U.S. DEPARTMENT OF ENERGY | Nuclear Energy

The Potential for Transformational Solutions to Fuel Cycle Challenges Through Innovative Department of Energy Research Programs

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Nuclear Fuel Cycle Options

- **Fuel cycle options support National energy objectives that focus on clean energy, economic prosperity, and national security.**
- **DOE-NE goal:**
  - Extending nuclear fuel resources
  - Minimizing waste
  - Reducing impact to human health and the environment
- **Currently no country has commercially implemented a fully closed fuel cycle.**
  - The US currently uses a once through fuel cycle
- **Used Nuclear Fuel: Is it a waste or a source of energy?**
  - Need to keep options open until society determines an appropriate path

Mission and Program Objectives

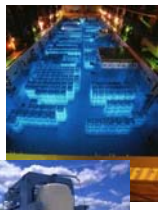
- **Support decision-makers by developing a suite of options to manage used fuel**
- **Demonstrate technologies that support commercial deployment of sustainable fuel cycles by 2050**

Sustainable fuel cycles are those that:
- Improve uranium resource utilization
- Maximize energy generation
- Minimize waste generation
- Improve safety
- Protect the environment
- Limit proliferation risk
- Are economically viable

Used Fuel Generation

- **Each year, U.S. nuclear power plants generate about 2,000 metric tons of used fuel.**
  - Commercial reactors have capacity for a few decades of water basin storage of used nuclear fuel
  - Most utilities have added dry cask storage capacity to handle overcrowding in pools
- **Contained in the 2,000 tons of used fuel is about 18 tons of plutonium.**
- **All of the used fuel generated by these plants is scheduled for geologic disposal.**

Is reprocessing an alternative option?



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What are the Incentives for Reprocessing?

- **Source of Energy**
  - Residual used fissile material can be recycled to new fuel
  - There is the potential for nearly limitless fuel
- **Resource Conservation**
  - Low-cost uranium supply is finite.
- **Waste Management**
  - Superior storage and/or disposal forms relative to UNF
  - Separate transuranics (Pu, Am, Np) for transmutation
- **Nonproliferation**
  - Limits use of enrichment facilities
  - Support weapons disposition goals
  - Avoid sending fissile materials to repository or long-term storage

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What are the Challenges for Reprocessing?

- **Cost**
- **Impact to the environment**
- **Proliferation risk and safety concerns**
- **Public acceptance**

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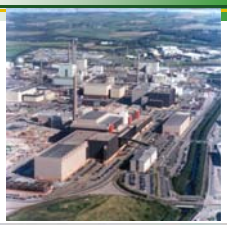
All Commercial Operating Facilities are Based on the PUREX Process

THORP, UK



La Hague, France

Rokkasho, Japan

Mid-2000's Technology Approach

- **Short-term resulted in incremental improvements that lead to quick commercial deployment alternatives, but do not bring radical improvements**
  - COEX, UREX+, NUEX
    - Processes do not completely separate plutonium from uranium
    - Processes are compatible with existing reactors
- **Mid-term development focused on dry processes**
  - Electrochemical processing
    - Plutonium not separated from transuranics and uranium
    - Fuel requires hot cell fabrication
    - Supports transmutation systems for waste management
- **Long-term development focused on alternatives to aqueous and dry processes**
  - Supercritical extraction
  - Chlorine and fluorine volatility

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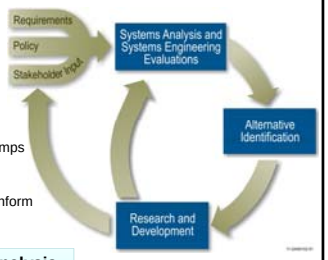
Current Approach is Based on System Engineering and Analysis

- **Objective is to inform**
  - Fuel cycle R&D
  - Programmatic decisions
  - Strategy formulation
  - Policy development
- **Goal**
  - Evaluate technology alternatives
  - Identify gaps, disconnects, and off-ramps
  - Examine deployment options
  - Understand system dynamics
  - Identify critical program elements to inform where R&D should be targeted



The systems engineering and analysis is used to drive a focus R&D program

Separations and Waste Forms

Today's Technology Challenges

- Minimizing waste generation from the fuel cycle
- Recovering fuel resources, from natural materials or used fuel, in an economic manner

Development Path

- Develop fundamental understanding of separation processes and waste form thermodynamics
  - Exploit thermodynamic properties to effect separations
  - Elucidate microstructural waste form corrosion mechanisms

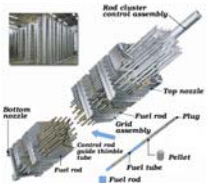
Outcomes

- Advanced separations technologies
- Robust waste forms
- Predictive models for separations technology and waste form performance

Transmutation Fuels

Today's Technology Challenges

- Producing fuels that enable improvements in waste management and resource utilization
- Enabling fuels with variable compositions
- Minimizing defects and process losses from fuel fabrication



Development Path

- Develop a fundamental microstructural understanding of fuels and materials
- Develop clean and reliable fabrication techniques with tightly controlled microstructures tailored to desired performance

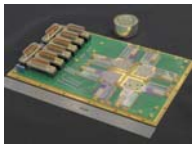
Outcomes

- Advanced fuel forms
- Predictive models for fuel performance

Materials Protection, Accounting, and Control Technologies

Today's Technology Challenges

- Developing nuclear material management systems for new advanced nuclear processes
- Develop more economical nuclear material management systems for large fuel cycle facilities



Development Path

- Develop next generation instrumentation enabled by new physics data
  - High sensitivity and specificity
  - New sensor materials
- Improve data management
  - Real time assessments
  - Probability basis with uncertainties

Outcomes

- Real time nuclear materials management with continuous inventory
- Predictive models for nuclear material management

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Summary

- DOE-NE is performing R&D to support decision-makers by developing a suite of options to manage used fuel
- The focus is on technology advances that are needed to fully utilize the energy potential of nuclear fuel while addressing the challenges of historic reprocessing concepts
- A systems engineering and analysis based approach is used to instill requirements that drive a focus R&D program

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