Diversion Detection in Cyclus

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Outline

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    - Inter-facility diversion
2) PyRe
3) Diverter
4) Demonstrations
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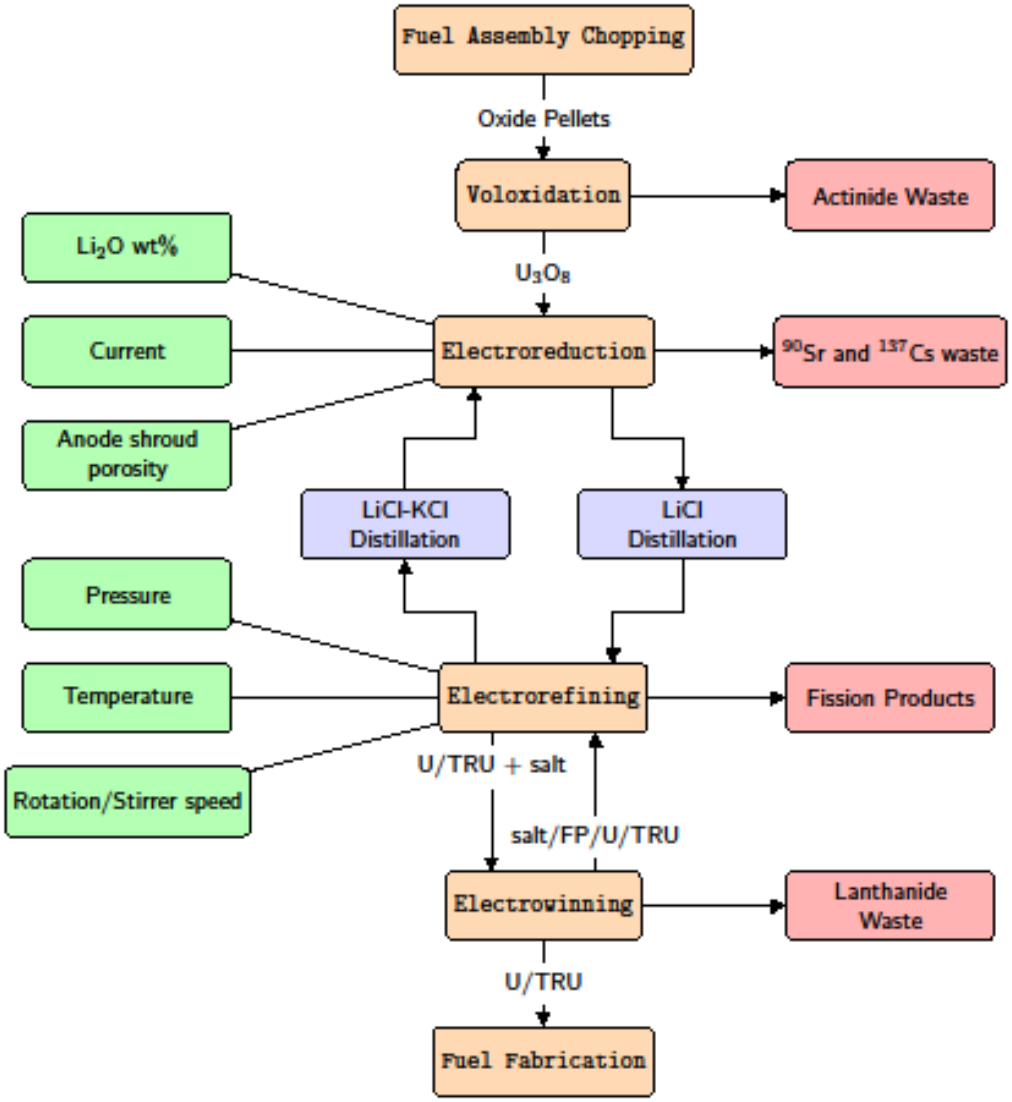
Motivation/Goals

- Motivation:
  - Safeguard by design
  - Transition from LWR to SFR
  - Model diversion inside facilities
- Goals:
  - Detect diversion using signatures and observables
  - Optimum detector and inspection locations in pyroprocessing
  - Expand to the rest of Cyclus
  - Characterize detection sensitivities and false positive rates.

PyRe – Design

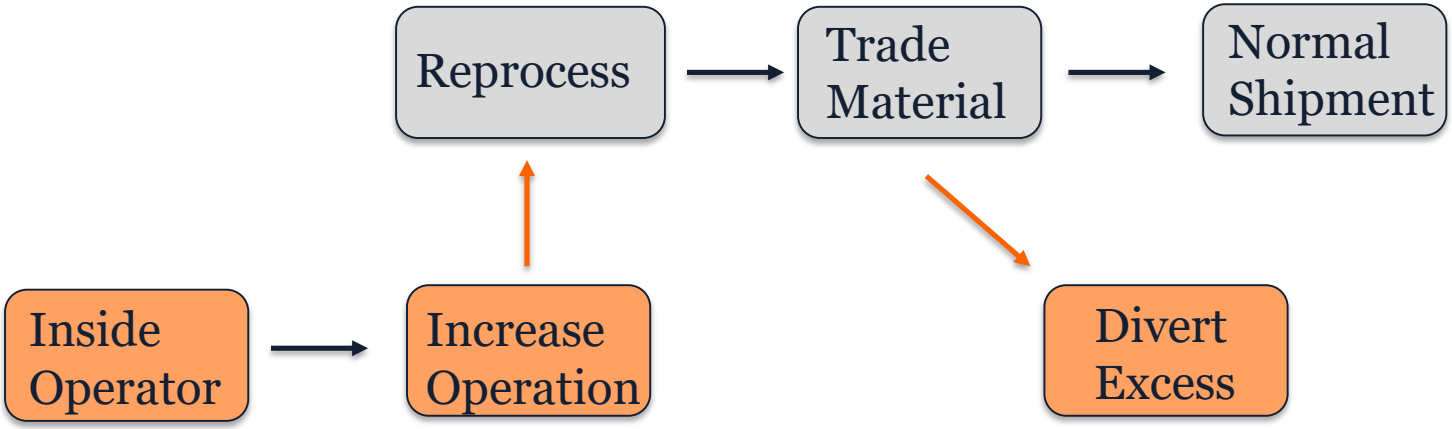
- Facility containing multiple sub-processes:
  - Separately handled
  - Independent transactions, possibility of diversion
- Operation settings impact efficiency
- Generic facility:
  - Multiple types of pyro plants
  - LWR vs SFR



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.



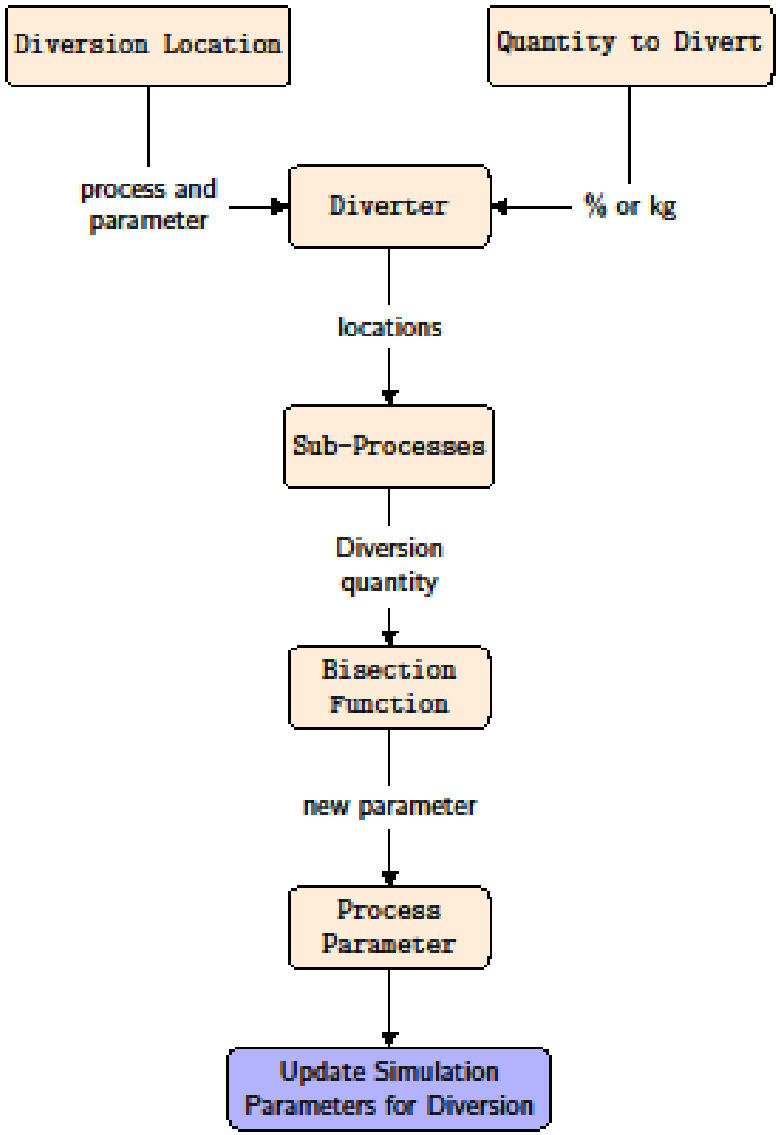
Diverter Class

Inputs:

- Location
  - Sub-process
  - Operation Setting
- Quantity
- Frequency
- Number of Diversions

The purpose:

- Cyclus toolkit
- Currently only implemented into PyRe

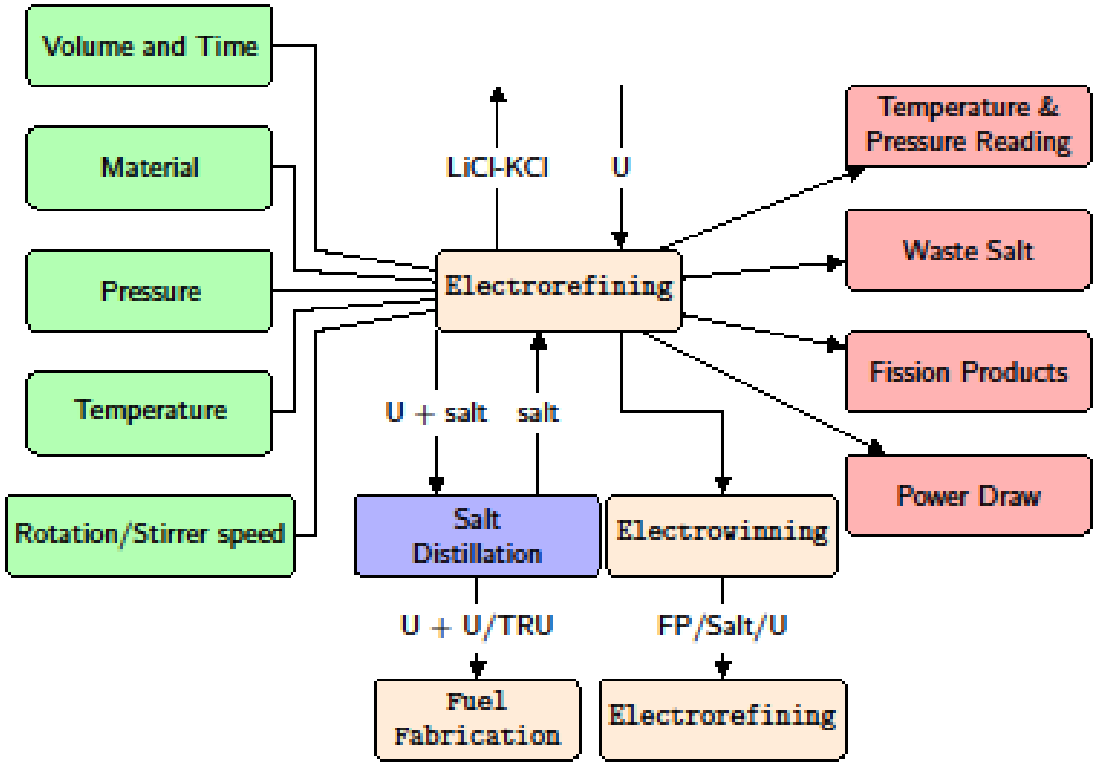


Diversion Detection

Nefarious:
- Transactions

Operator:
- Material transactions are no longer reliable
- Signatures and Observables

CUSUM Method:
- Startup time
- Generic
- 3 σ sets alarm



Transition Scenario

A main attraction of pyroprocessing is the ability to handle LWR and SFR waste.

- To verify this capability in PyRe, we ran an EG01 – EG24 transition scenario.
- We want to observe the following:
  - Appropriate deploying of PyRe
  - Ability to meet demand of new SFRs
  - Diversion capabilities
  - Accurate transition from UOX to SFR fuels

Transition Scenario - Setup

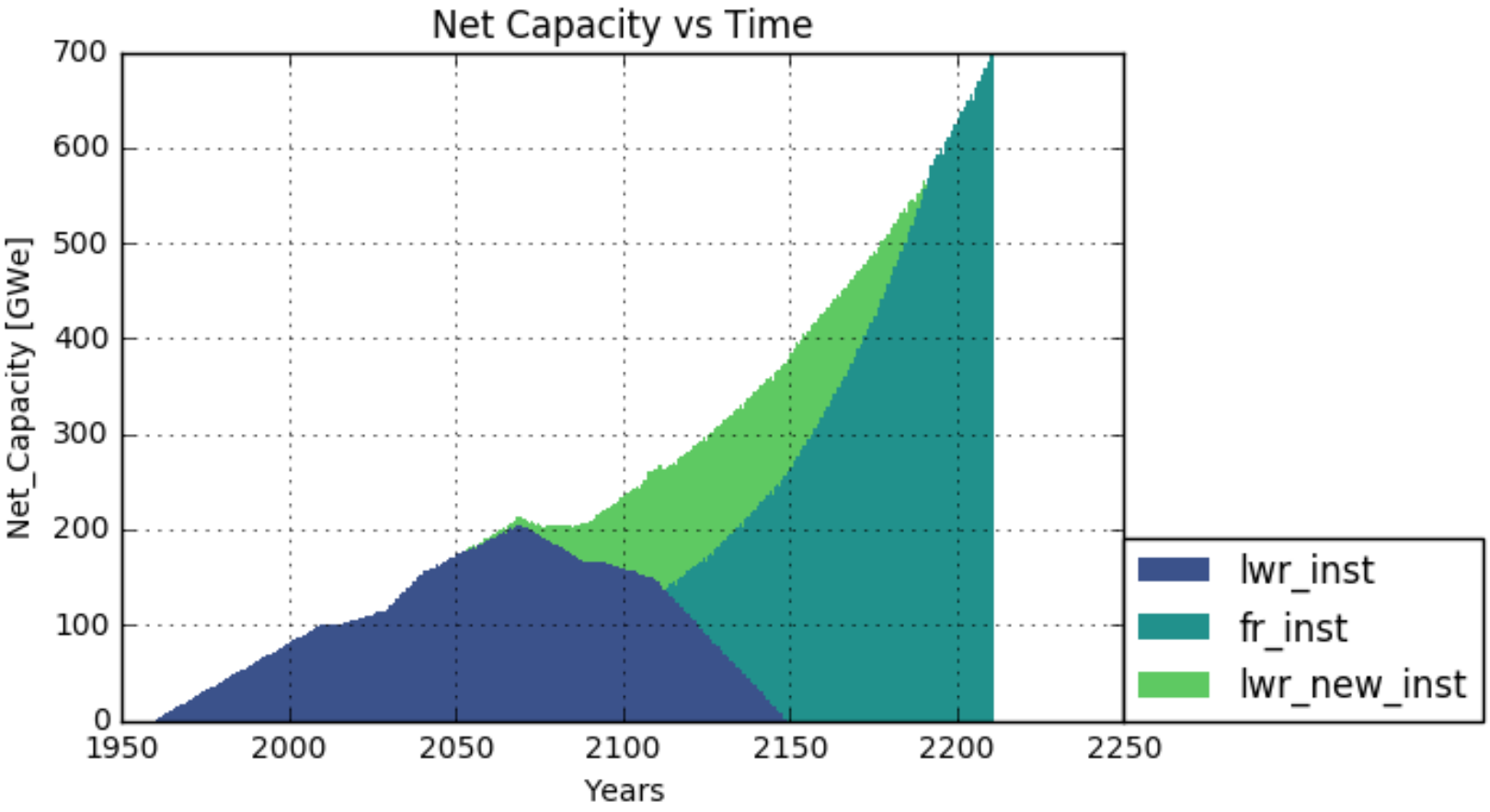
Legacy:

- 200 LWRs
  - 50% 60yr lifetime
  - 50% 80yr lifetime
- LWR PyRe

Transition:

- ~200 LWRs starting in 2015
  - 80yr lifetime
- SFR starts in 2050
  - 80yr lifetime
- SFR PyRe

Transition Scenario - Results

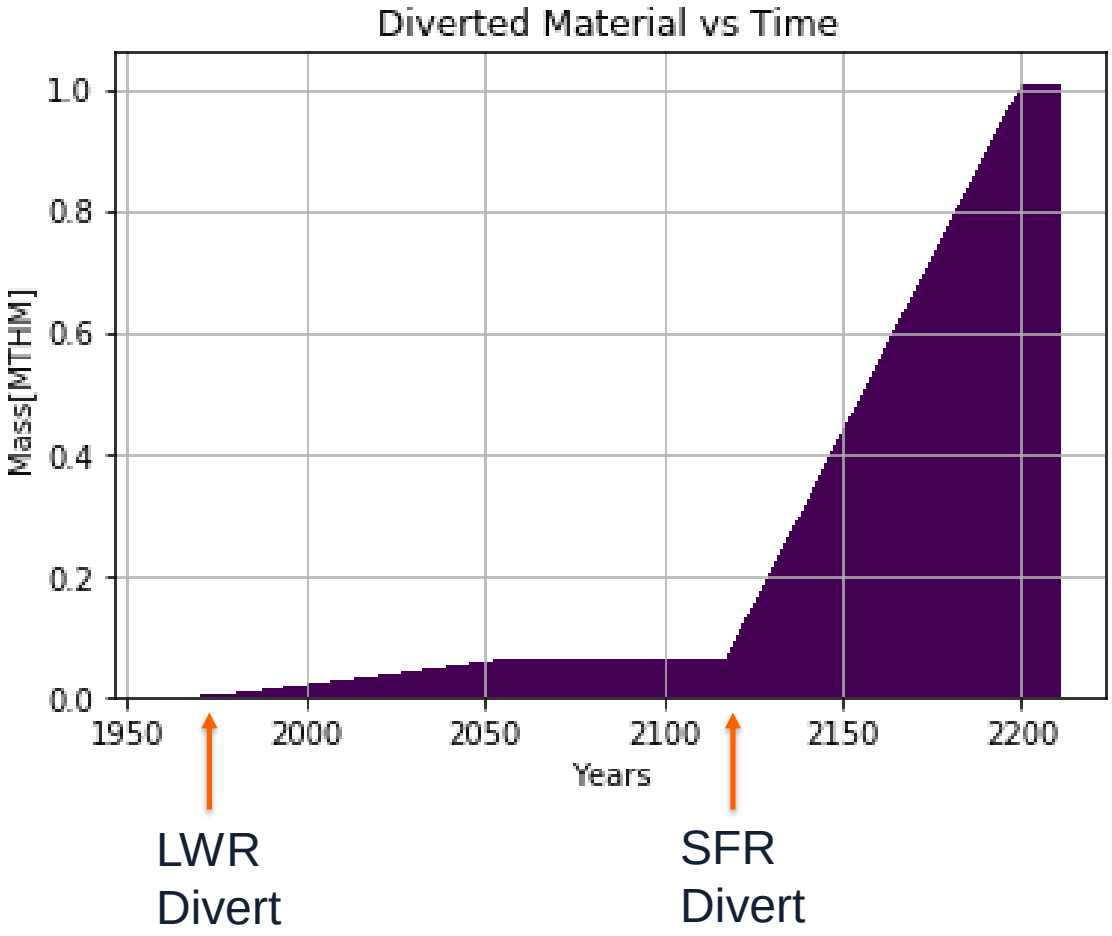


Diversion Settings

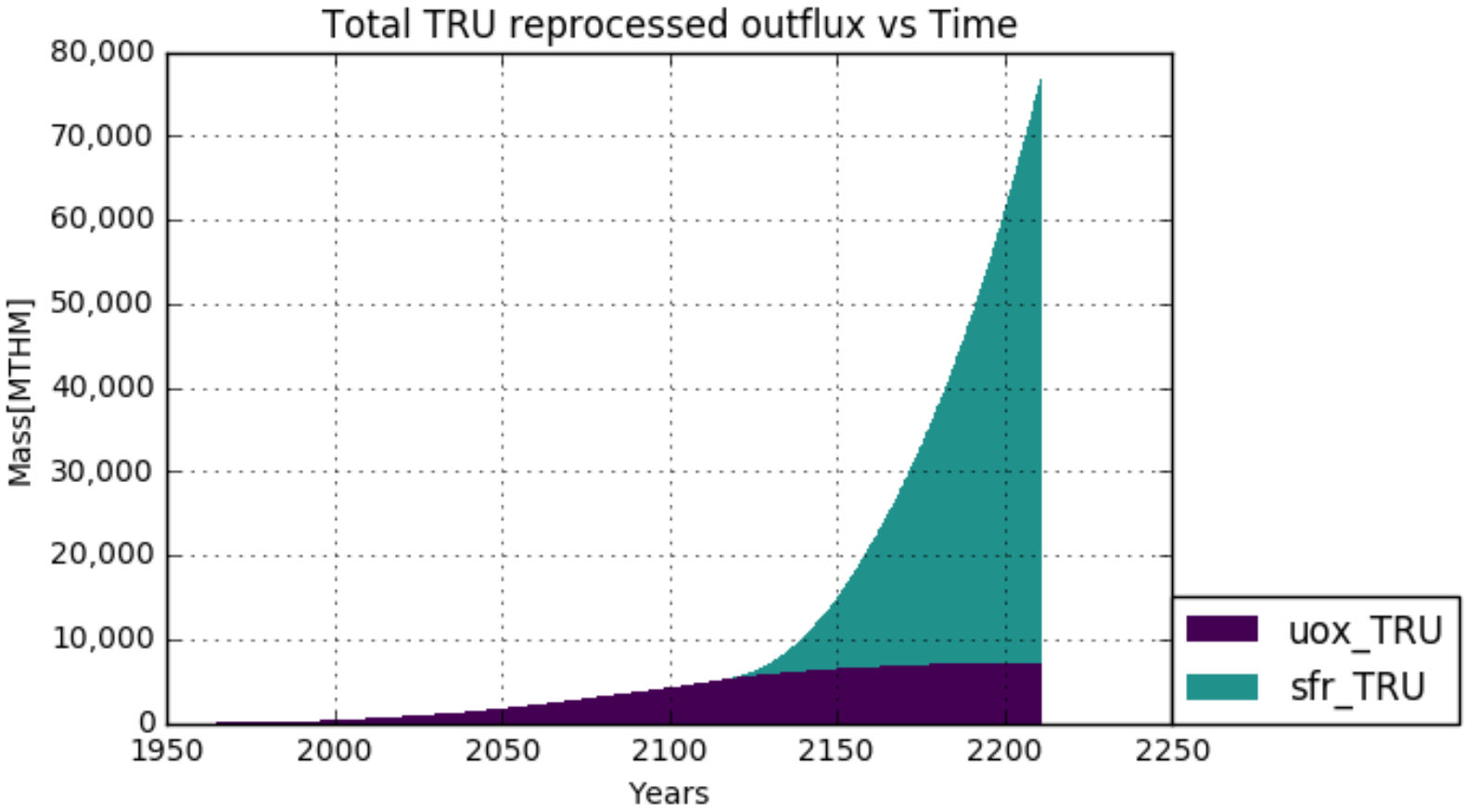
Two PyRe prototypes:
- LWR vs SFR

LWR:
- Fewer diversions
- More material per instance
- Less frequent

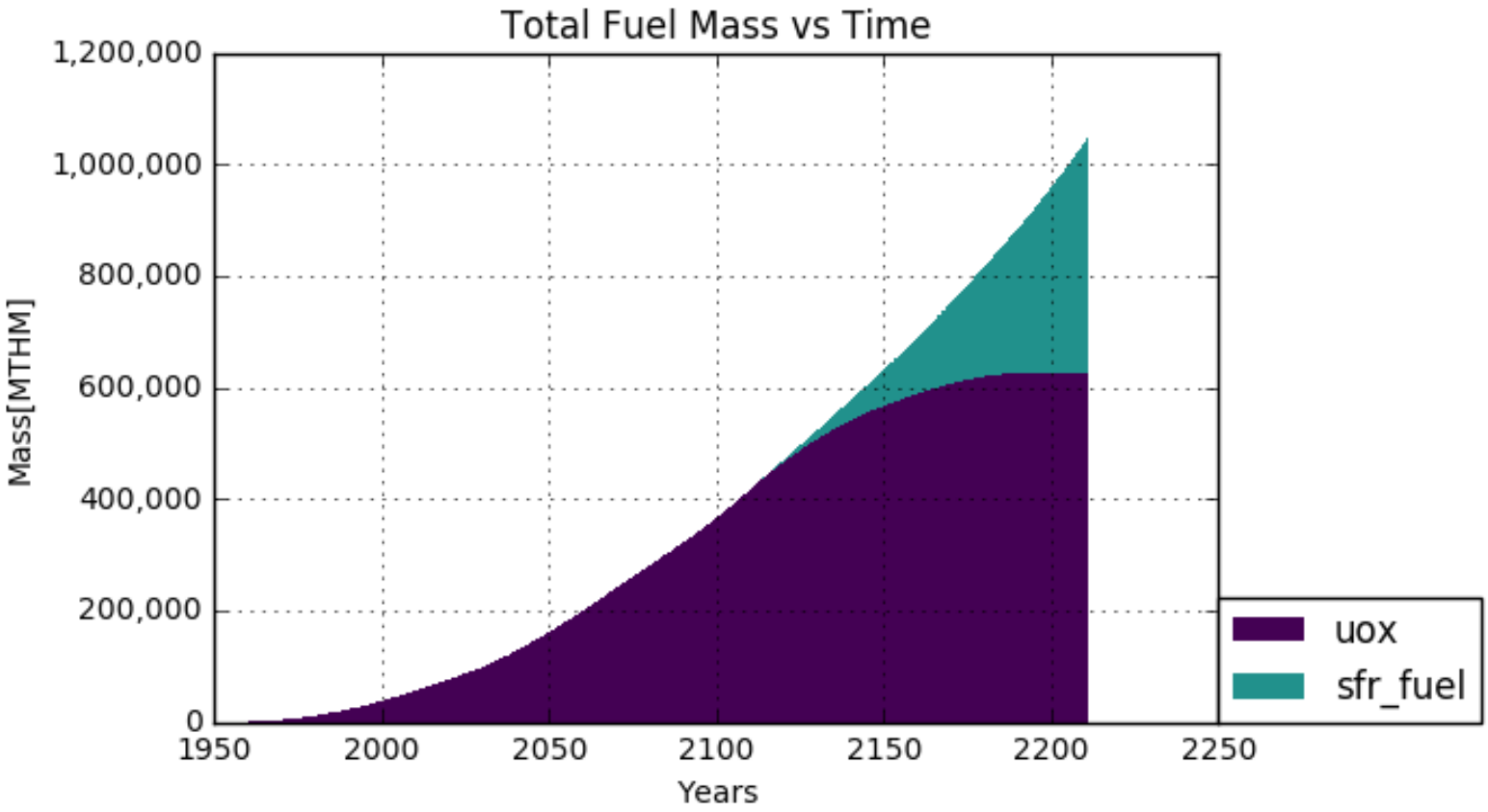
SFR:
- Frequent diversion
- Small quantities



Transition Scenario - Utilization



Transition Scenario - Utilization



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

- PyRe was demonstrated to function as both LWR and SFR reprocessing method
  - Capable of handling nefarious and operator 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
  - 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

Acknowledgements

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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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