Working title: Fuel cycle impacts of deploying High Assay Low Enriched Uranium (HALEU)-fueled reactors

I. Introduction

   A. Purpose of the work: investigate the effect of deploying HALEU-fueled advanced reactors on the nuclear fuel cycle in the US
   B. Scope:
      1. US facilities
      2. select advanced reactors: USNC MMR, X-energy Xe-100, NuScale VOYGR
      3. Front-end and back-end of the fuel cycle
   C. Motivations
      1. U.S. wants to develop a supply chain of HALEU
      2. HALEU has broad uses outside of reactors [1]
      3. Benefits of using HALEU in reactors
         a. higher burnups
         b. reduced LCOE
      4. Changing the fuel form affects fuel cycle dynamics
   D. Goals
      1. understand how deploying HALEU reactors affects resource demand
      2. understand which components of the fuel cycle are most sensitive to HALEU deployments
      3. understand how implementing recycling with HALEU reactors affects the fuel cycle
      4. understand how possible avenues to obtain fuel for HAELU reactors can affect neutronics
         a. neutron flux
         b. k-eff
         c. β-eff
         d. feedback coefficients,
         e. lifetimes
         f. uranium utilization in general
         g. breeding ratio

II. Lit Review

   A. The nuclear fuel cycle
      1. Once-through vs recycle [2]
      2. Enrichment facility/SWU calculations [2]
      3. Recycling processes [2]
         a. overview of aqueous reprocessing
         b. Known changes to LWR fuel cycle by recycling
   B. Fuel Cycle simulators
      1. Why we use them, their benefits
      2. why multiples have been created
      3. ideal functionalities and capcbilities [3, 4]
      4. uses of fuel cycle simulators
         a. Department of Energy (DOE) Evaluation & screening [5]
            (1) Differences in EG 01 and EG 02
         b. EG29 analysis [6]
         c. verification [7]
      5. Cyclus [8]

a. basic fundamentals
b. Cycamore [9]
c. addresses many of the things brought up by [3]
d. comparison to other codes [10]
e. verification [11]

6. sensitivity analysis

C. Reactors with HALEU

1. fuel forms (ceramic vs metallic vs TRISO)
2. Effects of changing from 5% to 7% for PWR [12]
    a. no effects on reactivity coefficients
    b. more mining and enrichment per energy unit generated
    c. reduced energy normalized quantity of waste
    d. slight decrease in radioactivity of waste
3. Effects on NuScale SMR [13]
    a. increases fast to thermal flux ratio
    b. more burnable poisons
    c. larger concentration of fission product poisons
4. Effects of impurities [14]

III. Transition modeling methodology

A. Reactors, inculuding serpent models

1. USNC MMR [15]
2. X-energy Xe-100 [16]
3. NuScale VOYGR [17, 18]

B. material flow in fuel cycles

1. Once-through
    a. once-through flow figure
    b. scenario definitions
2. recycle
    a. recycle-flow figure
    b. scenario definitions

IV. Material requirements – Once through fuel cycles

A. Results

1. Scenario 1 – current fleet
    a. reactor deployment – compare to actual data??
    b. uranium resources
    c. SWU capacity
    d. Waste
2. Reactor deployment
    a. No growth scenarios
    b. 1% growth scenarios
3. Uranium resources
    a. No growth scenarios
    b. 1% growth scenarios
4. SWU capacity

a. No growth scenarios
b. 1% growth scenarios

5. Waste
   a. No growth scenarios
   b. 1% growth scenarios

V. Model fuel cycle with recycle

A. Results

1. Reactor deployment
   a. No growth scenarios
   b. 1% growth scenarios
2. Uranium resources
   a. No growth scenarios
   b. 1% growth scenarios
3. SWU capacity
   a. No growth scenarios
   b. 1% growth scenarios
4. Waste
   a. No growth scenarios
   b. 1% growth scenarios

VI. Sensitivity analysis and optimization

A. Methdology

B. Results

VII. Effects on neutronics

A. Methodology

B. Models

C. Results

VIII. Conclusions

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