

# LEU+ to HALEU transitions in advanced reactor fuel cycles

## ANS Great Lakes Local Section

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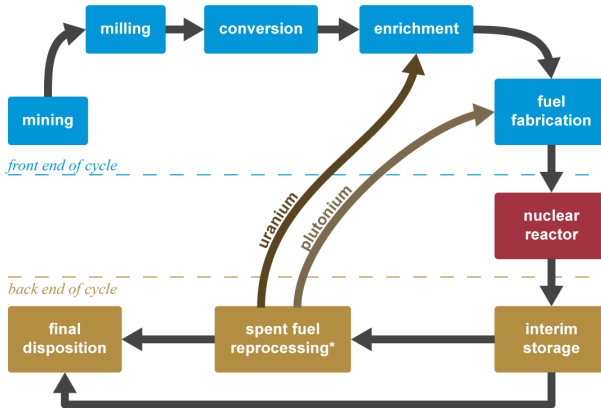




# Outline

- ① Nuclear Fuel Cycle
- ② Fuel Cycle Modeling
- ③ LEU+ to HALEU
- ④ Conclusion

## 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.



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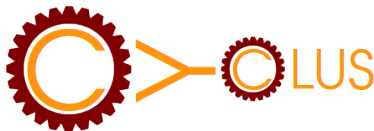
## Big questions in fuel cycle modeling

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](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

OpenMCcyclus [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

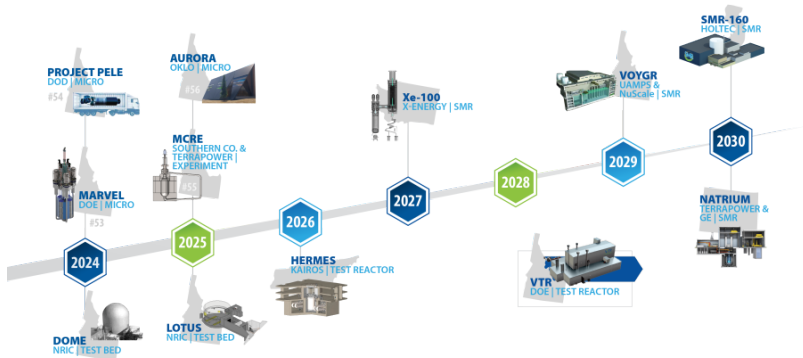
We will talk a little about that today!



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## A mildly provocative question



Source: [inl.gov/nuclear-reactor-sustainment-and-expanded-deployment/](https://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?



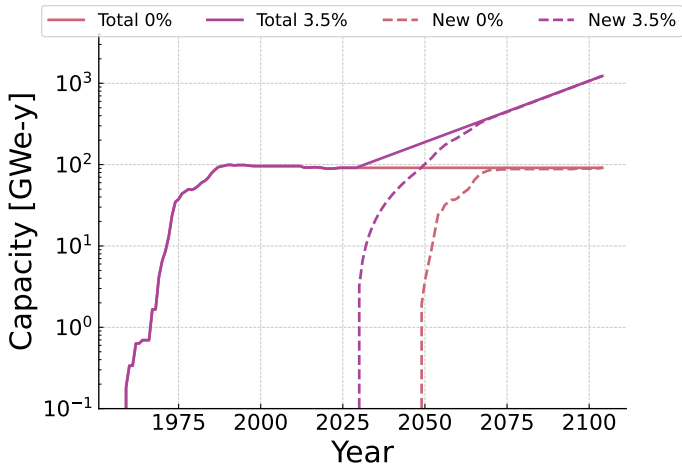
## We define the enrichment levels as...

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

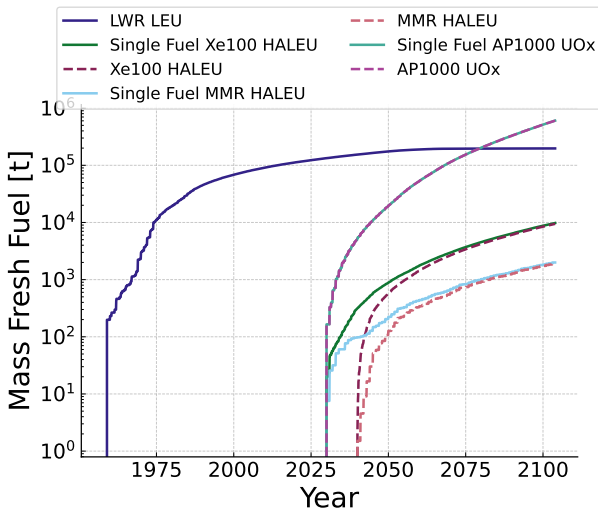
Enrichment levels and their ranges.

Enrichment Level	Range [% $^{235}\text{U}$ ]
Natural	< 0.711
LEU	0.711-5
LEU+	5-10
HALEU	10-20
HEU	$\geq$ 20

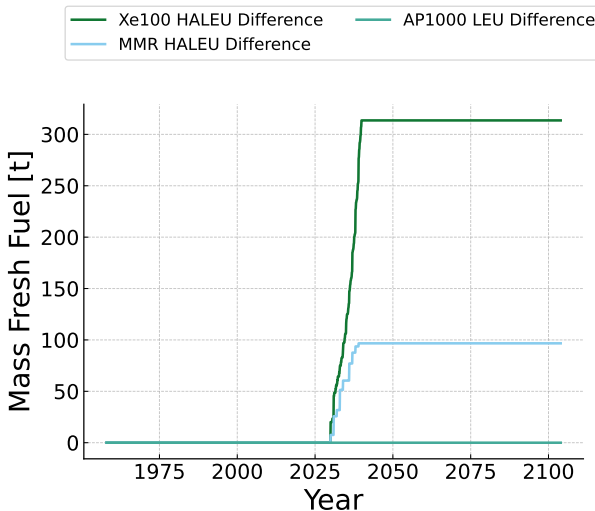
## Our demand for energy is going up



# Staggering enrichment could give the supply chain time to develop



The difference is on the order of hundreds of tons





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## Fuel cycles modeling is useful for energy 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?



Consider volunteering as a TA or mentor in the Computational Resource Access NEtwork (CRANE) so we can support more students!



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