Argonne NATIONAL LABORATORY

… for a brighter future

U.S. Department of Energy

UChicago ▶ Argonne LLC

Office of Science U.S. DEPARTMENT OF ENERGY

A U.S. Department of Energy laboratory managed by UChicago Argonne, LLC

Technical Challenges

Mark T. Peters
Deputy Associate Laboratory Director
Energy Sciences and Engineering
Argonne National Laboratory

September 23, 2009

The Grand Challenge for Nuclear Waste Disposal

- **There is scientific consensus that the disposal of spent nuclear fuel and high-level radioactive waste in deep geologic formations is potentially safe and feasible**
  - Provided that sites are chosen and characterized well, and
  - Provided that the combination of engineered and natural barriers is designed appropriately

- **Need to understand and predict with sufficient confidence flow and transport processes and performance of materials (engineered and geologic) over geological time scales (at least to a million years), with long-term climate changes and the impact of extreme (disruptive) events (e.g., seismic and volcanic events) taken into account**
  - The longevity of engineered barrier components depends on the quantity and chemistry of fluids in the surrounding natural system

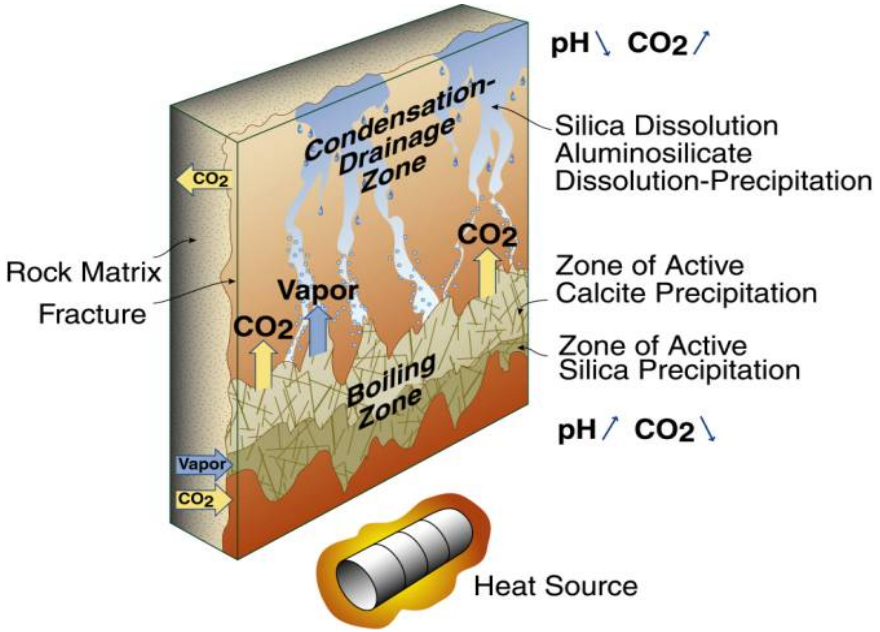
- **Finally, there is a need to establish a sound foundation for model abstraction and stochastic approaches used for performance assessment**

Potential World-Wide Geologic Repository Environments

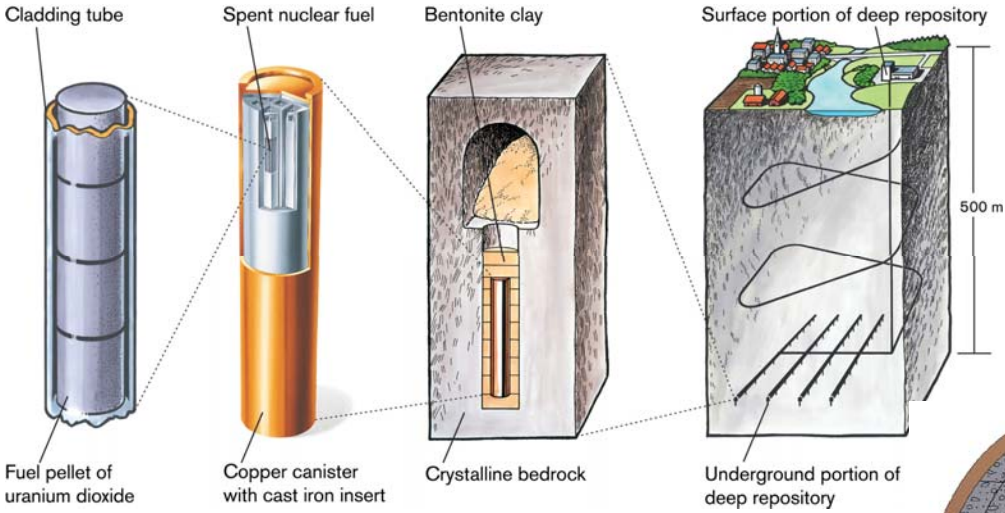
Hydrologic Environment	Rock Type	Key Features	Countries Considering this Option
Unsaturated	Ash-flow tuff	Limited seepage, fluid flow predominantly in fractures, zeolitic units have high sorptivity, oxidizing environment	USA
Saturated	Crystalline rock	Low porosity and permeability, fluid flow predominantly in fractures, reducing environment	Canada, China, Finland, France, Germany, Hungary, Japan, Russia, Sweden, S. Korea, Spain, Switzerland
	Clay	Low permeability, high sorptivity, reducing environment	Belgium, France, Germany, Hungary, Japan, Russia, Spain, Switzerland
	Salt	Low-permeability, self-sealing, reducing environment	Germany, USA

Research Needs – Natural Systems

- Long-term climate change
- Groundwater recharge and discharge
- Percolation processes and definition of groundwater flow fields
- Near-field effects and thermally coupled processes
- Radionuclide transport
- Low probability disruptive events (such as volcanic and seismic events)

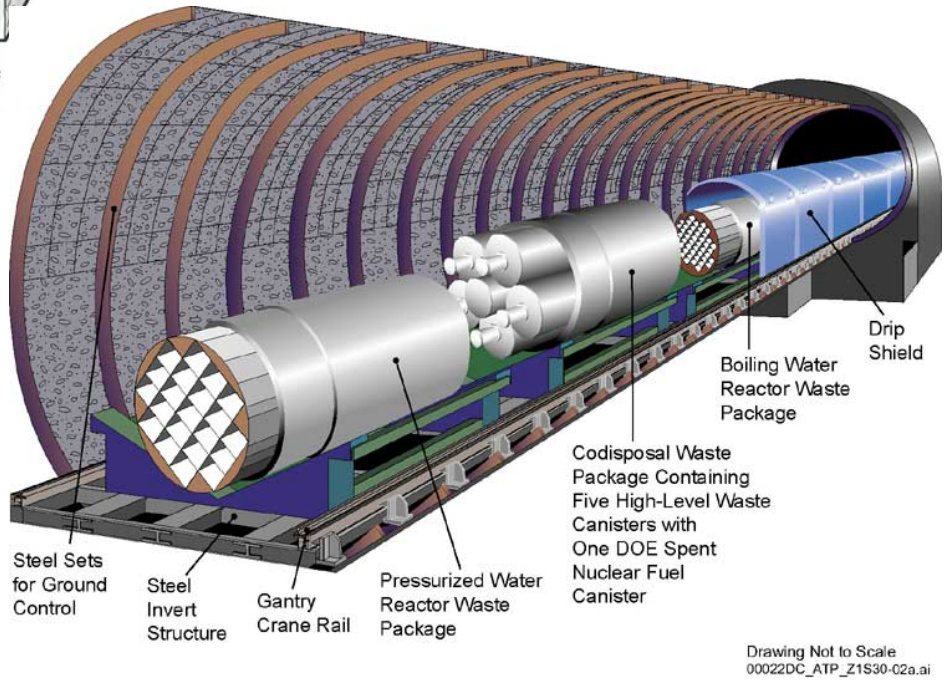


Engineered Barriers



Swedish Concept (after Lundqvist, 2006)

United States Concept



Research Needs – Source Term

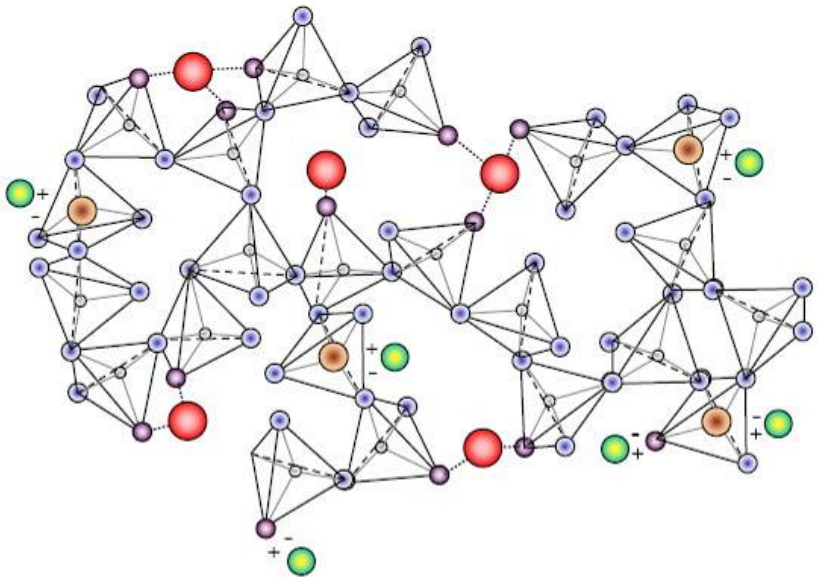
- **Enhance the understanding of the performance and evolution of nuclear waste forms (spent nuclear fuel, nuclear waste glass, and other advanced waste forms) and to quantify the release of radionuclides in the evolving near-field environment expected in the repository**

- **A basic understanding of the fundamental mechanisms of radionuclide release and a quantification of the release as repository conditions evolve over time, particularly at longer times (>10^5 years), must be developed**

- **Among the important processes that can control radionuclide release are:**
  - Kinetics of waste form corrosion
  - Formation of secondary, alteration phases
  - Reduction and sorption onto the surfaces of near-field materials
  - Biogeochemical processes and microbial activity
    - *May influence the geochemical environment and promote colloid formation with resultant impacts on waste form stability and radionuclide transport.*

Requirements for Waste Forms

- Performance (durability, heat transfer, radiation stability)
- Cost effective (low disposal volumes, low cost processes)
- Flexibility (waste composition, loading, process ranges, etc.)
- Predictable performance (natural analogues, release models)
- Match the waste stream to waste form and disposal environment



A Science-Based Engineering Approach to Understanding Waste Form and Repository Performance

- **An integrated science and technology program to provide technical options – systems analyses, experiments, modeling and simulation**

- **Future Directions**
  - Development of advanced, more durable, tailored waste forms
  - Development of advanced geologic disposal concepts in a range of geologic settings and geochemical environments
  - Enhanced understanding of geologic repository performance
  - Systems optimization of repository designs and fuel cycles