Waste Management Implications of Fuel Cycle Alternatives

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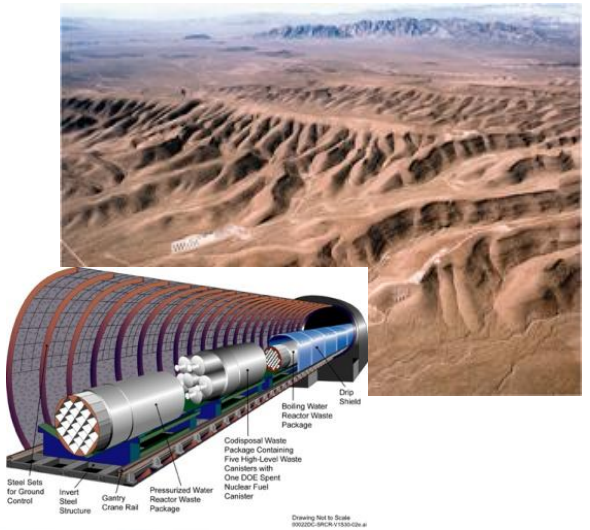
Waste Generation Projections

- **Different scenarios considered in DOE System studies**
  - Used-fuel discharge rate depends on nuclear power generation & fuel burnup
  - Used-fuel burnup affects its composition and emission characteristics
  - Recycle of used fuel leads to waste streams with lower actinide content
- **DOE recently developed estimates of used fuel and waste quantities**
  - Used-fuel amount and composition vs. burnup & cooling time
  - Four alternative nuclear energy use scenarios
  - Four alternative used-fuel recycle processes
  - A companion report projects LLW generation
- **<u>In all scenarios considered, both temporary storage of used fuel and long term waste isolation are required</u>**

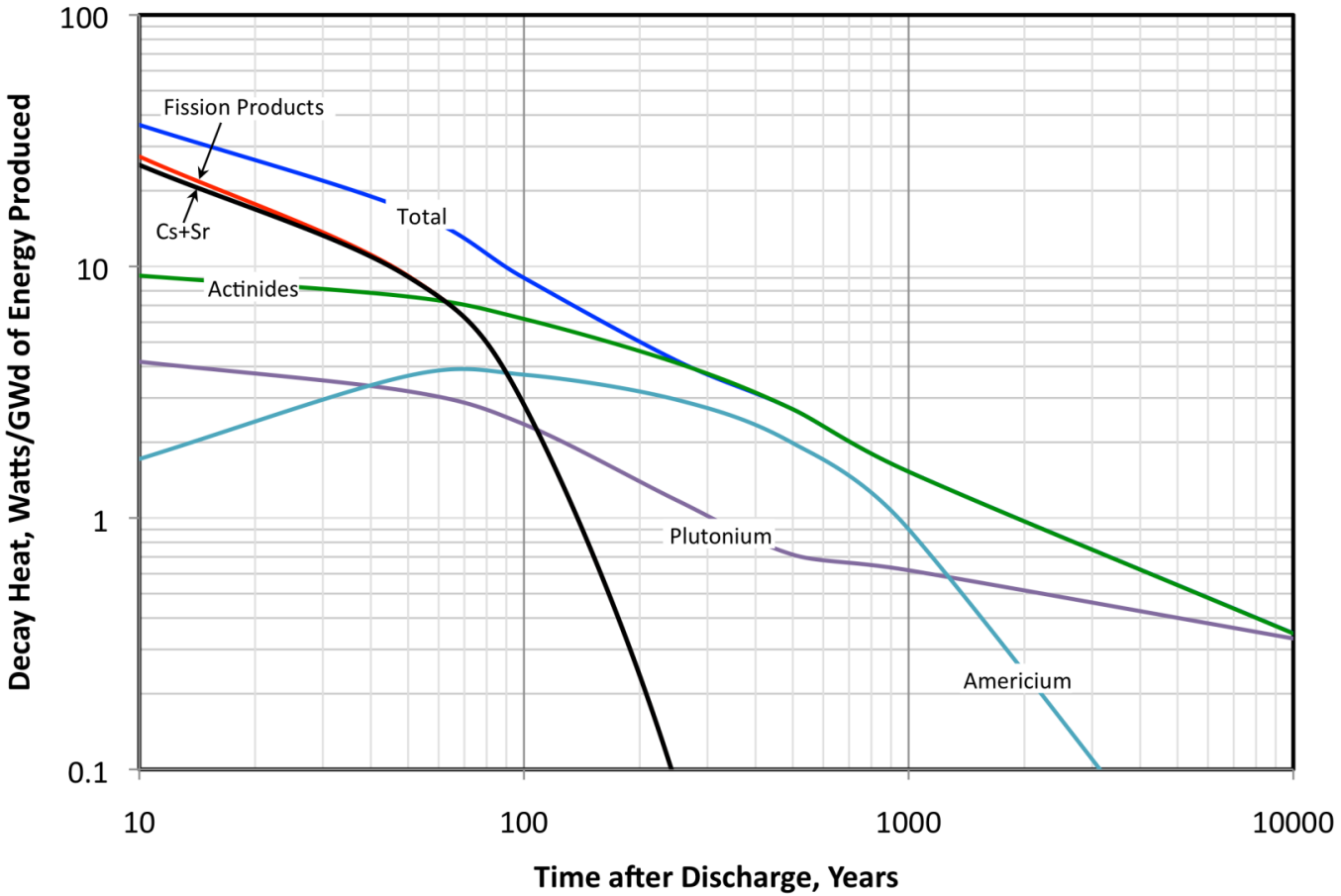


Heat Generation is a Key Waste Characteristic

- **Among the diverse waste attributes that impact, heat generation has a strong impact on disposal system capacity and operation**
  - Thermal limits are defined to preclude degradation and perturbation of engineered or natural barriers
  - Waste emplacement capacity (density) and configuration constrained by heat load
  - Cooler wastes are more readily handled, could be placed into repository sooner, and require less ventilation
- **Heat generation increases the complexity of modeling the performance (dose mitigation) of a disposal system**
  - Geochemistry in the near-field
  - Degradation rate of engineered materials
  - Hydrologic flow and mechanical processes

Reduced heat generation expected to facilitate licensing

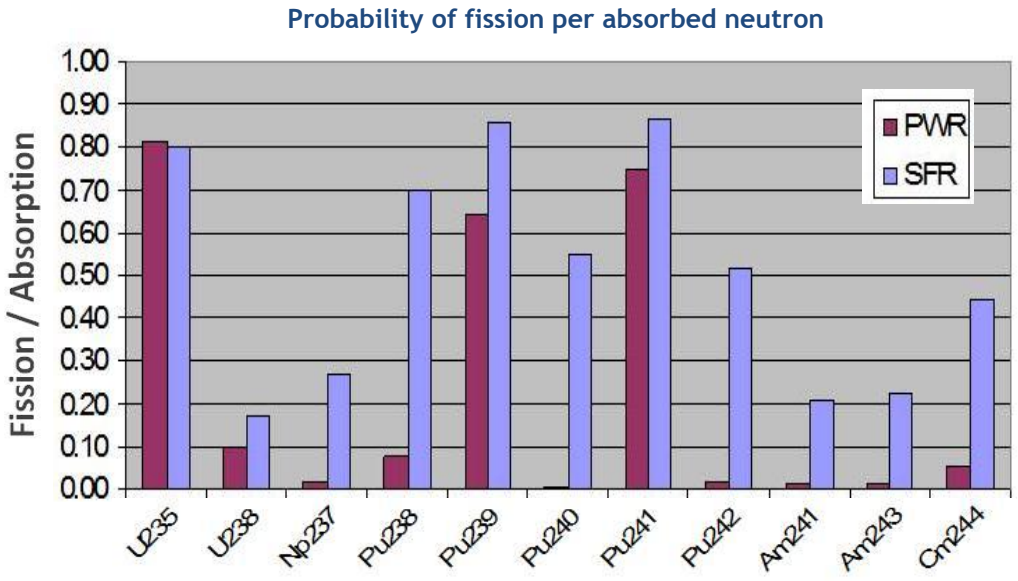
Heat Sources in LWR Used Fuel



Note: 1) The fission products (Cs and Sr daughters) dominate for the first 60 y
2) Thereafter, the dominant heat source is the actinides

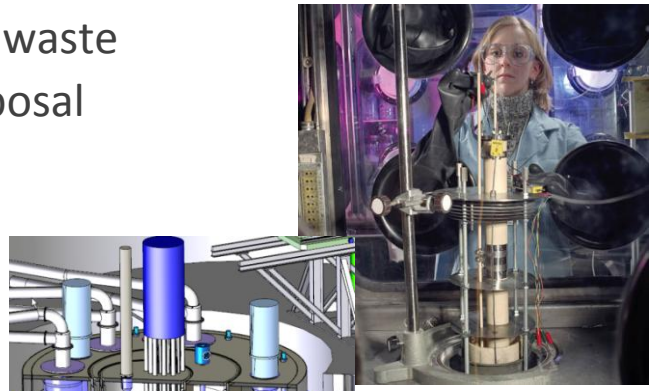
Fuel Cycle Options to Reduce Heat Load

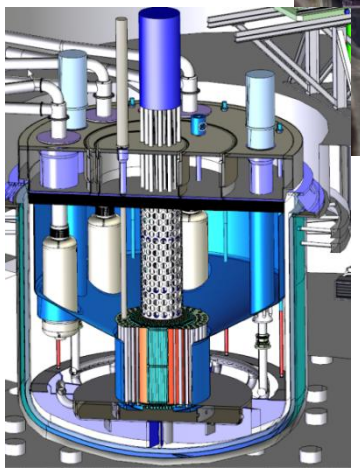
- **For the used-fuel storage period, *fission products* dominate the heat emission**
  - Heat emission decays with a ~ 30 year half-life
- **For long-term disposal, the *actinides* will dominate the heat emission**
- **Fuel cycle options that consume (fission) key heat emitting actinides (Am and Pu):**
  - Convert the actinides to fission products, in direct proportion to energy generation
  - Greatly reduce the long-term (>100 y) and integrated heat load
  - Facilitate disposal system design, licensing, and operation
- **Achievable through**
  - Enhancement of actinide fission probability
  - Efficient recycle of discharged actinides
  - Durable waste forms



Impact of Advanced Fuel Cycles

- **Fast Reactors and recycle have the potential to reduce the cost and improve the performance of waste disposal systems**
  - Primarily through reduced heat generation from waste
  - Waste forms may be engineered to enhance disposal system performance
- **Recycle has additional benefits, beyond waste management**
  - Improved uranium utilization
  - Reduced reliance on uranium enrichment
- **Challenges for fast-reactor recycle include**
  - Cost reduction
  - Safety and reliability assurance
  - Efficient implementation of safeguards





- **<u>In any case, a full used-fuel management infrastructure is required</u>**
  - Storage of used nuclear fuel
  - Transport to either processing or disposal locations
  - Final disposal of high-level waste in a repository

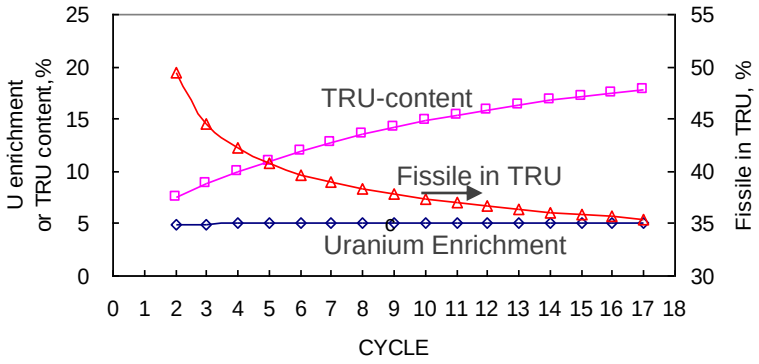
Extra Slides

TRU Multi-recycling in LWRs (CORAIL Fuel Assembly Concept)

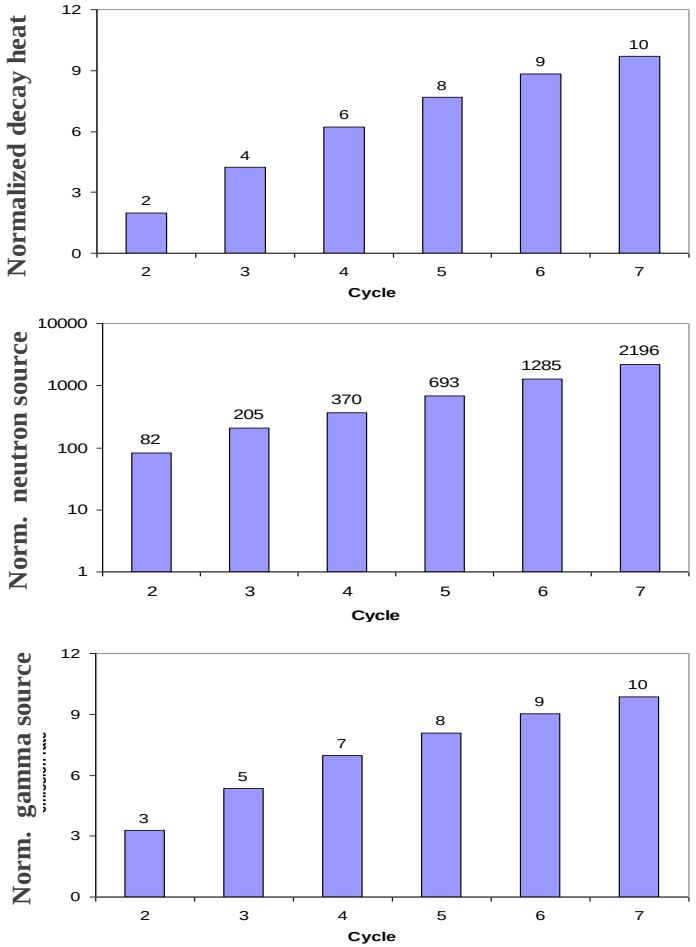
- **From purely a physics perspective, LWR multi-recycle can be achieved**
  - TRU/U ratio increases with recycle stage
  - Enriched uranium "support" needed

However

- **High MA content greatly complicates fuel handling, so number of recycle stages is limited in practice**
- **Fuel performance and safety not established**



Evolution of Fuel Composition with TRU Recycle Stage



Fuel Handling Indices at Fabrication Stage Compared to CORAIL-Pu Cycle 7

Reactor Technology Choices for Recycle

- In closed fuel cycle, used fuel separated into re- useable and waste materials
- Residual waste will go to a geological repository
- Fast spectrum recycle reactor provides great <u>flexibility</u>
  - Allows repeated use in recycle reactor for waste management
  - Allows conversion of depleted uranium to fuel resources