U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

Topic Area 2 – Fuel Cycle Technologies

Up to 3 years and up to $1,000,000

FC-1: Aqueous Separations Chemistry | *Stephen Kung, Federal POC*

FC-2: Molten Salt Separations and Solution Chemistry | *Jim Willit, Federal POC*

FC-3: Spent Fuel and Waste Disposition: Disposal | *John Orchard, Federal POC*

FC-4: Spent Fuel & Waste Disposition | *John Orchard, Federal POC*

FC-5: Other Fuel Cycle Technologies Topics

Topic Area 2

Fuel Cycle Technologies Overview

NE develops used nuclear fuel management strategies and technologies to support meeting federal government responsibility to manage and dispose of the Nation's commercial used nuclear fuel and high-level waste and to develop sustainable fuel recycling technologies and options that improve resource utilization, reduce waste generation, enhance safety, and limit proliferation risk.

Fuel Recycling and Separation Chemistry Activities focus on developing advanced fuel recycling technologies and addressing fundamental materials separation and recovery challenges that present significant degrees of technical risks and financial uncertainties. We employ a science-based approach to foster innovative and transformational technology solutions.

The Used Nuclear Fuel Disposition R&D Program conducts scientific research and technology development to enable long term storage, transportation, and disposal of spent nuclear fuel and wastes. The primary focus of this program supports the development of disposition-path-neutral waste management systems and options in the context of the current inventory of spent nuclear fuel and waste.

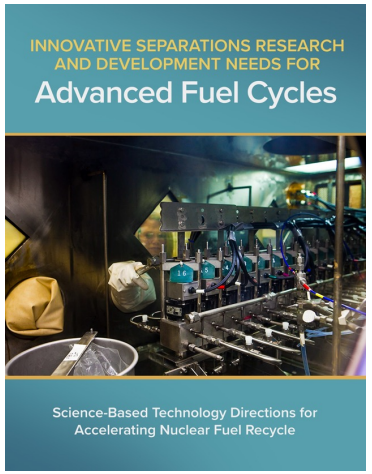
Additional research opportunities in Fuel Cycle Technologies involve development of processes and tools to evaluate sustainable fuel cycle system and used fuel management options that can be communicated effectively to stakeholders.

Topic Area 2 FC-1

Aqueous Separations Chemistry (FC-1)

Aqueous technologies use solvent extraction to separate fission products and actinides. Current reprocessing technologies (PUREX/UREX) are hampered by high capital & operating costs.

This topic seeks innovative approaches that improve fundamental understanding of aqueous separation chemistry to enable simplifying aqueous processing.



Research opportunities include, but not limited to:

- **Innovative Ligand Design and Synthesis to Simplify Actinide Separations**
- **Understand the Molecular-level Interactions at the Interface for Nuclear Separations**
- **Intensify Nuclear Separations through External Forces and Fields**
- **Develop Technologies for Real-Time Quantification of Chemical Species**

Innovative Separations R&D Needs for Advanced Fuel Cycles Workshop Report
https://www.ornl.gov/file/innovative-separations-research-and-development-needs-advanced-fuel-cycles/display

Topic Area 2 FC-1

Ongoing NE Work Relevant to FC-1

Our current R&D activities emphasizing the development of **simplified single cycles**

- ✓ Establish simplified single cycle baseline using monoamides
- ✓ AI/ML aided ligands design, synthesis for tailored actinide to enhance separation efficiency
  - Simplified methods for managing problematic elements / Ru, Tc, Zr
  - Evaluate promising novel organic and aqueous-soluble complexants / CHON
  - Design and optimize innovative recycling systems
- ✓ Explore autonomous testing systems and ML algorithms for accelerated data acquisition
- ✓ Direct dissolution of oxidized fuel into the organic phase – skipping nitric acid dissolution
- ✓ Develop real-time chemical species characterization methods
- ✓ Develop options for recycling adv reactor fuel types
- ✓ Understand and innovative manage / control of irradiation damage

Topic Area 2 FC-1

Areas Not of Interest

- ✓ Recycling of MOX fuels from LWR
- ✓ Evolution of TBP based PUREX / UREX technologies
- ✓ Minor Actinide Separations
- ✓ Hybrid aqueous and non-aqueous method – unless can justify significant enhanced simplicity
- ✓ Example of proposal topics to be submitted to FC-5: OTHER FUEL CYCLE TECHNOLOGIES
  - Advanced Vol-oxidation
  - Vapor Phase Extraction

Topic Area 2
FC-2

Molten Salt Separations and Solution Chemistry (FC-2)

Molten salts have unique composition–dependent chemical, thermodynamic, thermophysical, and neutronic properties that make them well-suited for applications on front and back ends of the nuclear fuel cycle as well as for thermal storage.

- These unique properties are determined by dynamic **speciation** and **atomic level structures** of the molten salt solution.
- This topic seeks proposals on innovative modeling and experimental approaches that accurately predict and characterize speciation and structure of molten salts to
  - Improve our fundamental atomic level understanding of molten salt ***solution chemistry***
  - Improve our fundamental atomic level understanding of molten salt ***solution properties***
  - Enable a broad scope of molten salt applications.

Topic Area 2 FC-2

Ongoing Work Relevant to FC-2

- The Fuel Cycle Initiative in the Office of Nuclear Energy supports on-going fundamental and applied research through many avenues of funding including directed research, NEUP, SBIR/STTR, and Industry FOA.
- Examples of completed and on-going NEUP research on molten salt separations and solution chemistry can be found by clicking on the R&D tab at https://neup.inl.gov/
  - Clicking on a year under "Final Project Reports" gives a list of final reports available from OSTI.
  - Clicking on a year under "NEUP Funded Projects" and then selecting "Fuel Cycle Research and Development" gives a list of projects that began that year and a brief description. Clicking on the title opens the extended abstract for the project.
- Additional information is available in a recent workshop report "*Technology and Applied R&D Needs for Molten Salt Chemistry,*" (https://www.ornl.gov/sites/default/files/Molten%20Salt%20Workshop_Final_092917.pdf)
- Funded projects typically combine modeling with experimental measurements that provide insights on the speciation and atomic structure of one or more molten salt solutions.

Topic Area 2 FC-2

Areas Not of Interest

- Applications should focus on research that support the **DOE-NE mission**
- Molten salt-based proposals with the following focuses would be considered not relevant to this topic:
  - Room-temperature ionic liquids (RTILs) based on organic ions
  - Concentrated solar power
  - Molten salt batteries
  - Separations based on halide volatility

Topic Area 2 FC-3/4

Spent Fuel and Waste Disposition Overview

- As our country continues to deploy nuclear energy as a solution for decarbonization, increasing access to energy, and tackling climate change, we need to make progress on the back end of the fuel cycle.
- The U.S. Department of Energy Office of Spent Fuel and Waste Disposition is responsible for managing the nation's spent nuclear fuel and high-level radioactive waste, including finding sites to store and dispose of the spent nuclear fuel.
- To focus on this challenge, the Office of Spent Fuel and Waste Disposition has established two offices: the Office of Integrated Waste Management, which is the applied side that focuses on the design and siting of consolidated interim storage and preparing for transportation to the interim storage, and the Office of Spent Fuel and Waste Science and Technology, which focuses on the R&D side.
- The mission for the Office of Spent Fuel and Waste Science and Technology is to provide a sound technical basis for the safety and security of long-term storage, transportation, and disposal of spent nuclear fuel and high-level radioactive wastes from commercial nuclear power plants.

Spent Fuel and Waste Disposition: Disposal (FC-3)

Disposal Research Mission

- Provide a sound technical basis for assurance that the US has multiple viable disposal options for mined deep geologic repository available when national policy is ready
- Identify and research generic sources of uncertainty that challenge the viability of disposal concepts
- Increase confidence in robustness of generic disposal concepts to reduce the impact of site-specific complexity
- Develop the science and engineering tools required to address the needs above

Topic Area 2 FC-3

Ongoing NE Work Relevant to FC-3

Representative Activities in Disposal Research:

Argillite/Shale Disposal R&D

- Effect on repository performance of coupled THMC processes
- Integration of process models into GDSA framework
- Modeling THMC processes within the EBS

Crystalline Disposal R&D

- Flow and transport in fractures
- Modeling coupled THM processes affecting fracture transmissivity
- Performance of candidate buffer materials

Topic Area 2 FC-3

Ongoing NE Work Relevant to FC-3

Salt Disposal R&D

- Effects of heat-generating waste on performance
- Evolution of Engineered Barriers in salt
- Brine Availability Test in Salt (BATS) 2.0 borehole completion and test setup
- Model development

Engineered Barrier System R&D

- Experiments on bentonite, cement, WP materials at higher temperature
- Analyze effects of thermal, mechanical, and chemical processes on performance of EBS designs for each host rock type
- Modeling of bentonite clay dehydration-swelling and creep (thermal-hydrogeologic) behavior

Topic Area 2
FC-3

Ongoing NE Work Relevant to FC-3

Geologic Disposal Safety Assessment

- GDSA Framework capability expansion (e.g., fracture transport, high-T systems, uncertainty and sensitivity analysis)
- Surrogate model (neural network) approaches and advanced solvers development
- DECOVALEX-2023 Reference Cases for international PA model comparisons
- Cladding degradation model for post-closure criticality configuration and source-term performance

Direct Disposal of Dual Purpose Canisters

- Filler experiments and demonstration performance criteria
- Hydrothermal testing of Zircalloy cladding
- Criticality consequence performance modeling

Topic Area 2 FC-3

Areas Not of Interest

Applications should focus on research that supports the **SFWST Disposal Research mission**

Applications with the following focuses would be considered not relevant to this mission:

- Technologies not primarily related to mined deep geologic repository issues
- Technologies solely related to site-specific issues
- Technologies solely related to Yucca Mountain Repository
- Technologies solely related to Deep Borehole Disposal
- Technologies solely related to tuff host rock
- Technologies solely related to International Disposal Issues

Applications on technologies that crosscut with any of these areas could be considered responsive if they clearly demonstrate relevance to the mission.

Spent Fuel and Waste Disposition: Storage & Transportation (FC-4)

Storage & Transportation Mission

Develop the technical bases:

- To demonstrate spent fuel integrity for extended storage periods
- To support fuel retrievability and transportation after extended storage
- For transportation of high burnup fuel

Topic Area 2 FC-4

Ongoing NE Work Relevant to FC-4

Current Activities in Storage & Transportation:

Fuel Integrity Testing and Analysis

- Destructive testing and inspection of HBU Fuel sibling pins
- Continue Phase 1 testing and discuss/plan for Phase 2 testing

Dry Storage Canister Stress Corrosion Cracking

- Development of quantitative hand-sampling methods for dust sampling of the Canister Deposition Field Demonstration
- Collecting and analyzing corrosion test data (nitrate solutions)
- Crack repair/mitigation/coatings studies for storage canisters

Topic Area 2 FC-4

Ongoing NE Work Relevant to FC-4

Canister Failure Consequence Analysis

- Aerosol source term analyses (to quantify time evolution of respirable fraction)
- Aerosol Transmission through idealized SC cracks

External Load Testing and Analysis

- Planning for the Seismic Shake Table test of full scale canister and storage overpack/module
- Design and fabrication of the vertical concrete cask (VCC) and the dummy assemblies (on-site at UCSD)
- Seismic pretest modeling of cask and soil-structure interactions

Topic Area 2 FC-4

Ongoing NE Work Relevant to FC-4

Thermal and Drying

- Testing updates for the Dashpot Drying Apparatus (DDA)
- International round-robin modeling for the HBU demo
- Small scale test drying methodology development

Canister Deposition Field Demonstration

- Instrumentation of sample canisters progressing, with heater testing
- Surface sampling methodology shake-down/ protocol development

HBU Fuel Field Demonstration

- Continue monitoring an interpreting HBU Fuel canister temperature
- Design and prepare facility and procedures for investigating contents of HBU Fuel field demonstration canister

Topic Area 2 FC-4

Areas Not of Interest

Applications should focus on research that supports the **SFWST Storage & Transportation mission**

Applications with the following focuses are considered not relevant to this mission:

- Technologies not primarily related to storage and transportation of domestic commercial spent nuclear fuel and high-level radioactive waste
- Technologies not primarily related to conventional LWR fuels and HBU fuels
- Technologies solely related to site-specific issues
- Technologies solely related to Consent Based Siting issues
- Technologies solely related to design or operation of storage or transportation equipment or facilities

Applications on technologies that crosscut with any of these areas could be considered responsive if they clearly demonstrate relevance to the mission.

Topic Area 2 FC-5

Other Fuel Cycle Technologies Topics (FC-5)

Proposals that are relevant to fuel cycle technologies as described in the Topic Area 2 overview but are not covered by the previous topic categories can be submitted to FC-5 for consideration.

It is important to note that any submission to this category can be crosscutting, but must reinforce the Office of Nuclear Energy's mission and the following supporting goals:

"Advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs."

1. Enable continued operation of existing U.S. nuclear reactors.
2. Enable deployment of advanced nuclear reactors.
3. Develop advanced nuclear fuel cycles.
4. Maintain U.S. leadership in nuclear energy technology.

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Questions?