Research Activities in the ARFC Group

A Brief Summary

Advanced Reactors and Fuel Cycles Group

University of Illinois at Urbana-Champaign

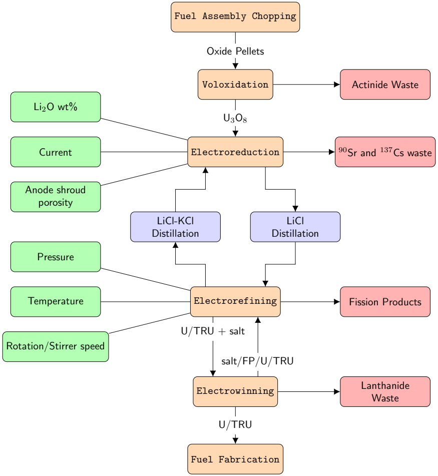
September 5, 2019

ILLINOIS

Outline

Education

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



Washington University

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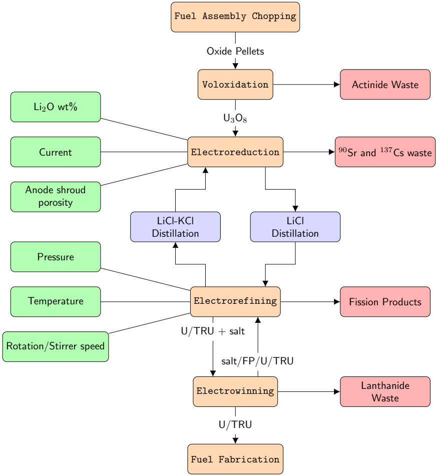

CNEC - UIUC

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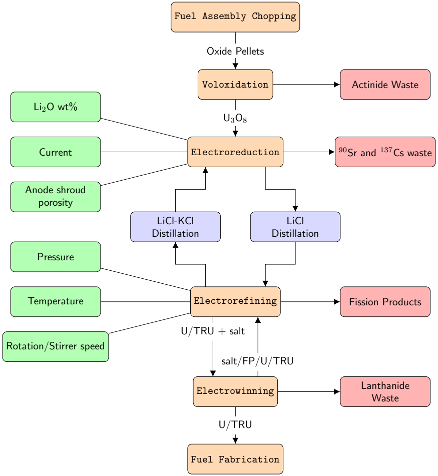

IAEA NDA Training

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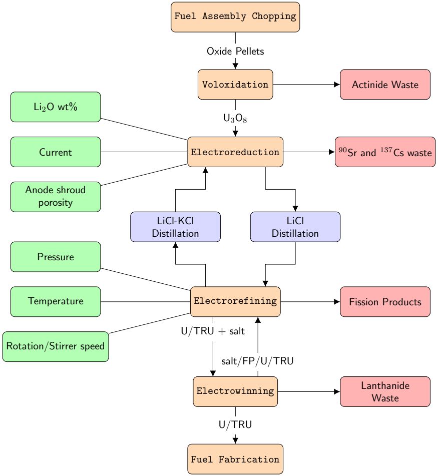

Outline

Introduction

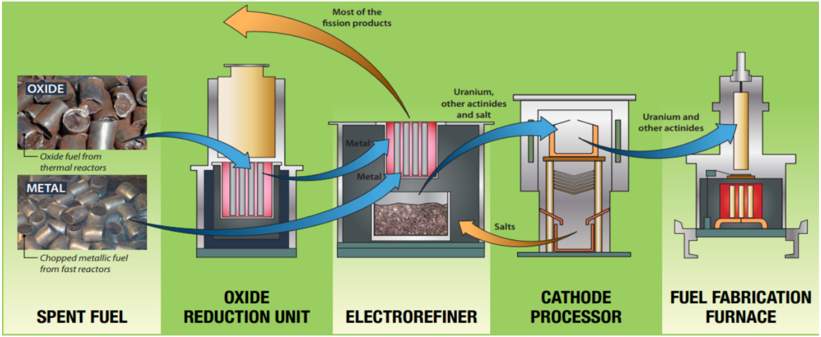

Figure: Argonne demonstration of a basic pyro plant [3].

Motivation/Goals

Motivation

- Safeguard by design
- Model diversion inside facilities
- transition from LWR to SFR

Goals

- Detect diversion using signatures and observables.
- Optimum detector and inspection locations in pyroprocessing
- Characterize detection sensitivities and false positive rates

Inspiration

NUCLEAR TECHNOLOGY · VOLUME 197 · 248–264 · MARCH 2017

DOI: http://dx.doi.org/10.1080/00295450.2016.1273713

Approaches to a Practical Systems Assessment for Safeguardability of Advanced Nuclear Fuel Cycles

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Received August 16, 2016
Accepted for Publication November 29, 2016

Abstract — *Many nations are expanding or initiating nuclear energy programs as part of a national energy portfolio. Transitioning to advanced nuclear energy systems improves sustainability and promotes energy independence. These advanced nuclear energy systems also must be shown to enhance safety, safeguards, and security in order to be realistically deployed. This is of particular concern to non–nuclear weapons states, to assure compliance with International Atomic Energy Agency treaty obligations.*

Outline

Assumptions

Cyclus Requirements

- Modular.
- Time step ≥ 1 month
- Streams must be in a trade-able form.
- Parameters are constant for the simulation.
  - Equation input toolkit under development.
- Diversion detection must be added after.

Subprocesses - Voloxidation

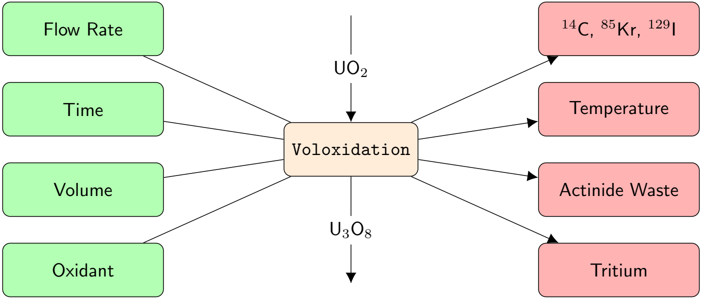

Figure: Voloxidation material balance area [1].

Subprocesses - Electroreduction

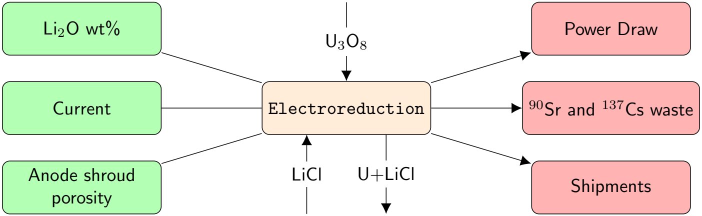

Figure: Reduction material balance area [2].

Subprocesses - Electrorefining

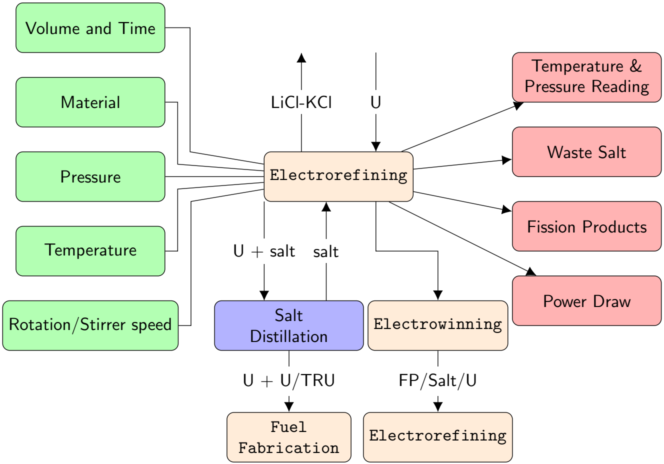

Figure: Refining material balance area [2].

Subprocesses - Electrowinning

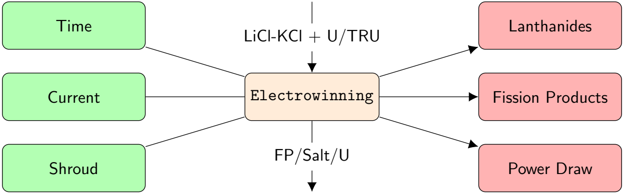

Figure: Winning material balance area.

Outline

Pyre Archetype

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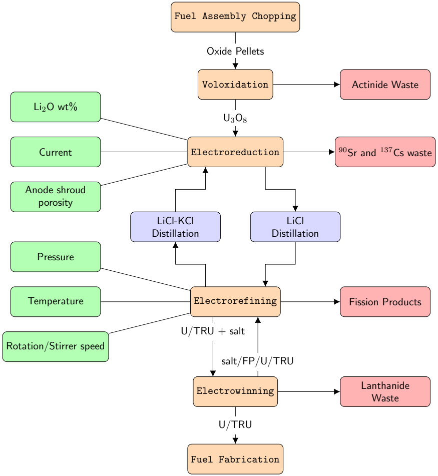


Pyre - Diversion Options

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.

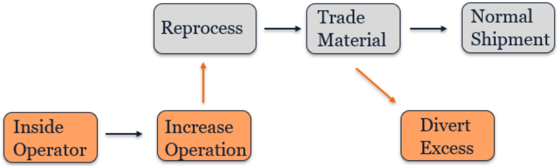


Figure: Operator vs nefarious diversion.

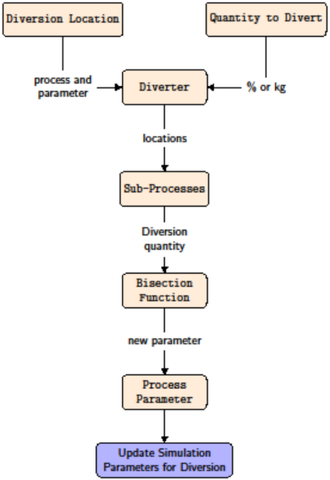
Diverter Class

Inputs:

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

Purpose

The goal of a separate diverter class is to allow this method to be used by facilities other than pyre through a toolkit.



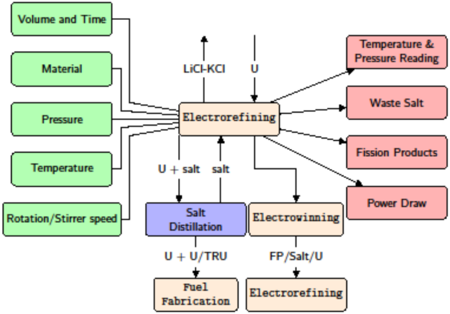
Diversion Detection

Diversion Detection

Material transactions are no longer a reliable method. Instead we use signatures and observables:

- Temperature, power draw, etc.

A Cumulative Sum change algorithm is used to detect any significant changes.



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

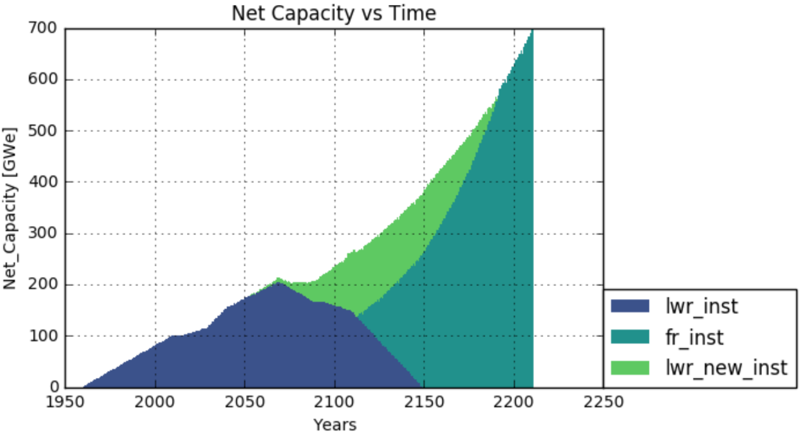
Legacy:

- 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:

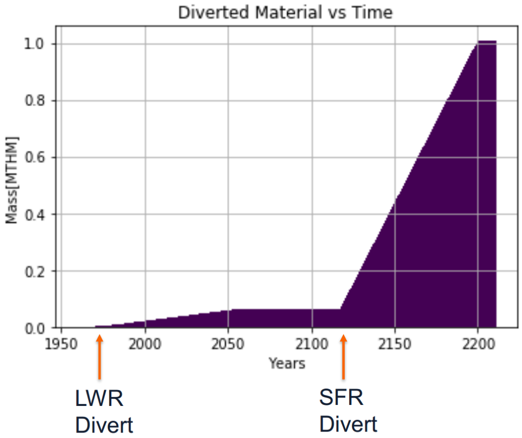
- LWR vs SFR

LWR Pyre:

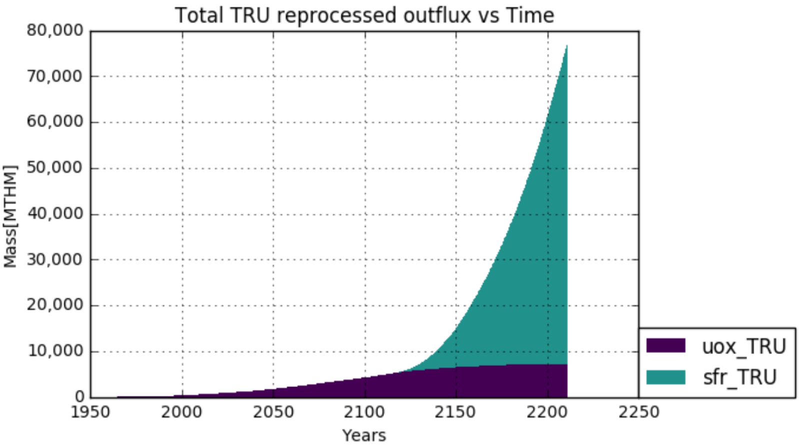
- Fewer diversions
- More material per instance
- Less frequent

SFR Pyre:

- Frequent diversion
- Small quantities



Transition Scenario - Utilization



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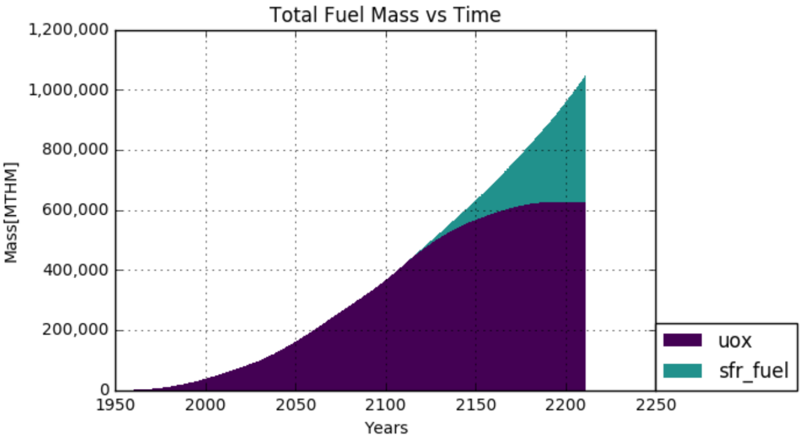

Conclusions

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

PyRe was demonstrated to function as both LWR and SFR reprocessing method

- Generic facility capable of modeling multiple facility layouts

Outline

Acknowledgement

This work is supported by U.S. Department of Energy, Nuclear Energy University Program, under contract #NEUP-FY16-10512.

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