

## **High-Level Waste and Spent Fuel Management**

### **Program Overview**

#### **Program Description**

The High-Level Waste and Spent Fuel Management Program examines a range of complex scientific and technical issues affecting waste management, including advanced fuel cycles, spent fuel transportation, geologic disposal, and interim storage requirements. Research related to these issues informs utility decisions on waste management and provides insight into technical advances required to develop an integrated solution.

#### **Industry Needs and Issues Addressed**

- Efficient spent fuel management strategies to maintain plant operability
- Technical analyses to assess spent fuel transportation risks and identify infrastructure issues related to developing an efficient spent fuel transportation system
- Tools to optimize on-site wet and dry storage of spent nuclear fuel
- Technical and economic analyses of advanced fuel cycles (design, operations, scale-up, research needs)

#### **Impact**

- Technical basis to support design and operation of long-term geologic repositories
- Technical basis to resolve generic spent fuel storage and transportation issues
- Identification of research gaps in bringing new fuel cycle technologies to full commercial scale

#### **Key Accomplishments**

- First dry cask storage probabilistic risk assessment, which showed the storage risk to be extremely low
- Probability assessment of a criticality occurring during spent fuel transport (on the order of 10-14 over 11,000 individual shipments)
- Technical input supporting regulatory relief in spent fuel drying for dry cask storage; partial “burnup credit” (lower estimated k-eff for criticality); and a workable definition of “damaged” fuel
- Demonstration of feasibility of direct disposal of dual-purpose (storage and transportation) spent fuel canisters in a geologic repository

#### **Current Year Objectives**

- Develop technical bases for a defense-in-depth approach to demonstrating high burnup spent fuel transportation safety
- Develop models to assess high-level waste/spent fuel storage, transportation, and disposal impacts due to advanced fuel cycle options

#### **Industry Involvement**

- Estimated 2009 funding: \$2.9M

#### **Program Technical Lead**

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## Summary of Projects

Project Number	Project Title	Value
	Repository Performance Assessment	EPRI has been actively developing experts in all of the major Yucca Mountain technical areas and has developed its own total system performance assessment code. EPRI also has provided influential input to the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC) to make their Yucca Mountain regulations more sensible.
	Repository Pre-Closure	Participate in Yucca Mountain pre-closure issues by engaging the Department of Energy (DOE) and NRC to develop sensible regulatory and compliance approaches and developing independent capability to assess the DOE probabilistic risk assessment
	Transportation Studies to Support Repository Development	Technical analysis to evaluate the general risk of spent fuel transportation and specific risks and infrastructure issues related to developing an efficient spent fuel transportation system to Yucca Mountain
	Storage and Transportation of High-Burnup Spent Fuel	Development of technical bases together with the collection of confirmatory experimental data to obtain regulatory acceptance of practical approaches for dry storage and transportation of spent pressurized water reactor (PWR) and boiling water reactor (BWR) fuels with initial U-235 enrichment up to 5% and discharge burnup greater than 45 GWd/MTU
	Fuel Works/Cask Loader	This supplementally funded project develops computer codes to optimally select spent fuel from the pool inventory to load into dry storage casks using a series of user-defined and –weighted criteria.
	Wet Storage Technology	This supplementally funded project provides members with a database of information on available neutron absorber materials and is developing a neutron absorber material qualification plan.
	Parts 71 & 72 Generic	This project provides the technical bases for resolving generic issues associated with 10 CFR Part 71 (spent fuel transportation) and Part 72 (spent fuel storage). Most of the regulatory issues have significant operational and economic impact not adequately addressed in the vendors' topical safety and design reports. Activities conducted under this project directly support Nuclear Energy Institute efforts.
	Risk-Informed Storage and Transportation	Probabilistic risk assessment studies of dry storage and transportation systems to risk-inform regulatory practices applicable to dry storage and transportation; provide a risk-based framework for the resolution of generic issues; and support the implementation of licensing conditions under which changes can be made to existing storage approaches without regulatory review
	Fuel Cycle Waste Studies	Cofunding of major effort at Massachusetts Institute of Technology (MIT) on advanced fuel cycles. In-house evaluation and development of advanced fuel-cycle codes and the ability of next-generation plants to use MOX fuel.

## Project Descriptions

### Repository Performance Assessment (052495)

#### Issue

Regulatory and technical issues impede the development of the Yucca Mountain repository. Proposed regulations for Yucca Mountain require prediction of the behavior of the repository system and the complex geology in which the repository is located over the next 1,000,000 years using probabilistic methods. This poses both technical and regulatory challenges. Opportunities exist for developing appropriate methodologies for long-term prediction of the repository system, as well as developing an approach to establishing adequate regulatory confidence at each stage of repository development.

#### Description

This project reviews Department of Energy and Nuclear Regulatory Commission documents and technical interactions impacting the development and licensing of the Yucca Mountain repository and develops repository performance assessment capabilities to evaluate DOE and NRC approaches to Yucca Mountain licensing. EPRI has been actively developing experts in all of the major Yucca Mountain technical areas and has developed its own total system performance assessment code. EPRI also has provided influential input to the Environmental Protection Agency and NRC to make the Yucca Mountain regulations more sensible. Specific technical issues that EPRI has addressed to-date include igneous probability and consequence analyses; seismicity and rockfall effects; effects of deliquescent brines on waste package degradation; colloid-aided radionuclide transport; neptunium solubility limits; biosphere dose conversion factors; and total system performance assessment.

#### Value

- Provide technical support for more implementable Yucca Mountain regulations
- Ease the Yucca Mountain licensing path
- Increase the likelihood of a successful Yucca Mountain licensing process
- Advance the time at which EPRI members can begin shipping spent fuel off their sites

#### How to Apply Results

Members apply results through EPRI and Nuclear Energy Institute (NEI) efforts prior to and during the Yucca Mountain licensing process. For example, EPRI work on a sensible Yucca Mountain regulatory standard has been presented to EPA and NRC directly, and via NEI letters. Specific EPRI technical work has been used by both DOE and NRC contractors to inform actions on specific issues or to bolster the technical bases. Finally, the entire body of EPRI work will be used during the formal Yucca Mountain licensing process.

#### 2009 Products

Product Title & Description	Planned Completion Date	Product Type
<b>Evaluation of a Spent Fuel Repository at Yucca Mountain, Nevada – 2009 Progress Report</b> This report will summarize the work EPRI conducted in 2009 related to the licensing and development of Yucca Mountain. It is anticipated that EPRI's work in 2009 will be devoted largely to supporting the anticipated construction application licensing process.	12/23/2009	Technical Report

## **Repository Pre-Closure (062612)**

### **Issue**

The proposed regulations for the surface and subsurface handling facilities at Yucca Mountain are risk-based. DOE plans to prepare a Pre-Closure Safety Assessment (PCSA) that is similar to, but not exactly the same as, the more familiar probabilistic risk assessments used for reactors. Early indications are that without an established PCSA precedent, both DOE and NRC organizations will select more conservative approaches than warranted.

### **Description**

EPRI will participate in Yucca Mountain pre-closure issues by engaging DOE and NRC to develop sensible regulatory and compliance approaches and by developing an independent capability to assess the DOE PCSA for use prior to and during the formal licensing process.

### **Value**

- Facilitate opening of Yucca Mountain
- Maintain “waste confidence” for the continued operation of nuclear plants
- Accelerate the date at which spent fuel can begin to be removed from member facilities

### **How to Apply Results**

Members apply results through EPRI and NEI efforts prior to and during the Yucca Mountain licensing process. The entire body of EPRI work will be used during the formal Yucca Mountain licensing process.

## **Transportation Studies to Support Repository Development (062611)**

### **Issue**

Spent fuel transportation to Yucca Mountain will be a contentious issue. Concerns about the safety and security of spent fuel shipments highlight the need for an independent evaluation of the transportation risks. Nuclear plant operators need assurance that the Department of Energy is moving efficiently toward providing the necessary transportation infrastructure. Finally, concerns about transportation accidents require an assessment to determine whether the necessary permits and licenses will be granted to allow spent fuel shipments to Yucca Mountain.

### **Description**

This project supports two research activities:

- Analysis and reviews supporting qualification of spent fuel transportation systems. EPRI will participate in formal reviews the NRC’s Package Performance Study (PPS), an experimental program aimed at full-scale testing of licensed spent fuel transportation casks. As appropriate, EPRI will perform independent analyses to evaluate test results.
- Analysis of transportation systems and issues specific to moving spent fuel to Yucca Mountain. EPRI will provide insights regarding transportation issues that could impede the development of the candidate spent fuel and high-level waste repository at Yucca Mountain. Targeted research, based on these insights, develops solutions for the most important issues.

### **Value**

- Assure adequate spent fuel transportation infrastructure development
- Allay public fears of spent fuel transportation.
- Establish a high level of public protection due to the existing spent fuel transportation regulations.

### **How to Apply Results**

Members apply EPRI analyses and results through industry participation in public forums, during Yucca Mountain transportation infrastructure development, and for internal evaluation purposes.

## **Storage and Transportation of High-Burnup Spent Fuel (052407)**

### **Issue**

Safe and cost-effective management of growing spent fuel inventories can be hampered by overly restrictive regulatory guidance. An outstanding issue is transportation of spent fuel with discharge burnups in excess of 45 GWd/MTU. Agreements about relevant technical bases and appropriate methodologies for calculating nuclear reactivity (moderator intrusion/exclusion, fuel burnup credit) together with a better understanding of spent fuel structural response (changes in spent fuel assembly geometry and potential damage leading to reconfiguration) under normal and accident conditions of transportation could resolve regulatory impasses.

### **Description**

This project develops sound technical bases and collects confirmatory experimental data to support regulatory acceptance of practical approaches for implementing dry storage and transport of spent nuclear fuels with initial enrichment up to 5% and discharge burnup greater than 45 GWd/MTU. Several research elements are being pursued: probabilistic assessment of a criticality event during transportation; options for excluding intrusion of water in the waste package, or moderator exclusion; data collection for full burnup credit methodology benchmarking; analytical modeling and experimental programs for assessing zirconium-based cladding integrity under normal and accident-impact loading conditions; and effect of reconfiguration on effective neutron multiplication factor.

### **Value**

- Resolved: Provide a predictable approach for licensing dry storage of spent fuel without any discharge burnup limitations. This issue was effectively resolved in July 2002 with the NRC publication of *Interim Staff Guidance 11, Rev. 2*, which was the result of interactions between the NRC and EPRI. Several nuclear plants facing shortfalls in wet storage capacity would have had to devote considerable resources to find alternate, higher-cost alternatives.
- Unresolved: Provide predictable approaches for licensing transportation of spent fuel without any discharge burnup limitations. Although there is presently no centralized interim storage facility or repository licensed to accept spent fuel, licensees want to be able to move spent fuel off their sites as soon as permitted.

### **How to Apply Results**

The technical information generated by EPRI will be submitted to NRC's Spent Fuel Storage & Transportation Office by the Nuclear Energy Institute (NEI) on industry's behalf to resolve, in a generic manner, present impasses preventing the safe and cost-effective transport of spent fuel assemblies with burnup greater than 45 GWd/MTU.

## **Fuel Works/Cask Loader (052410)**

### **Issue**

Spent fuel pools at nuclear power plants are at full or near full capacity and are in danger of not being able to allow a full-core offload. While some spent fuel can be stored outside the reactor building on concrete pads, the data needed to load spent fuel into dry casks are often in disparate locations, and some are not in electronic form. A software program containing the necessary data to meet plant and

cask vendor technical specifications is needed to choose fuel that would meet the specifications in the cask's Certificate of Compliance.

### **Description**

The Cask Loader software package provides a tool for loading dry storage casks that enables plant personnel to minimize the need for fuel movement and significantly reduce documentation errors. Cask Loader helps select the appropriate spent fuel assembly for each cask and then prints the utility move sheets and other required forms.

### **Value**

- Optimize cask loading for cost and schedule
- Maintain data for DOE and NRC reporting
- Interact with cask vendor models and technical specifications
- Ease crowding in spent fuel pools
- Mitigate personnel concerns on efficiency and dose
- Import current utility data; obtain reports in utility-specific format
- Facilitate easy updates for new utility or regulatory requirements
- Allow customization of new cask vendor and reports
- Perform gamma and neutron calculations
- Perform decay heat calculations based on Reg. Guide 3.54 (default) or NRC Branch Technical Position ASB 9-2

### **How to Apply Results**

Members input data into Cask Loader from spreadsheets or ShuffleWorks files. The data include bundle/assembly as-built data, exposure, core location, and failure status; core data, including cycle dates, exposures; and cask data including as-built data. Cask Loader populates the chosen casks based on cask technical specification requirements and fuel available that meet the requirements of the cask. Members may choose to replace automatically chosen bundles with other candidates from the candidate pool. Reports can be printed and data output to spreadsheets or other proprietary report formats.

## **Wet Storage Technology (052409)**

### **Issue**

The neutron absorber materials used in spent fuel pool storage racks and in spent fuel dry storage and transportation systems to maintain nuclear subcriticality have exhibited some type of degradation or other unanticipated operational problems. Boraflex has encountered the most severe problems, including a propensity to form blisters under some conditions. The neutron poison issue is compounded by the fact that the poison materials are used to maintain criticality control, and, therefore, the problems must be addressed in both a regulatory as well as a technical framework. Nuclear plants must expend large sums of money to implement necessary corrective actions and licensing changes.

### **Description**

The Neutron Absorber User Group (NAUG) shares information and experience about managing widely used neutron absorber materials, identifies performance issues, and, if necessary, funds the initial development of new materials or common qualification approaches. This project accomplishes these objectives by 1) participating in the development and/or qualification of improved neutron absorbers; 2) documenting the technology and field performance of all neutron absorber materials used in spent fuel storage and transportation; 3) providing an annual forum for members to exchange operational experience and lessons learned relative to neutron absorber materials; 4) supporting member interactions with the NRC on licensing issues related to poison materials; and 5) maintaining and supporting the RACKLIFE software and the BADGER test equipment.

**Value**

- Increase reliability of neutron absorber materials used in spent fuel pool racks and dry storage and transportation systems
- Provide updated revisions of EPRI's *Neutron Absorber Materials Handbook*
- Participate in the annual Neutron Absorber Technology Information Workshop
- Access RACKLIFE and BADGER technologies

**How to Apply Results**

Members receive ready access to EPRI support in responding to regulatory actions related to neutron absorber performance issues.

**Parts 71 & 72 Generic (052406)**

**Issue**

The Nuclear Regulatory Commission proposes revisions to the applicable Standard Review Plans for storage and transportation applications in the form of interim staff guidance (ISG). Some of the proposed ISGs have significant operational and economic impacts not adequately addressed by the systems' designers. As a result, nuclear plants must remain actively involved in resolving generic issues associated with 10 CFR Part 71 (Transportation) and Part 72 (Storage).

**Description**

This project develops sound technical bases, white papers, and comments to assist in resolving generic issues associated with 10 CFR Parts 71 and 72. Activities conducted under this project support the Nuclear Energy Institute's efforts to articulate joint industry responses to potential regulatory actions.

**Value**

- Reduce unnecessary regulatory burden that could result from technically unsound draft regulatory guidance for Parts 71 (Transportation) and 72 (Storage)

**How to Apply Results**

The technical information generated by EPRI will be submitted to NRC's Spent Fuel Storage & Transportation Division to inform proposed changes in regulatory guidance to Parts 71 and 72.

**Risk-Informed Storage and Transportation (062909)**

**Issue**

Although a large body of knowledge has been developed about accident frequency and risk-significant sequences for nuclear reactors, similar studies for the management of spent fuel are only emerging. Probabilistic risk assessments enable risk-informed regulations and regulatory practices to be developed for dry storage and transportation; provide a framework for risk-informed decisionmaking in resolving generic issues; and support the implementation of 10 CFR 72.48, which establishes the conditions under which licensees or certificate holders may make changes in facility, design, or procedures and conduct tests and experiments without prior NRC approval.

**Description**

EPRI conducted two probabilistic risk assessments of bolted storage casks, of increasing completeness, in the 2002-2006 timeframe. In 2008, these assessments will be used to evaluate the effectiveness of regulations and regulatory practices governing dry storage activities. EPRI will work with NEI and its

members to identify potential dry storage practices that could benefit from a more risk-informed regulatory approach. The results from this evaluation will define the 2009 work scope for this project.

**Value**

- Develop a risk-based framework for resolving generic issues or proposing cost-effective changes in operational burden associated with the management of spent fuel
- Support the 72.48 process under which changes can be made without prior regulatory review

**How to Apply Results**

To support the 72.48 process, members will need to develop a plant-specific probabilistic risk assessment. Members can develop a more effective plant-specific probabilistic risk assessment by using the generic PRA developed by EPRI as a starting point.

**Fuel Cycle Waste Studies (064955)**

**Issue**

Nuclear energy's long-term role in meeting future energy demand in a carbon-constrained world has stimulated discussion on various waste management issues, including centralized interim storage of used nuclear fuel; uranium availability; readiness, cost, and environmental benefits of advanced (closed) nuclear fuel cycles; and concomitant proliferation concerns. Better understanding of the options available for managing the technical, economic, environmental, and institutional aspects of advanced fuel cycles and their potential consequences is needed to inform decisionmaking. Areas of emphasis include the complex technological and policy challenges associated with introducing new reactor types at scale (for example, fast spectrum reactors), new fuel forms, new separations technologies, new international institutional arrangements, and system integration and operational issues.

**Description**

This project will evaluate technically based strategies for ensuring a sustainable nuclear energy fuel cycle. EPRI will conduct a multi-disciplinary study of the options for managing the technical, economic, environmental, and institutional aspects of the nuclear fuel cycle and their potential consequences, with specific emphasis on the "back-end" of the fuel cycle. The project will propose a program for technology development and deployment, taking into account uncertainties for managing commercial spent nuclear fuel and ultimate waste disposal. Several nuclear fuel simulation codes will be tested to evaluate their ability to model the operation of a nuclear fleet and associated fuel-cycle facilities over long periods of time.

**Value**

- Shape energy policy and national/international research priorities
- Improve management of used nuclear fuel, including recycling of plutonium and leftover uranium in existing and advanced reactors
- Enhance environmental stewardship by enhancing the capacity of geologic repositories for disposing high-level wastes

**How to Apply Results**

Most products will be published by the Massachusetts Institute of Technology. Members will apply results by sharing the results of the research with industry and government decisionmakers and the public to shape a research, development, and deployment path toward sustainable nuclear energy policies.