ANS Winter Meeting & Expo
2019
NUCLEAR TECHNOLOGY
FOR THE U.S. AND THE WORLD

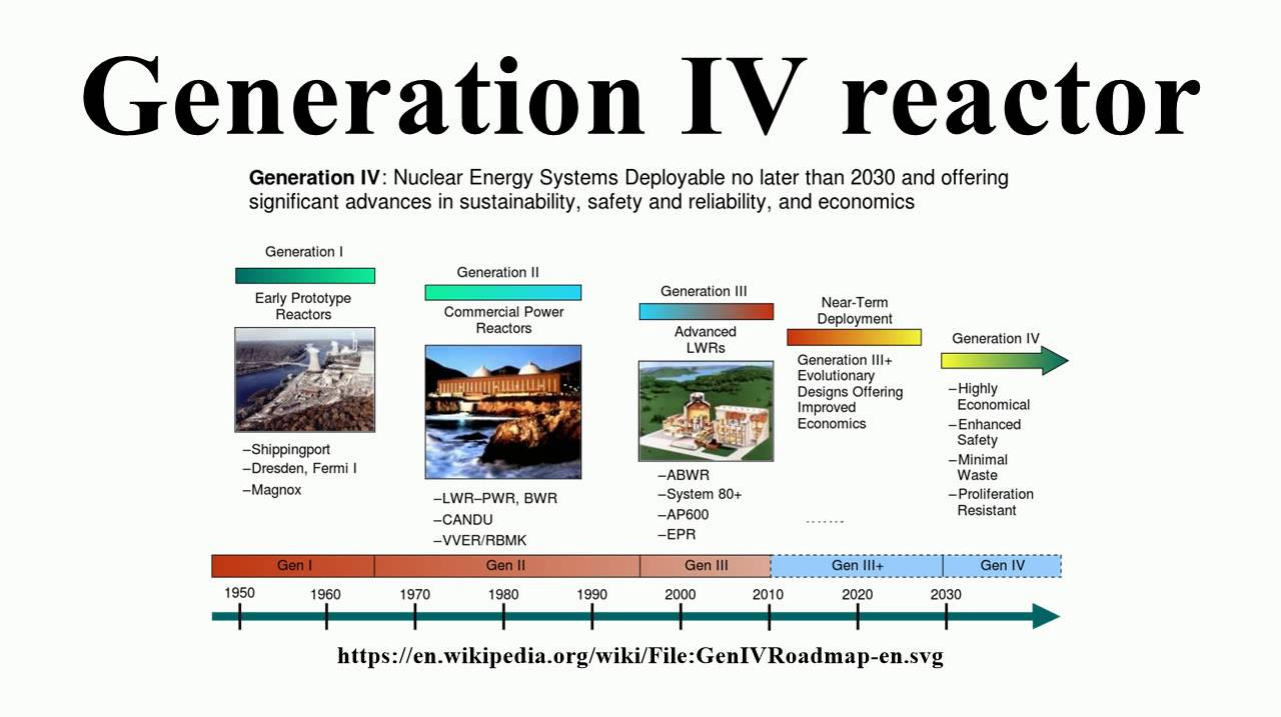
Investigation of Nuclear Safeguards Attributes through Neutronics Simulation of Pebble Bed Reactor Core

Dany Mulyana and Dr. Sunil S. Chirayath

Texas A&M University

Introduction

- Sustainability
  - Energy
  - Fuel
  - Minimum waste
- Safety & Reliability
  - Core damage likelihood
  - Offsite emergency response needs
- Economics
  - Life cycle cost advantage
  - Lower financial risk
- Security and Safeguards
  - Theft
  - **Diversion**
  - **Misuse**



Problem & Objective

No Nuclear system is 100% free of proliferation risk

- Round-the-clock online refueling process
- Various refueling and fuel type scenarios
- Needs a unique safeguards approach
- **No HTGR exists, yet**

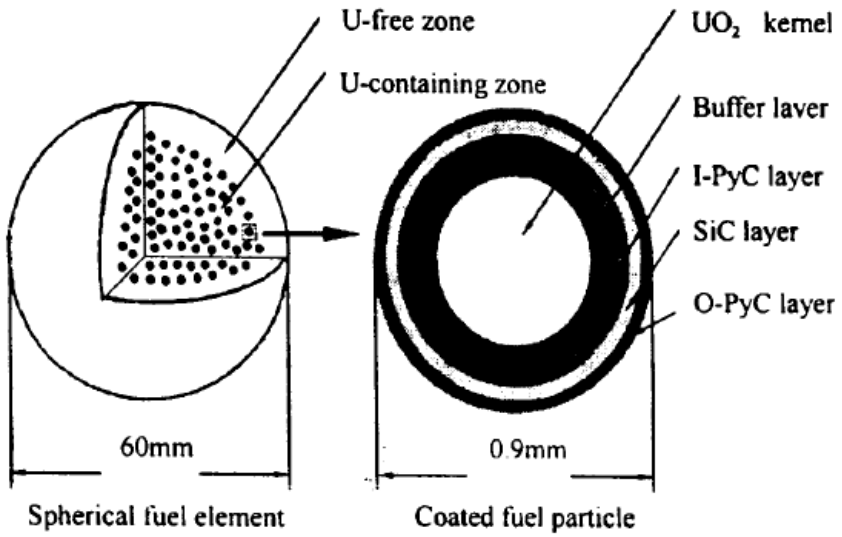
A model is required to be a reference:

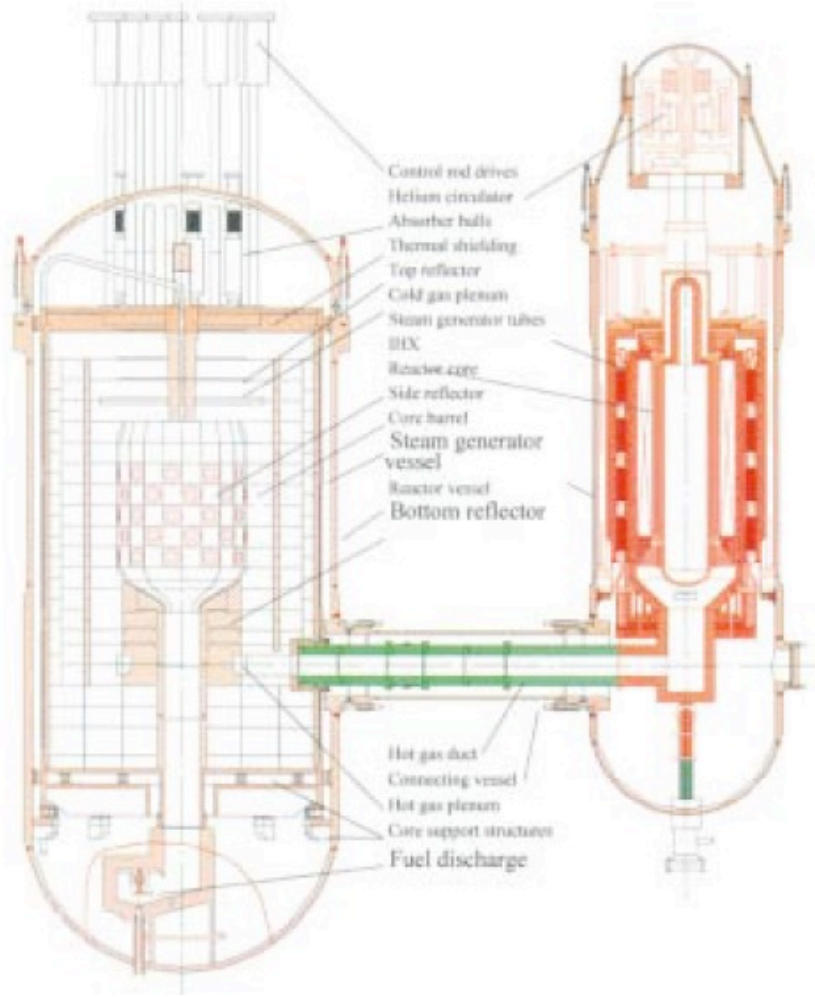
- **What are the isotopes in the core?**
- **How much?**

Methods

- Generate Isotopes model
  - Develop a single fuel ball modeling
  - Develop a full core modeling
- Methodology: Monte Carlo modeling
- Tool: MCNP 6.1
- Subject: A small (do-able) reactor design

HTR-10





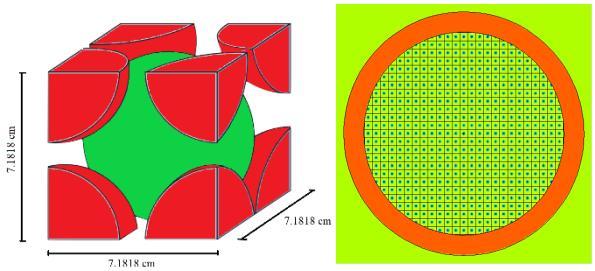
- Inlet: 250 °C
- Outlet: 700 °C
- Coolant: Helium
- Enrichment: 17.4%
- Target Burnup: 80 GWd/tU

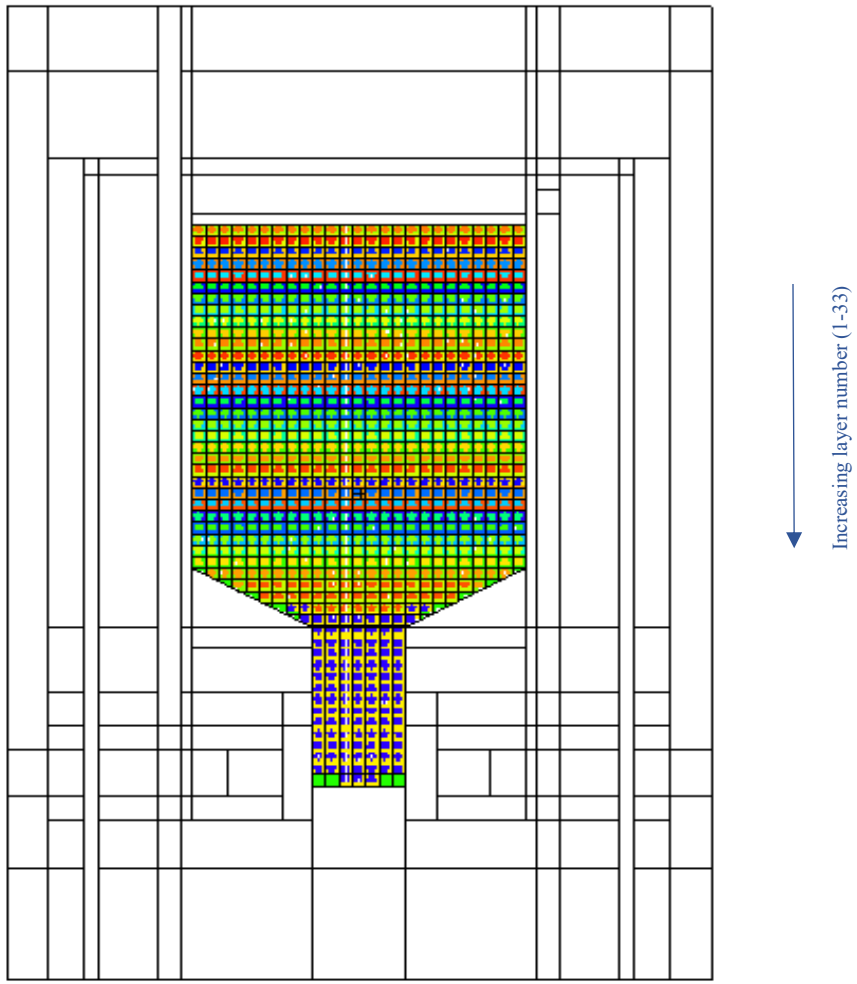
Focus

- Reach the burnup target → **refueling period**, constant power
- Constant & uniform temperature in the fuel and reactor material
- Why? NDT remedy as priority → looking for measurable isotopes using radiation measurement (Neutron and Gamma)

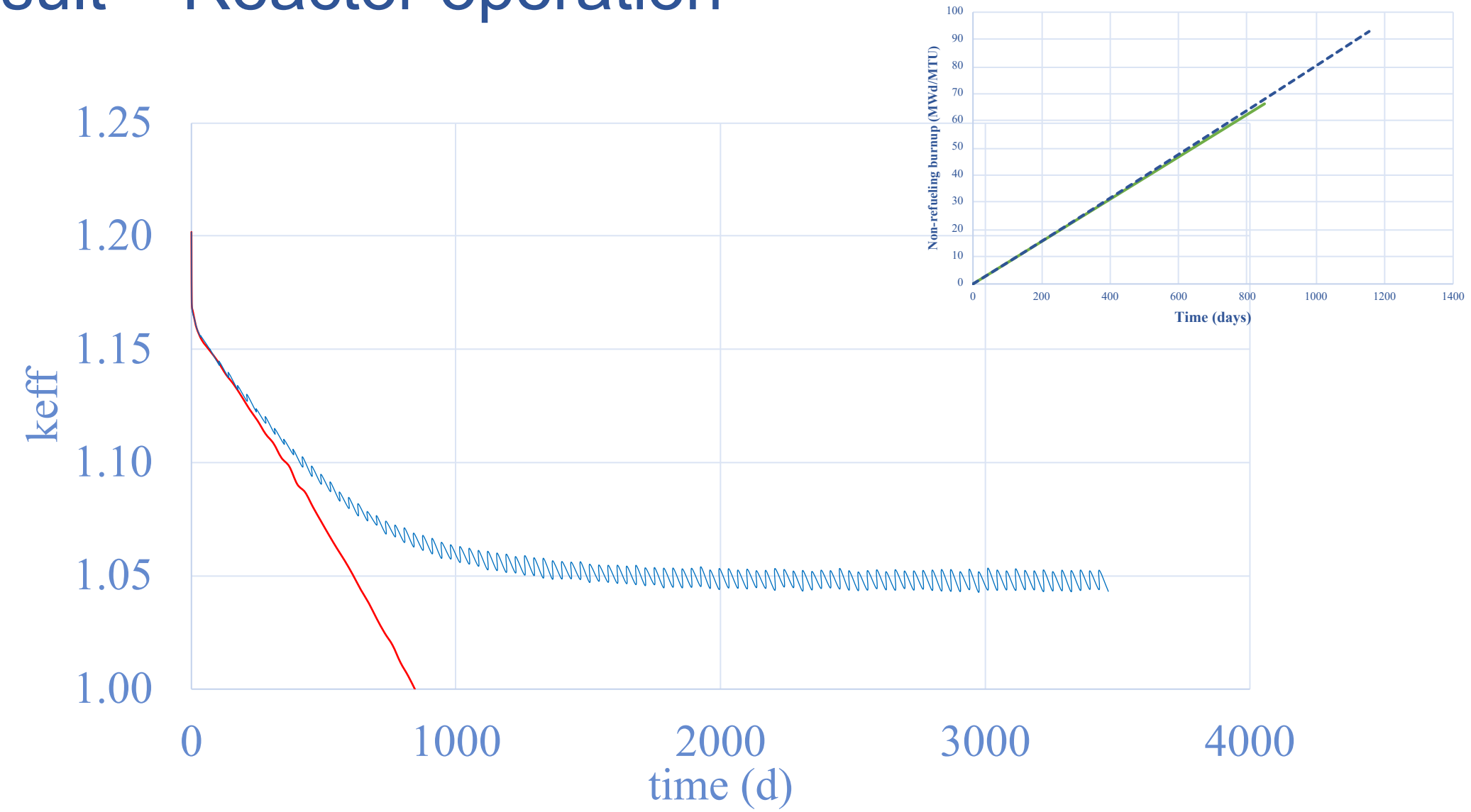
MCNP model

- Fuel:
  - 5 g UO2/ball
  - 29,106 balls
  - 33 layers
  - 120.65 kg total U
  - BCC arrangement
- Operation modes:
  - No-refueling
  - Single-pass refueling (OTTO)
  - Target: 95 GWd/MTU
  - 100% CF



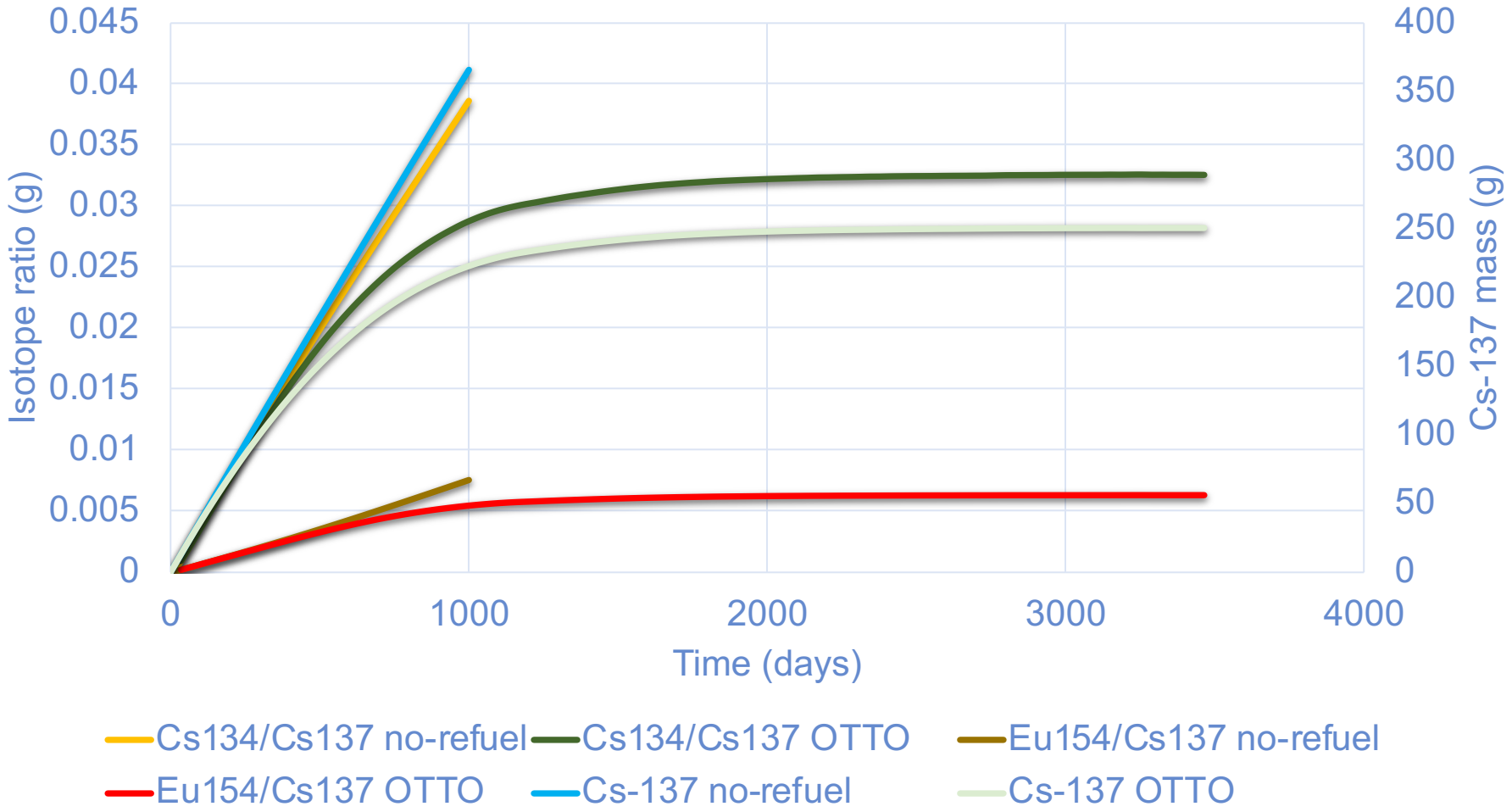


Result – Reactor operation

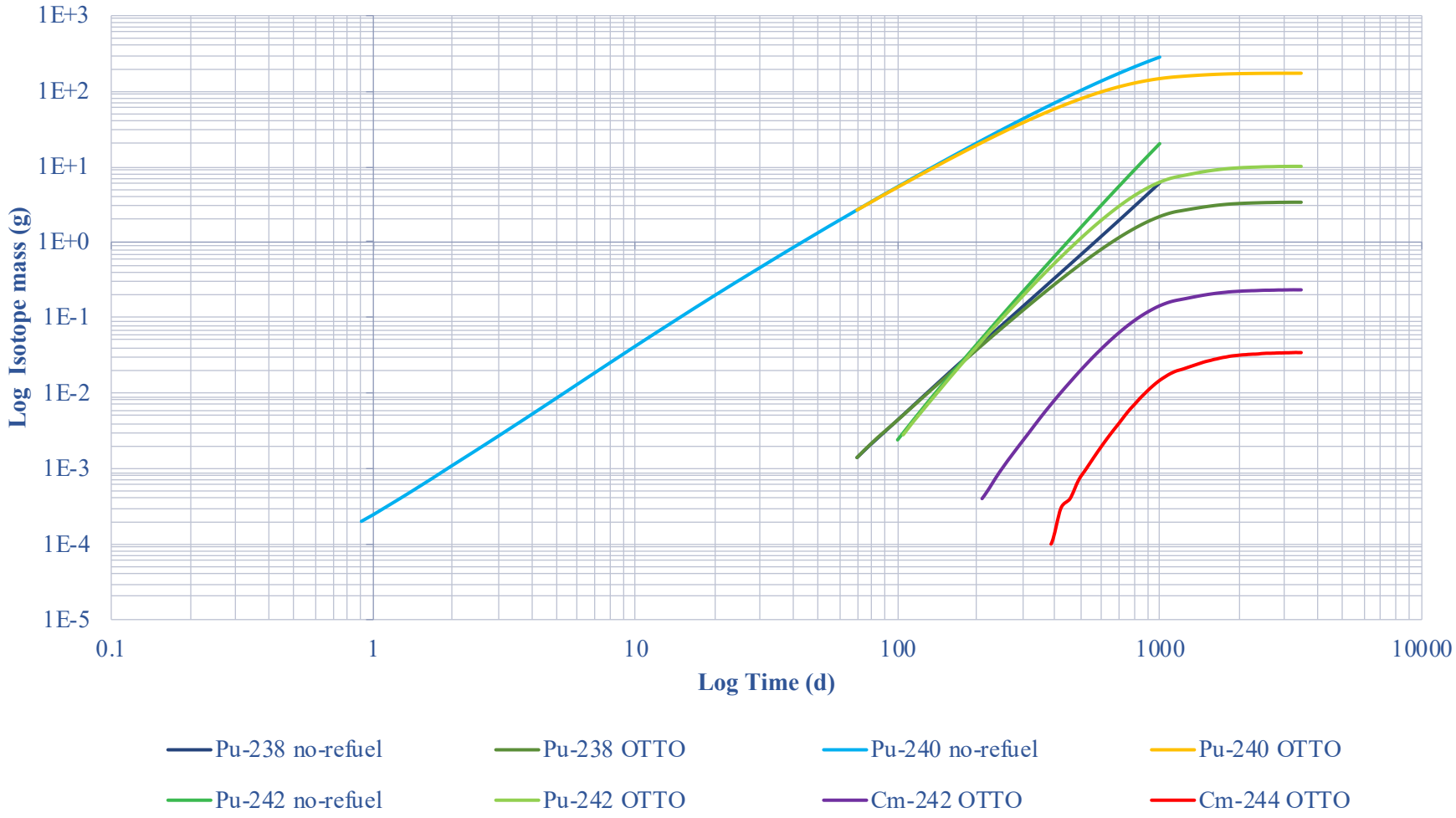


Burnup at equilibrium: 90.45 ± 8.02 GWd/MTU

Gamma source isotopes



Neutron source isotopes



Actinide

- No refueling:
  - Pu: 1.45 kg (1.24%) --> 13 yrs
  - U: 116.38 kg (96.45%) with 10.35% of U-235
- OTTO refueling (at equilibrium phase):
  - Pu/35d/layer: (51.54 ± 2.51) g (1.41%) → 15 yrs
  - U/35d/layer: (3.48 ± 0.03) kg (95.19%) with 8% of U-235

Proliferation concern

$$Burnup = \frac{[Power]\,[Capacity\ Factor]\,[time]}{[\text{mass of Uranium}]}$$

- Scaled to 2.5 GWt (1 GWe):
  - 32.07 tons of fresh uranium (17% enrichment)
  - Result in 452 kg of Pu and 30.527 tons of U leftover
- Pu-240 is 19.9%, and Pu-239 is 69.44% compared to PWR: 23.2% and 56.6%, respectively
- Waste size

Thank you

dmulyana@tamu.edu