Diversion Detection in Cyclus

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Outline

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    - Inter-facility Diversion
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3) Demonstrations
    - Diversion
    - Transition Scenarios
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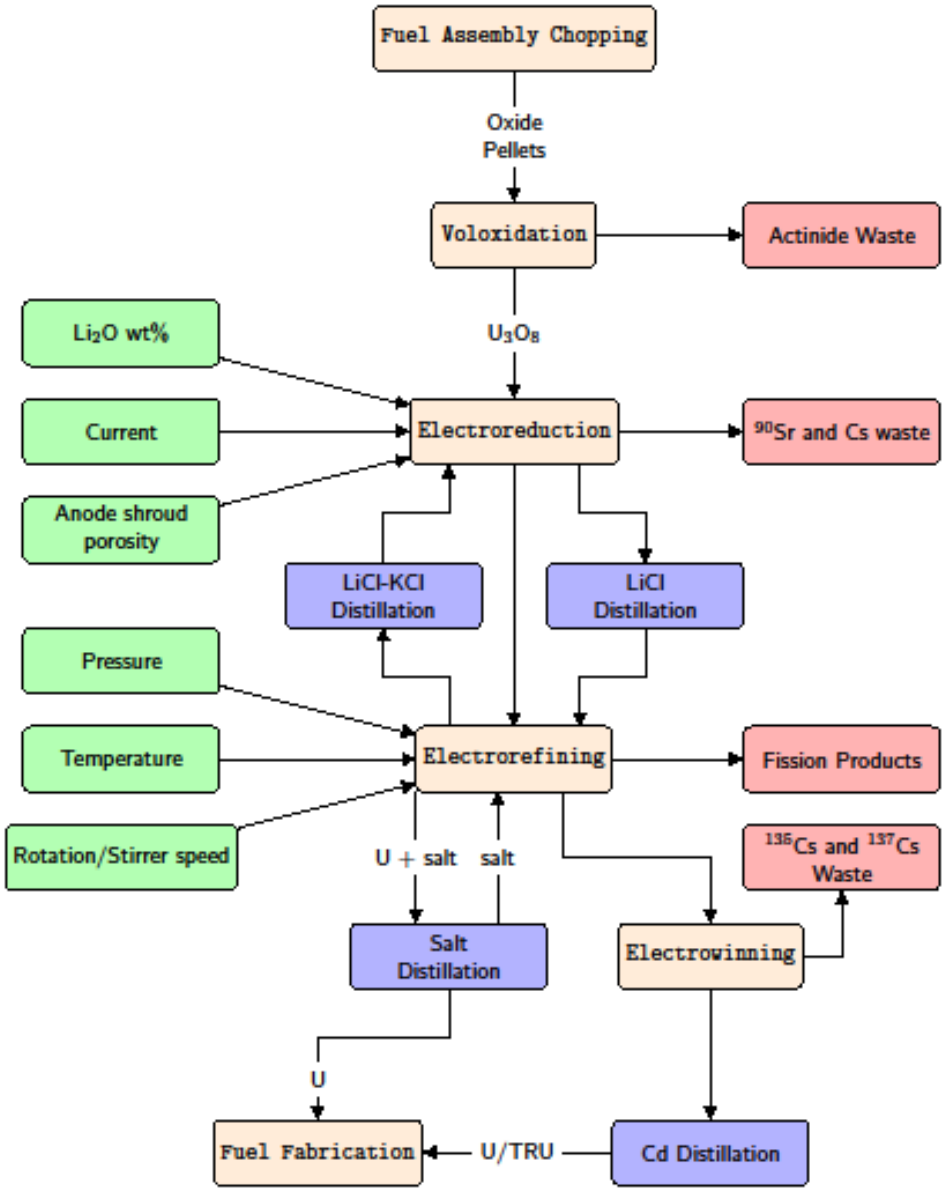
Motivation/Goals

- Motivation:
  - Safeguard by design
  - Transition from LWR to SFR
  - Model Diversion inside facilities
- Goals:
  - Timely detection of diversion relies on the identification of signatures and observables for unique facilities.
  - Determine optimum detector and inspection locations in pyroprocessing facilities using the Cyclus framework.
  - Adapt this work to be applicable to a wide range of nuclear fuel cycle facilities in Cyclus
  - Characterize required detection sensitivities and corresponding false positive rates.

PyRe – Design

- Facility containing multiple sub-facilities resembling the sub-processes.
  - Allows subprocesses to be handled separately.
  - Independent transactions, possibility of diversion
- Parameters act as Capacity Factor to the ideal separation efficiency input
- Generic facility allows for multiple types of pyro plants



PyRe – Diversion Options

Material diversion occurs in two different modes: **nefarious** or **operator**.

- **Nefarious Diversion** imagines diversion by a single bad actor with facility access.
- **Operator Diversion** imagines undeclared production.

- Either can be achieved by increasing plant throughput and siphoning off material excess for unsanctioned weapons production.

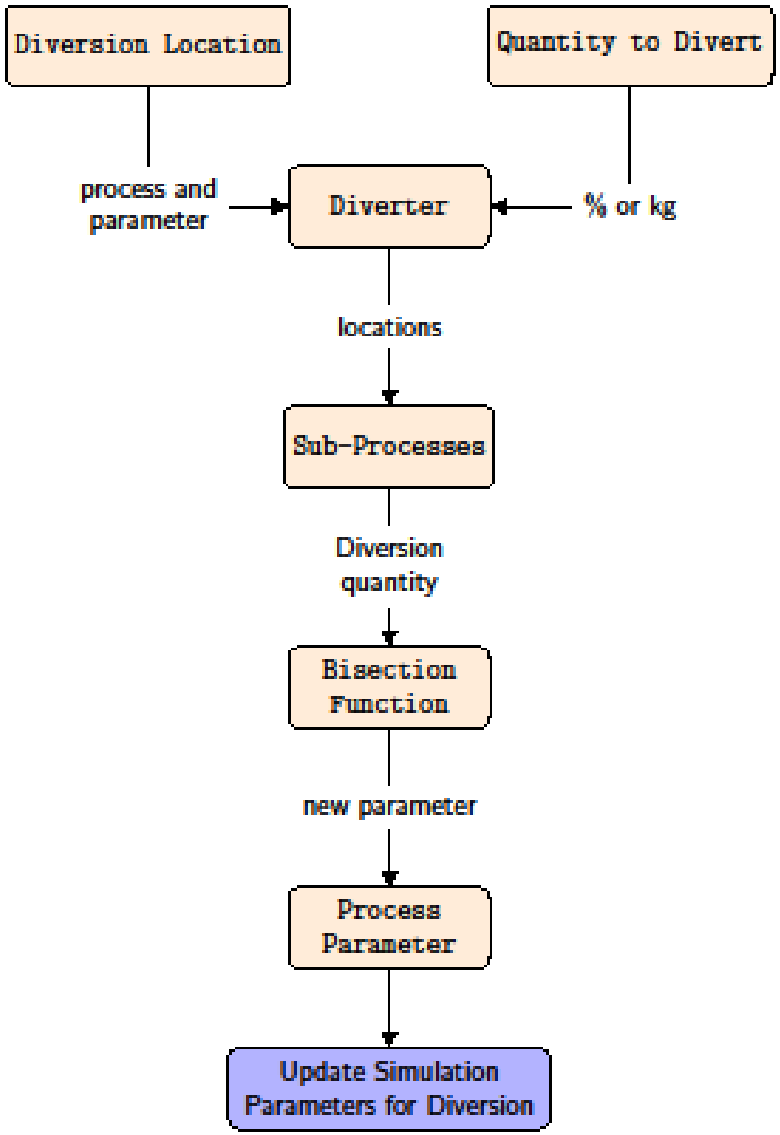
Diverter

This class handles all diversion:

- Which parameter to change
- What sub-process is compromised
- How much excess material needs to be produced for successful diversion

The purpose:

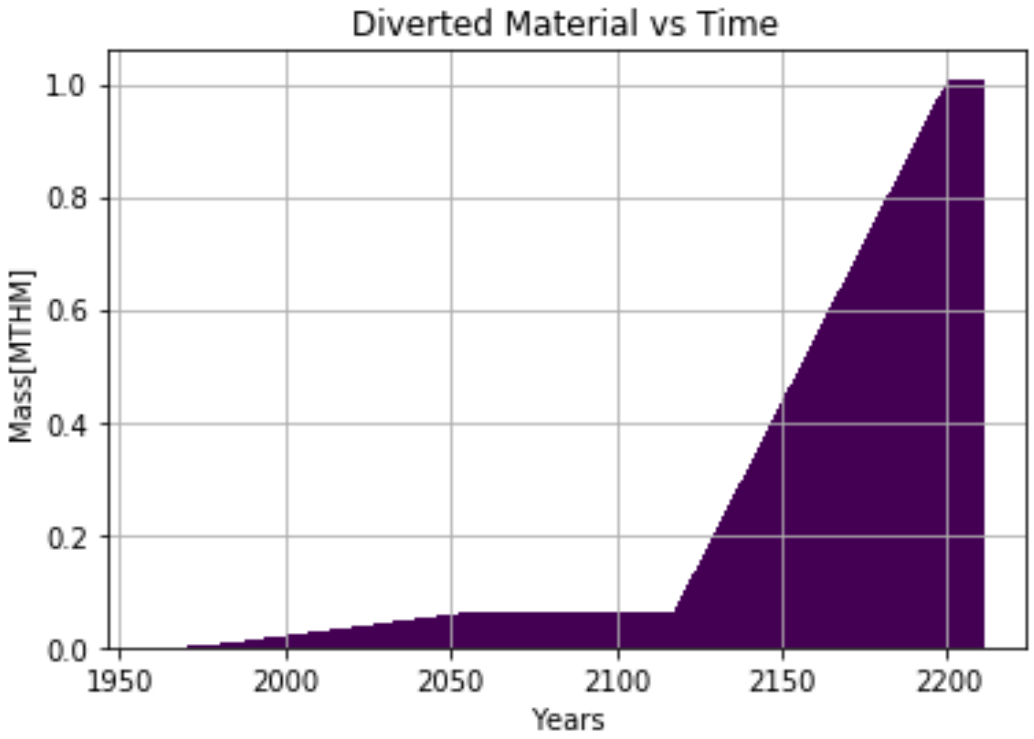
- Enable with future Cyclus facilities.
- Currently only implemented into PyRe



Diversion Settings

Each facility prototype can have unique diversion:

- Quantities
- Locations
  - Sub-process
  - Parameter
  - Type
- Number of Diversions
- Frequency

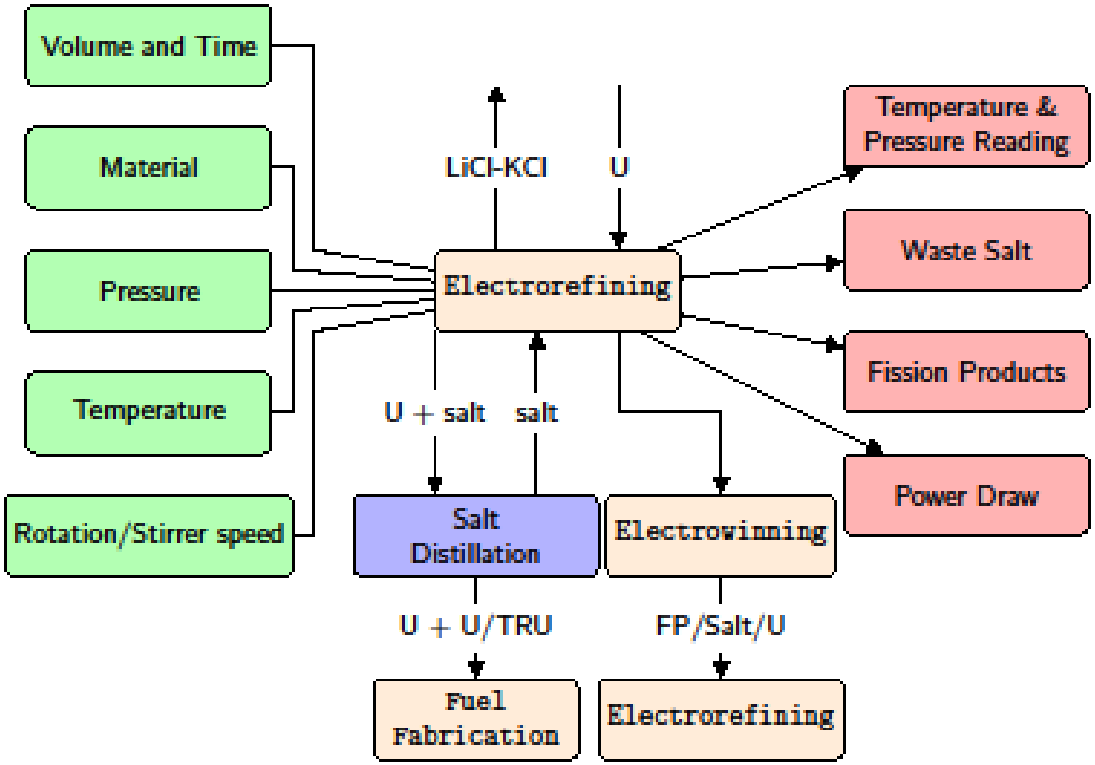


Diversion Detection

Nefarious:
- Can be detected by observing material transactions

Operator:
- Material transactions are no longer reliable
- Instead we use one or more of the parameters

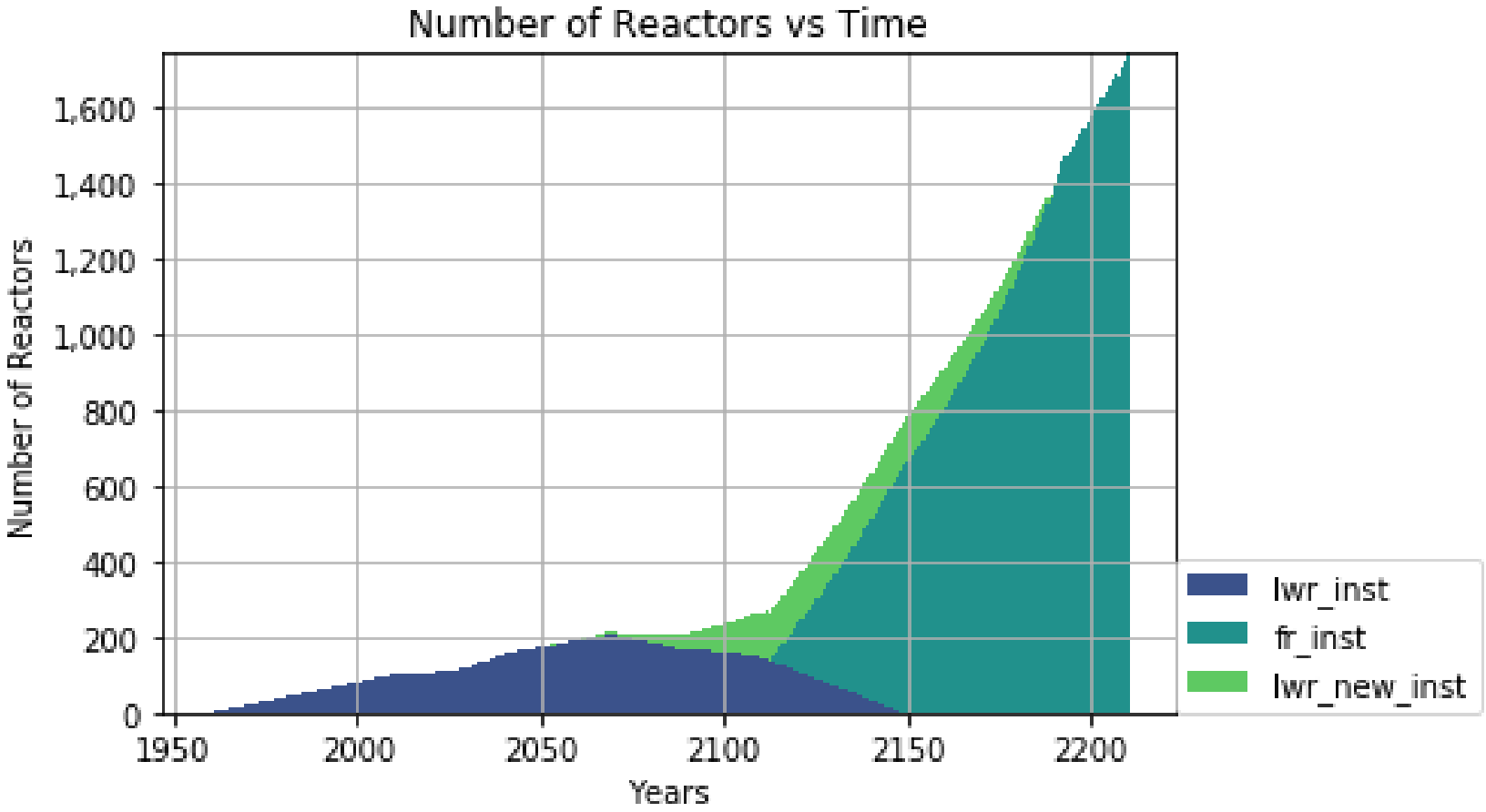
CUSUM Method:
- Startup time
- Generic
- 3 std. sets alarm



Transition Scenario

- A main attraction of pyroprocessing is the ability to handle LWR and SFR waste.
- To verify this capability, we ran a transition scenario from the current ~400 LWRs to approx. 2000 SFRs starting in 2050.
- We want to observe the following:
  - Appropriate deploying of PyRe
  - Ability to meet demand of new SFRs
  - Diversion capabilities (which was shown earlier)
  - Accurate transition from UOX to SFR fuels

Transition Scenario - Results



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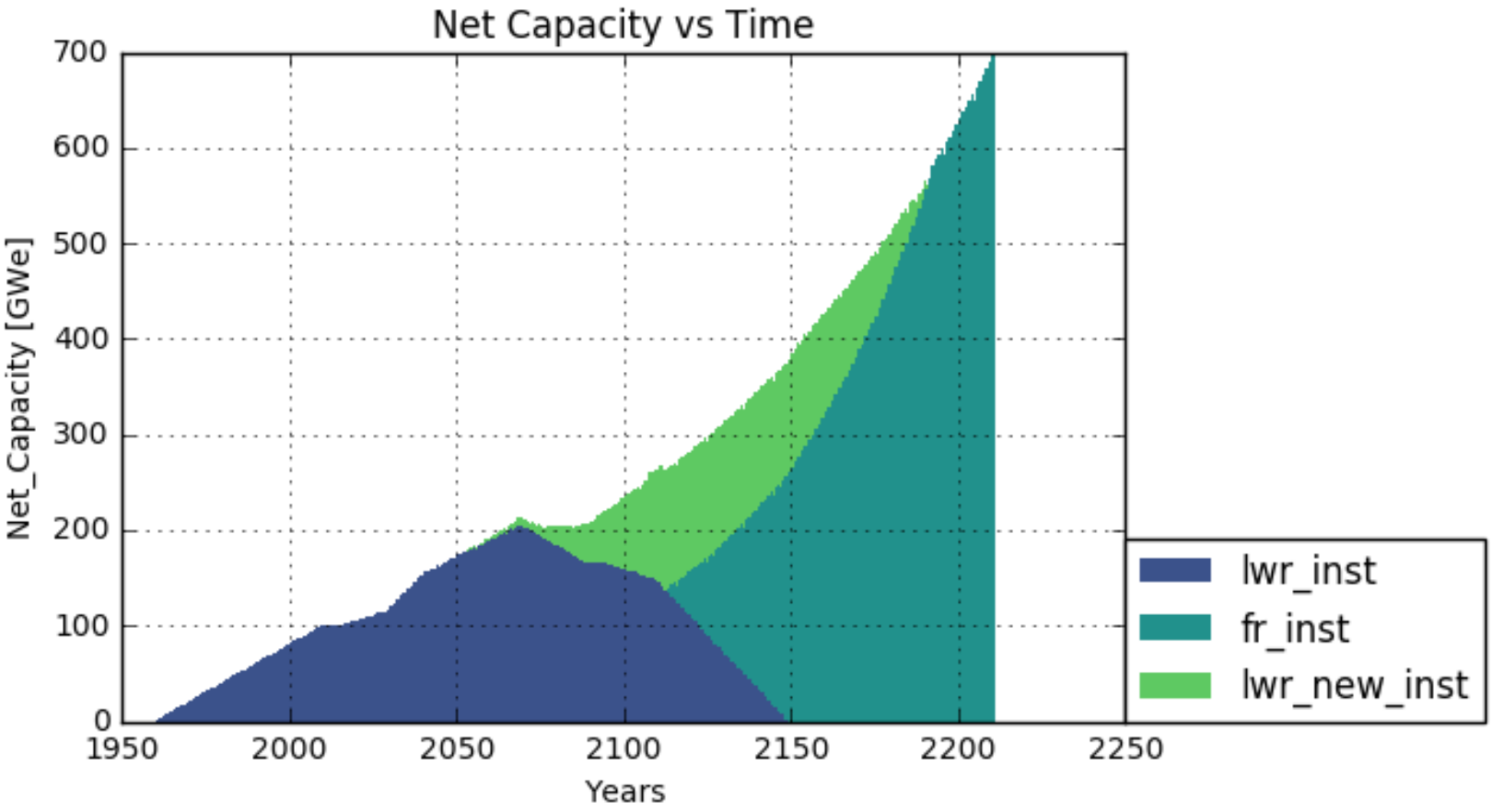
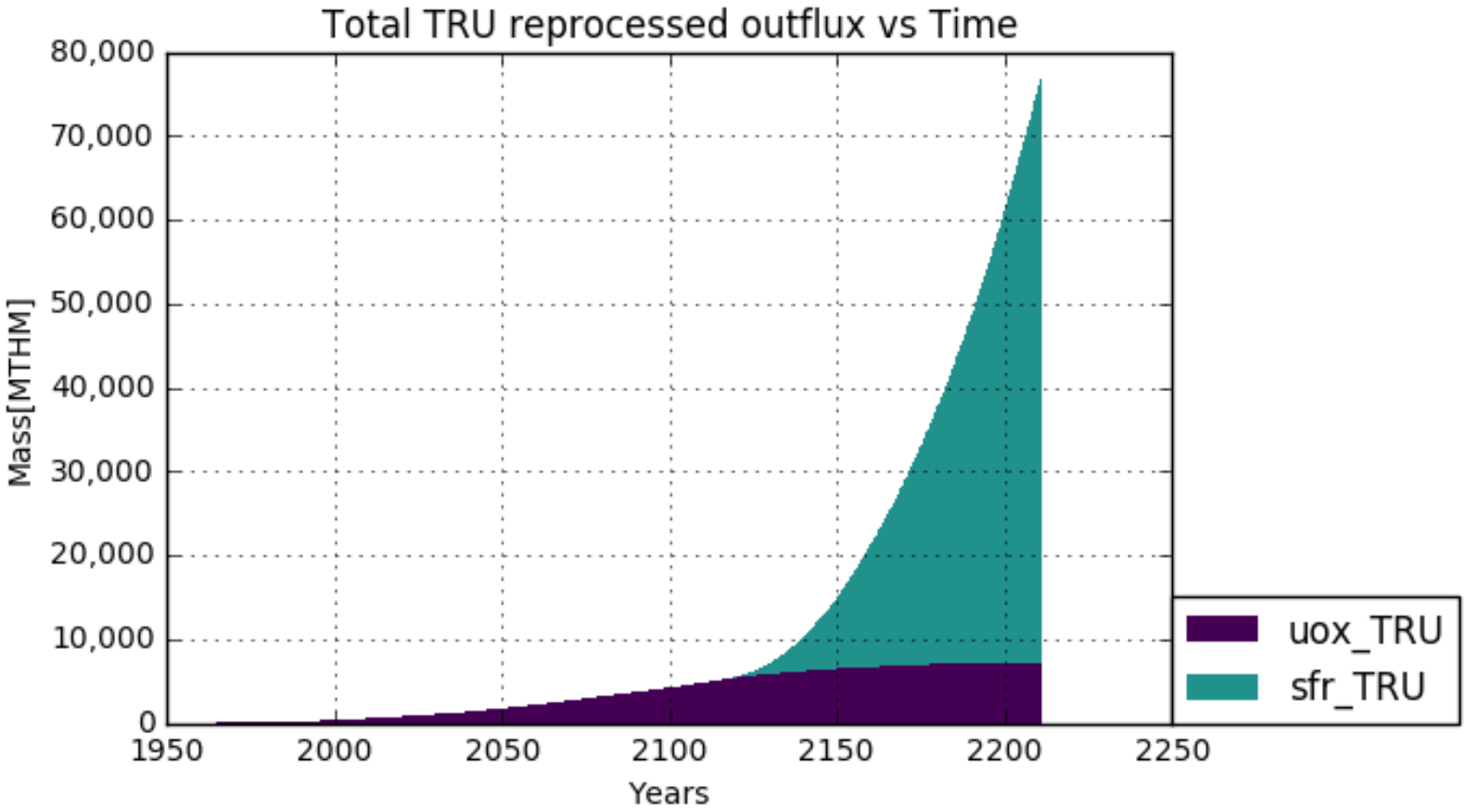


Transition Scenario - Utilization



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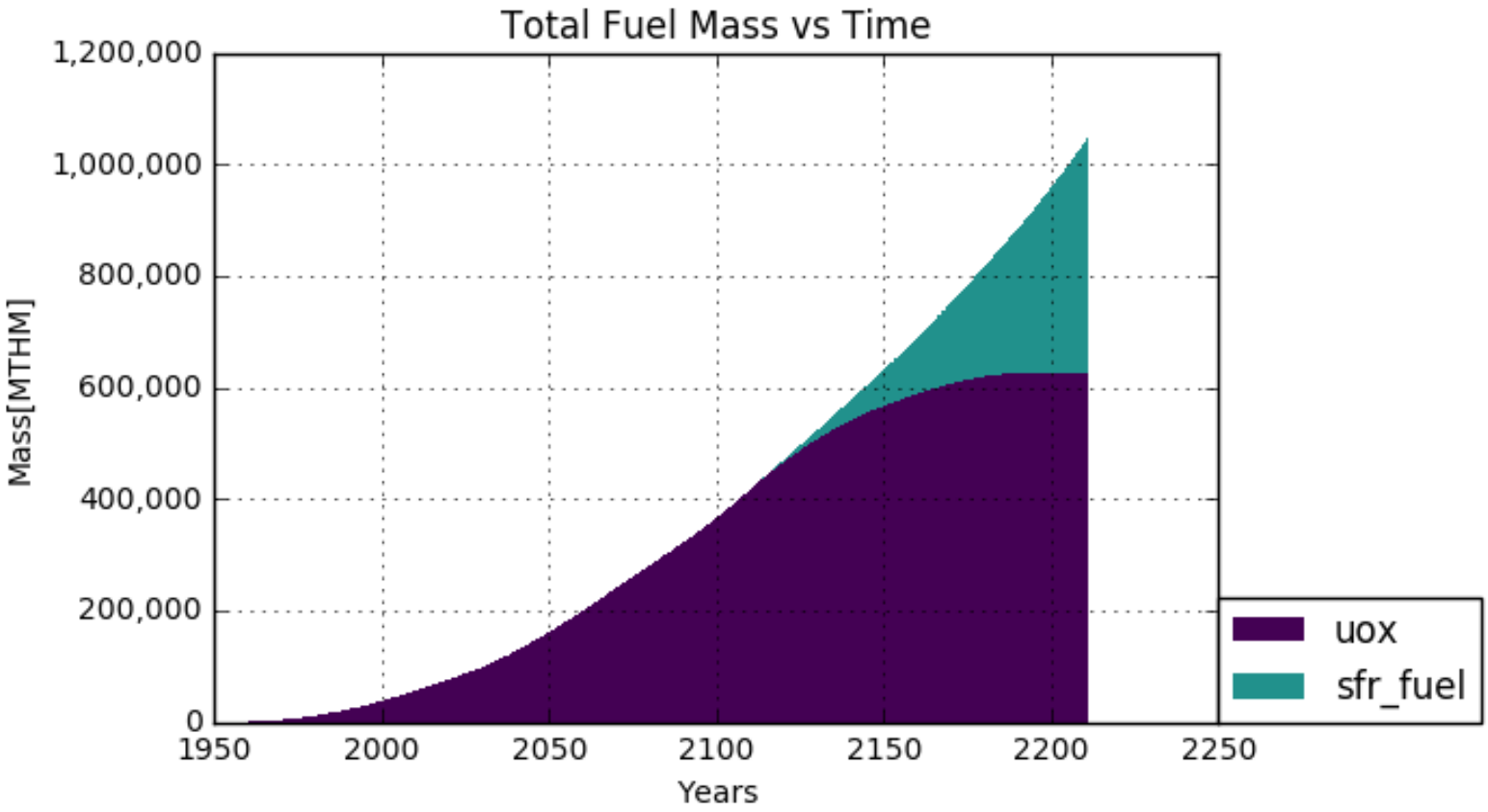

Conclusions

- We have developed a customizable method of diverting material from inside Cyclus facilities.
  - Preliminary work has been done on the detection of two different types of diversion: Nefarious and Operator
  - Initial results were demonstrated using the experimental PyRe archetype

- PyRe was demonstrated to function as both LWR and SFR reprocessing method
  - Capable of handling nefarious and operator diversion
  - Ability to handle independent waste streams for analysis/diversion
  - Generic facility capable of modeling multiple facility layouts

Future Work

Following this work, the following needs to be addressed:

- Finish CUSUM method for multiple parameters
  - Run a verification scenario
  - Perform sensitivity analysis on key parameters
- Adapt the Diverter class into a Cyclus toolkit so other archetypes can make use of it.
  - Initially designed for PyRe to test its functionality
- Run further test cases for PyRe, including different types of SFRs

References

[1]: K. D. HUFF, M. J. GIDDEN, R. W. CARLSEN, R. R. FLANAGAN, M. B. MCGARRY, A. C. OPOTOWSKY, E. A. SCHNEIDER, A. M. SCOPATZ, and P. P. H. WILSON, “Fundamental concepts in the Cyclus nuclear fuel cycle simulation framework,” Advances in Engineering Software, 94, 46–59 (Apr. 2016).

[2]: R. W. CARLSEN, M. GIDDEN, K. HUFF, A. C. OPO- TOWSKY, O. RAKHIMOV, A. M. SCOPATZ, Z. WELCH, and P. WILSON, “Cyclus v1.5.3,” Figshare (Jun. 2014), http://dx.doi.org/10.6084/m9.figshare.1041745.

Thank You

Any Questions?

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