Using SCALE for Fuel Cycle Analysis

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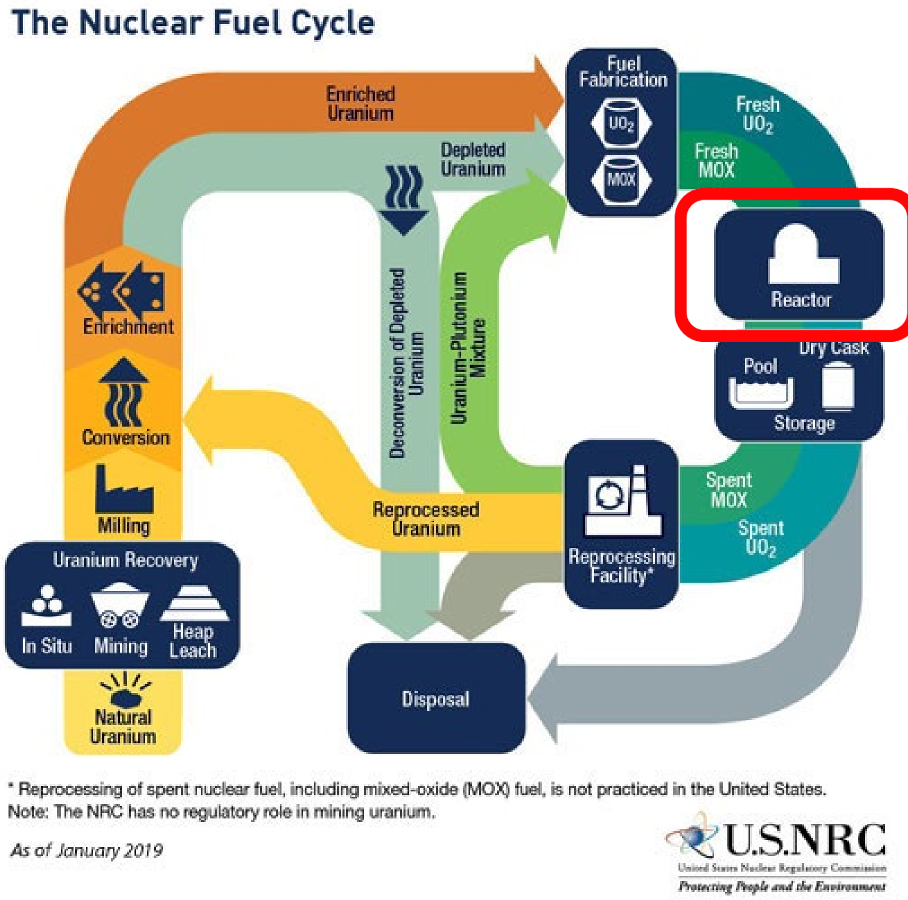
Introduction

- Recent advances in advanced reactors / fuel
  - Fuel composition
    - HALEU
    - Pu-U
    - TRU-U
  - Fuel technologies
    - ATF
    - Higher burnup
- How do we connect the impact of those technologies to the system?

Nuclear Fuel Cycle

- All the steps related to creating / treating nuclear fuel
- Frontend:
  - Mining /milling
  - Enrichment
- Backend:
  - Disposal
  - Reprocessing
- Focus for this presentation is on Reactor

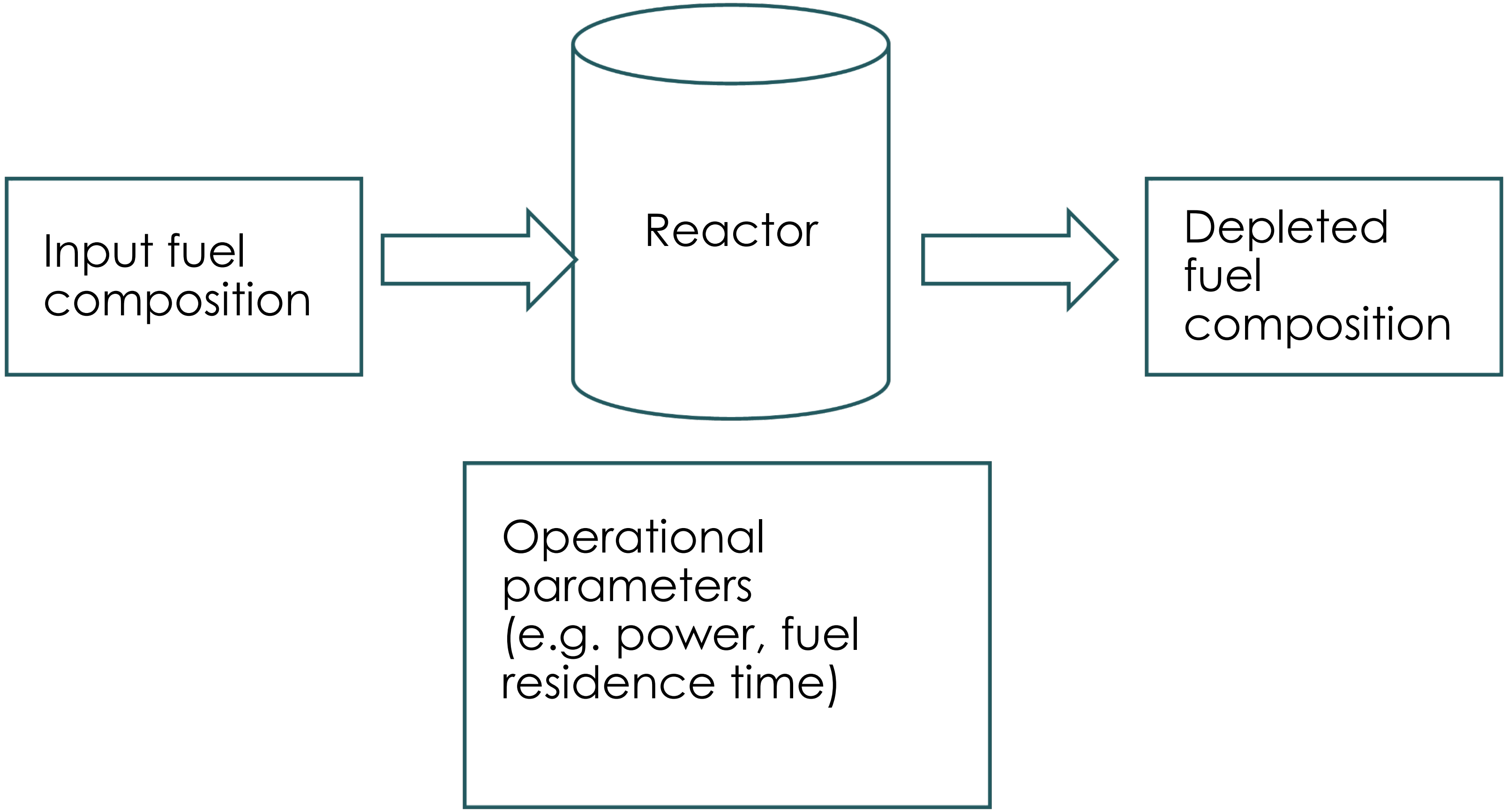


OAK RIDGE National Laboratory

Cyclus

- Flexible, modular, agent-based, market-driven fuel cycle simulator
- Open Source
- Collaborative development with multiple universities
  - Univ. Of Wisconsin
  - Univ. Of Illinois – Urbana Champaign
  - Univ. of South Carolina
  - Others
- Can couple external tools easily to `play' in the simulation

Depletion modeling in Fuel Cycle Simulations



Methods

Four levels of `doing depletion' in a fuel cycle simulator:

1. Data-driven, Recipes (low cost, low flexibility)
   - Simply define depleted fuel composition
   - Works when input composition and operational parameters are constant
2. ML Method(low cost, middle flexibility)
   - Trained ML algorithm to predict depleted composition
   - Requires a lot of data generation beforehand
   - CLASS
   - CYCLUS

Methods

3. Couple with ORIGEN (middle cost, middle flexibility)
   - Transport calculation result is obtained from external SCALE simulation (.f33)
     - One-group reactor data library (transition coefficients derived from collapsed multi-group flux spectrum)
     - Can also generate .f33 from pre-generated ORIGEN libraries (Steve Skutnik - CYBORG)
   - Responds to input composition and operational parameter change
4. Complete Coupling (high cost, high flexibility)
   - Run transport and depletion during Cyclus simulation
   - Prohibitively expensive

Use Cases: Dynamic Scenarios

- Continuously changing input fuel composition
  - Continuous reprocessing scenarios with multi-stage reprocessing
  - Reprocessed Pu vector changes -> Input MOX fuel composition changes
- Continuously changing operational parameters
  - Can model increasing burnup/enrichment throughout reactor lifetime
- Uncertainty Quantification
  - Given uncertainty in fuel burnup for each fuel assembly,
  - Whats the uncertainty of the final US UNF Pu inventory?

Workflow

1. Select Nuclear reactor design / fuel
2. Generate .f33 file for reactor design

   - One-group reactor data library (transition coefficients derived from collapsed multi-group flux spectrum)

3. Use Cyclus to assess impact
   1. Front end material demand per power
   2. Back end material composition
      1. UNF mass
      2. Radioactivity (specific activity)
      3. Decay heat
      4. Fissile content (for reprocessing)

Conclusion

- Project to create a repository of data for different fuel cycle technologies **in transition scenarios**
  - Resource demand per unit energy
  - Specific decay heat / activity for UNF for that technology
- Use this workflow to assess role of reactor technologies in more complex scenarios
  - Transition scenario (current LWR fleet-> advanced reactor)
    - Assessing fissile material demand
    - Repository demand / specifications (spacing between canisters)