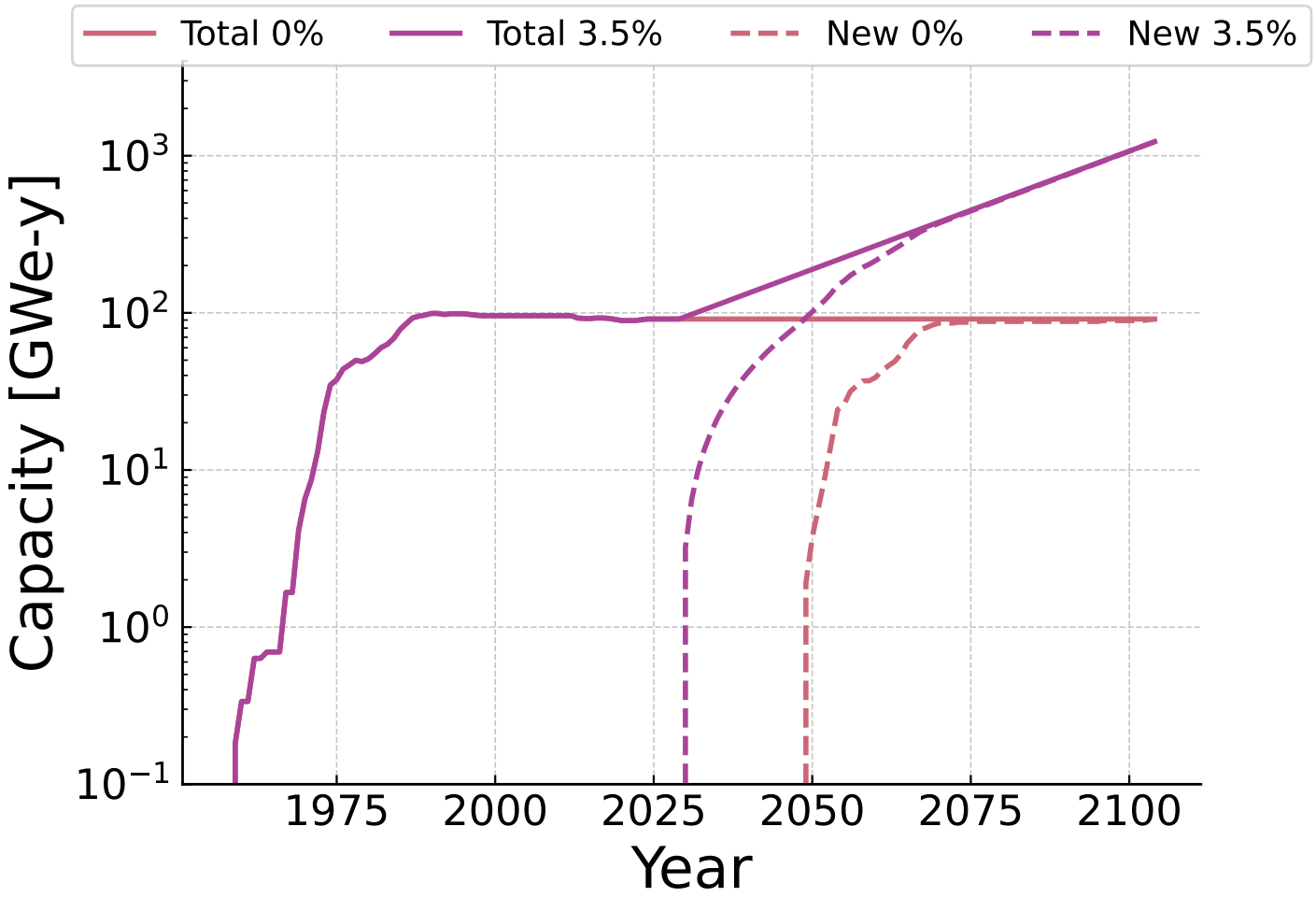
We define the enrichment levels as...

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

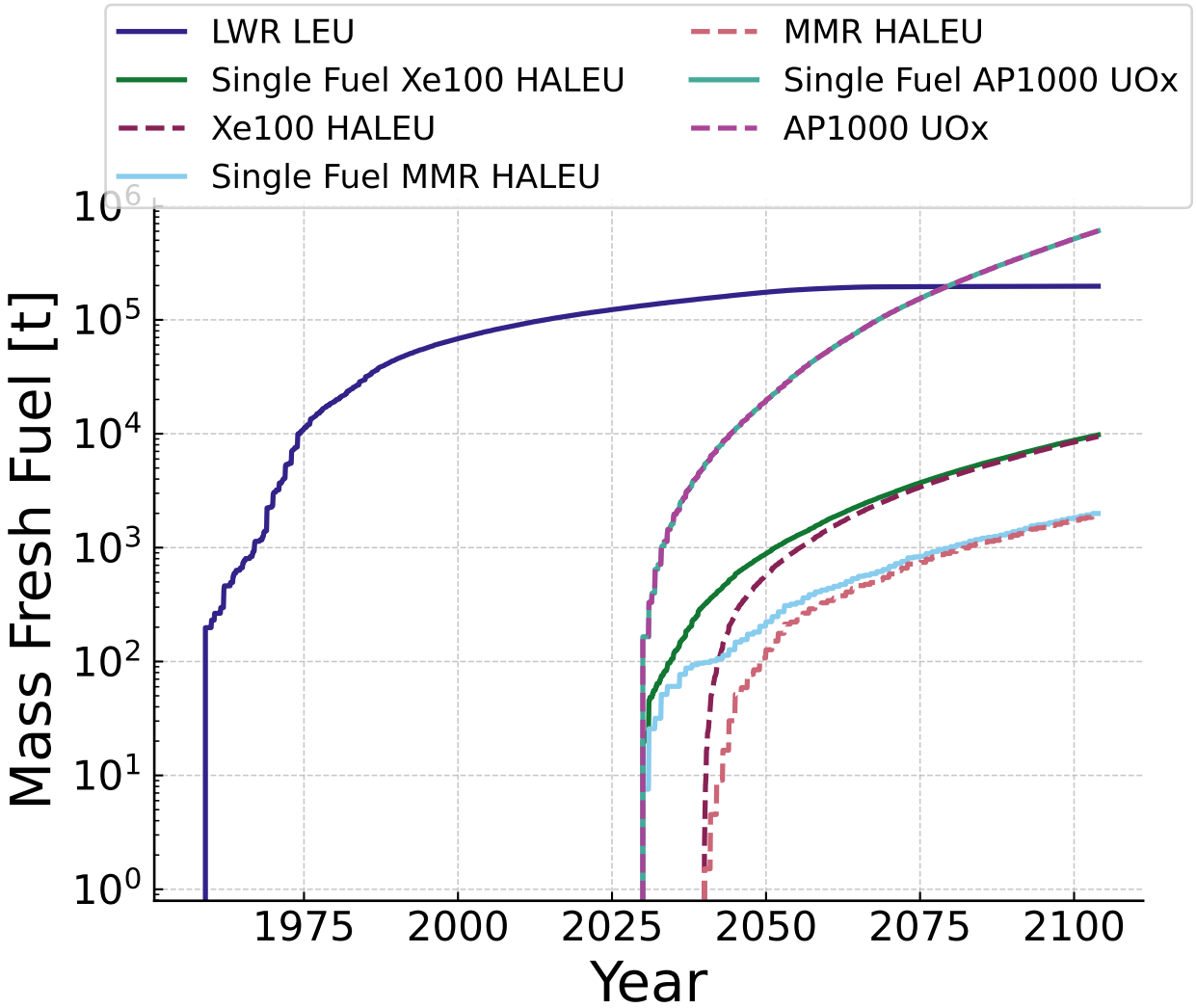
Enrichment levels and their ranges.

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

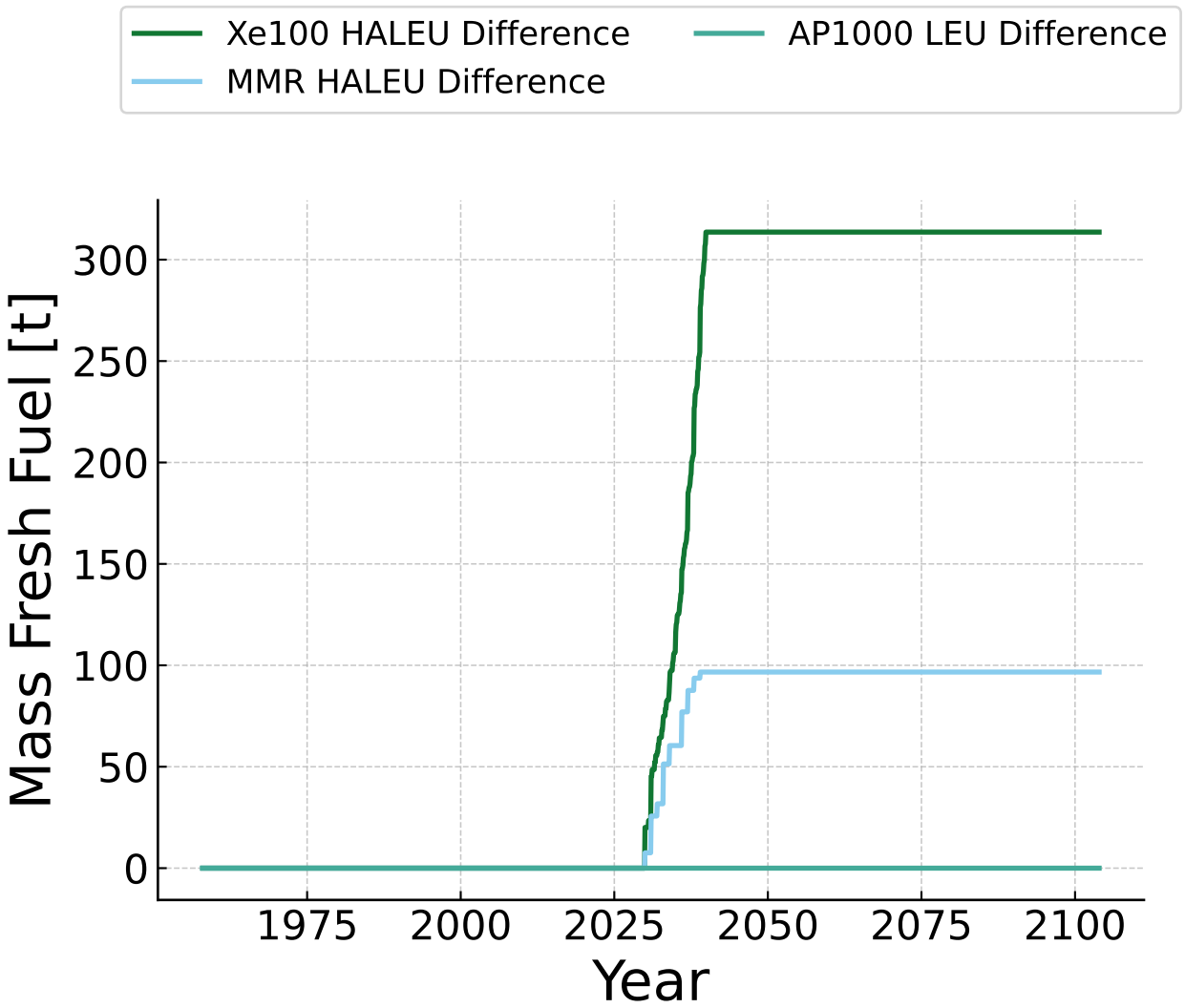
Our demand for energy is going up



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.

Acknowledgement

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References I

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Know how to code?

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Go to our website: `https://www.cranephysics.org`