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Fuel Cycle Options Campaign Transition Analysis

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Technical Workshop on Fuel Cycle Simulation
University of South Carolina
Columbia, SC
July 19-21, 2017

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Outline

- **Evaluation and Screening (E&S) Study**
  - Comparison of alternative fuel cycle options (and the transition to them)
- **FCO Transition Analysis Summary**
  - Identification of transition specific issues and challenges
  - Adaptation of single-system steady-state metrics and decision-analysis methods to multi-system dynamic evaluations
  - Integration and adaptation of fuel cycle simulation tools

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Introduction

- **The FCO Campaign transition analysis has a particular focus**
- **Identifying the issues and challenges of transition to a range of potential alternative fuel cycle options (specifically the 4 most promising)**
- **Inform on general performance under a range of different scenarios**
  - No particular scenario of interest – not designing a system – supporting decision making
- **Identification of near-term R&D needs**

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Evaluation and Screening (E&S) Study

https://fuelcycleevaluation.inl.gov/SitePages/Home.aspx

- **Most promising options**

Evaluation Group	Continuous Recycle?	Material Recycled	Feed Material	Reactor Type(s)
EG23	yes	U/Pu	new nat. U	fast critical
EG24	yes	U/TRU	new nat. U	fast critical
EG29	yes	U/Pu	new nat. U	fast and thermal critical
EG30	yes	U/TRU	new nat. U	fast and thermal critical

- **The FCO campaign is analyzing transition to these options**

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E&S Study Metrics

Nuclear Waste Management
- Mass of SNF+HLW disposed per energy generated
- Activity of SNF+HLW (@100 years) per energy generated
- Activity of SNF+HLW (@100,000 years) per energy generated
- Mass of DU+RU+RTh disposed per energy generated
- Volume of LLW per energy generated

Proliferation Risk
- Material attractiveness - normal operating conditions

Nuclear Material Security Risk
- Material attractiveness - normal operating conditions
- Activity of SNF+HLW (@10 years) per energy generated

Safety
- Challenges of addressing safety hazards
- Safety of the deployed system

Resource Utilization
- Natural Uranium required per energy generated
- Natural Thorium required per energy generated

Financial Risk and Economics
- Levelized Cost of Electricity at Equilibrium

Environmental Impact
- Land use per energy generated
- Water use per energy generated
- Carbon emission - CO_2 released per energy generated
- Radiological exposure - total estimated worker dose per energy generated (as leading indicator for public dose potential)

Development and Deployment Risk
- Development time
- Development cost
- Deployment cost from prototypic validation to FOAK commercial
- Compatibility with the existing infrastructure
- Existence of regulations for the fuel cycle and familiarity with licensing
- Existence of market incentives and/or barriers to commercial implementation of fuel cycle processes

Institutional Issues
- Compatibility with the existing infrastructure
- Existence of regulations for the fuel cycle and familiarity with licensing
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Identification of Transition Specific Issues and Challenges

- **Beyond the challenges identified in the E&S Study, there are a variety of issues and challenges related to the dynamic transition of the system**
  - Economy of Scale / Capacity Factor related economic challenges
    - Potential significant cost penalties related to matching the time evolving demand in an efficient way with systems that likely have large capital investments and significant economies of scale
      - Deploy at small scale – unit cost of product rises substantially (under sized)
      - Deploy at large scale – unit cost of product rises substantially (under utilized)
    - What is the cost structure as a function of size for many types of facilities producing a wide range of different products?
      - Important R&D need for informing on the transition economics
  - Transient inventories (e.g., amount of used nuclear fuel in storage)
    - Information such as the peak inventories and duration of storage don't apply to steady state but may be of interest

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Adaptation Metrics

- **Adaptation of single-system steady-state metrics and decision-analysis methods to multi-system dynamic evaluations**
  - Treatment of the existing, any intermediate, and final systems
    - How to account for what occurred in the past ("sunk costs")?
    - How to treat what remains to occur in the future regardless?
    - How and why to account for items?
  - Treatment of the time-varying performance
    - What time period do we integrate over?
    - Do we apply equal weights for items today versus items a century from now?
      - The nightmare of discount rates and arbitrary time periods
  - Treatment of the scale of the system
    - When to normalize and when to not
      - When do we care about efficiency and not total magnitude
        - » 20 MT of SNF per GWe-yr tells the story
      - When do we care about total magnitude and not efficiency
        - » 100,000 MT of SNF tells the story

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Fuel Cycle Simulation Tools

- **Tools must produce the data required for all areas of interest**
  - This should be obvious, but can be forgotten
  - What are the areas of interest and data required at the particular stage of engineering of the system?
  - Fuel cycle simulation is part of an integrated engineering analysis effort
    - Our focus is a mix of feasibility, scoping, sensitivity studies needed to develop the understanding necessary to make informed decisions, particularly on near-term R&D
- **A suite of simulation tools are needed for the complex set of analyses and information that we are evaluating**
  - Requires on-going adaptation for novel features and approaches
  - Requires on-going validation to ensure results are representative
  - Requires on-going modifications to generate the data required for informing on new/revised areas of interest or metrics
  - Lots of iteration as our understanding progresses and objectives evolve

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Summary

- **The FCO Campaign transition analysis has a particular focus**
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  - Inform on general performance under a range of different scenarios
    - No particular scenario of interest – not designing a system – supporting decision making
  - Identification of near-term R&D needs
- **Spreadsheet simulations are important**
  - Fast and easy to understand – often sufficient
- **Recipe simulations are important**
  - More realistic constraints and better details of dynamic behavior
- **Fuel composition simulations are important**
  - Identify issues and improve realism
- **Cross section / decay / equivalence simulations are important**
  - Identify issues and address questions that cannot be otherwise