

Used Fuel and High-Level Waste Management

Program Overview

Program Description

Nuclear power's long-term viability depends on safe, cost-effective management of used fuel and high-level waste. An integrated solution encompassing fuel reprocessing, centralized interim storage, transportation, and permanent geologic disposal is achievable, but requires significant research and technology development.

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

Research Value

Better understanding of the options available for managing the technical, economic, environmental, and institutional aspects of high-level waste and advanced fuel cycles is needed to inform decisionmaking. Electric Power Research Institute's (EPRI's) Used Fuel and HLW Management Program conducts research to characterize the various technical risks and risk mitigation options related to used fuel storage, transportation, and disposal. The program also pursues the identification of promising technologies for closing the fuel cycle, which could lead to significant increases in the amount of energy extracted from uranium and to reductions in the volume of waste requiring long-term geologic disposal. The Used Fuel and High-Level Waste Management Program participants gain access to the following:

- Technical guidance to support operation of long-term geologic repositories.
- Technical basis to resolve generic used fuel storage and transportation issues impacting plant operability, license renewal, decommissioning, and the licensees' ability to move fuel off-site.
- More efficient dry storage and transportation canister designs that offer economic savings and enhance the licensees' ability to move high-burnup used fuel off-site.
- Research gaps in bringing new fuel cycle technologies to full commercial scale.

Approach

The Used Fuel and HLW Management Program develops knowledge, guidance, and tools to reduce the risks and maximize the technical options for safe, cost-effective handling, storage, and disposal. The Program leverages international experience with fuel handling and fuel reprocessing, and collaborates with international entities on cross-cutting research addressing the nuclear fuel cycle and supporting elements.

- Identify efficient used fuel management strategies to maintain plant operability.
- Conduct technical analyses to assess used fuel transportation risks and identify infrastructure issues related to developing an efficient used fuel transportation system.
- Develop tools to optimize on-site wet and dry storage of used nuclear fuel.
- Conduct technical and economic analyses of advanced fuel cycles (design, operations, scale-up, research needs).

Accomplishments

EPRI's Used Fuel and HLW Management Program provides specialized technical analysis of spent fuel management and nuclear fuel cycles to ensure the safe, economic handling and disposal of used fuel and HLW and to inform decisions regarding the viability of various nuclear fuel cycles.

- Evaluated proposed operational approaches for Yucca Mountain to demonstrate how some used fuel in existing dry storage systems could be directly disposed .This would result in significant cost and worker dose savings.
- Provided recommendations on the form of an implementable one million-year regulation for the candidate Yucca Mountain repository .EPRI's recommendations were largely adopted by the U.S. Environmental Protection Agency and the U.S. Nuclear Regulatory Commission .This paves the way for a possible license for Yucca Mountain.
- Conducted probability assessments of a criticality occurring during used fuel transport (on the order of 10^{-14} over 11,000 individual shipments) .This supports industry efforts to obtain transportation licenses for used fuel with a burnup exceeding ~45 GWd/MTU.
- Performed first dry cask storage probabilistic risk assessment, which showed the storage risk to be extremely low.
- Analyzed high-burnup advanced cladding properties to support their continued use while allowing for used fuel storage and transportation .

Current Year Activities

Used Fuel and HLW Management Program R&D for 2010 will focus on generic used fuel storage and transportation issues and on evaluating strategies for the future of a sustainable nuclear energy fuel cycle. Specific efforts will include the following:

- Develop technical bases supporting licensing of high-burnup used fuel transportation systems.
- Collaborate with Massachusetts Institute of Technology (MIT) to examine technical challenges to closed fuel cycles.
- Identify existing and near-future light water reactors that could burn mixed oxide fuel.
- Initiate a program to provide the technical bases for very long-term (>60 years) used fuel storage.

Estimated 2010 Program Funding

\$3.3M

Program Manager

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Summary of Projects

Project Number	Project Title	Description
P41.03.01.01	Parts 71 & 72 Generic Licensing Issues	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.
P41.03.01.02	Risk-Informed Storage and Transportation	<ul style="list-style-type: none"> • Develop a risk-based framework for resolving generic issues or proposing cost-effective changes in operational burden associated with the management of used spent fuel • Support the 10 CFR Part 72.48 process under which changes can be made without prior regulatory review • Evaluate potential Nuclear Regulatory Commission (NRC) analyses related to the relative risks of wet versus dry storage
P41.03.01.03	Storage and Transportation of High-Burnup Used Fuel	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 used 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.
P41.03.01.04	Neutron Absorber Materials Studies	<ul style="list-style-type: none"> • Organize annual meetings of neutron absorber material users and manufacturers to share experience and guide future needs. • Maintain an up-to-date handbook on available neutron absorber material information related to materials properties, manufacturing processes, and field experience.
P41.03.01.05	Future of Nuclear Fuel Cycle Studies	<p>The project will be carried out in two major phases over a five-year period. The first phase – the only one to be described at this time – will last for 40 months followed by a two-year phase for completion of specific studies and initiation of new studies as warranted by the needs identified in the first phase and the availability of funding.</p> <p>Phase 1 will consist of the following tasks:</p> <ul style="list-style-type: none"> • Task 1: Summary Update of the 2003 MIT Study on "The Future of Nuclear Power" • Task 2: Technology Options Assessment • Task 3: Nuclear Fuel Cycle Simulation Code • Task 4: In-depth Technology Evaluations
P41.03.01.06	Advanced Fuel Cycle Modeling and Waste Management	This project will develop appropriate nuclear fuel cycle models that track materials and radionuclides through the system; determine the appropriate mixture of light water reactor and fast reactor technology for both start-up and long-term, steady-state operation; and evaluate the health and economic impacts. Detailed sensitivity and uncertainty analyses will be conducted to shed light on R&D, health, and economic risks. This project also will evaluate the readiness of the existing and near-future light water reactor fleet to utilize mixed oxide MOX fuel.

Project Number	Project Title	Description
P41.03.01.07	Very Long-Term Used Fuel Storage	Identify issues that need to be addressed to achieve very long-term dry storage in existing canisters, an appropriate aging management plan (including surveillance, testing, and eventual repackaging), and identification of regulatory issues to be addressed.
P41.03.01.08	Generic Spent Fuel and High-Level Waste Disposal	Identify potential generic disposal issues once the new U.S. national policy regarding used fuel and HLW disposition becomes clear .Work with EPRI's international members to identify needs for EPRI-sponsored disposal R&D.
P41.03.01.09	Fuel Works/Cask Loader User's Group	The Cask Loader software package provides a tool for loading dry storage casks that enables plant personnel to minimize 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.

Parts 71 & 72 Generic Licensing Issues (052406)

Key Research Question

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).

Approach

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.

Impact

Reduce unnecessary regulatory burden that could result from draft regulatory guidance for 10 CFR Parts 71 (Transportation) and 72 (Storage) which is not fully informed by technical data and analysis.

How to Apply Results

The technical information generated by the Electric Power Research Institute (EPRI) will be submitted to Nuclear Regulatory Commission's (NRC's) Spent Fuel Storage & Transportation Division to inform proposed changes in regulatory guidance to Parts 71 and 72.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Spent Fuel Pool Criticality - Options for Demonstrating Sub-criticality: Nuclear Regulatory Commission (NRC) requirements for demonstrating sub-criticality in spent fuel pools are inconsistent and in transition .The purpose of this report is to provide options for demonstrating sub-criticality based on existing Part 50 and Part 72 regulations and to establish the technical bases for aspects of criticality assessment methodology.	12/10/10	Technical Report

Risk-Informed Storage and Transportation (062909)

Key Research Question

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 used fuel are only emerging. Probabilistic risk assessments enable risk-informed regulations and regulatory practices to be developed for wet and dry storage and transportation, provide a framework for risk-informed decisionmaking in resolving generic issues, and support the implementation of relevant 10 CFR Part 50 and 72 regulations.

Approach

Electric Power Research Institute (EPRI) conducted two probabilistic risk assessments of bolted storage casks, of increasing completeness, in the 2002-2006 timeframe. In 2010, these assessments will be used to evaluate the effectiveness of regulations and regulatory practices governing wet and dry storage activities. EPRI will work with the Nuclear Energy Institute (NEI) and its members to identify potential wet and dry storage practices that could benefit from a more risk-informed regulatory approach.

Impact

Reduces unnecessary spent fuel storage expenses, analyses, operations, and worker dose related to regulatory requirements that are not risk-informed.

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 probabilistic reliability assessment (PRA) developed by Electric Power Research Institute (EPRI) as a starting point.

Storage and Transportation of High-Burnup Used Fuel (052407)

Key Research Question

Safe and cost-effective management of growing used fuel inventories can be hampered by overly restrictive regulatory guidance. One outstanding issue involves transportation of used 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 used 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.

Approach

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 used 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.

Impact

- Resolved: Provides a predictable approach for licensing dry storage of used fuel without any discharge burnup limitations. This issue was effectively resolved in July 2002 with Nuclear Regulatory Commission (NRC) publication of *Interim Staff Guidance 11, Rev. 2*, which was the result of interactions between the NRC and the Electric Power Research Institute (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 used fuel without any discharge burnup limitations. Although there is currently no centralized interim storage facility or repository licensed to accept used fuel, licensees want to be able to move used 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 impediments preventing the safe and cost-effective transport of used fuel assemblies with burnup greater than 45 GWd/MTU.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p>Spent Fuel Transportation Issues Resolution - Response to NRC Comments: A major report on spent fuel transportation issues resolution for high-burnup spent fuel will be provided to the Nuclear Regulatory Commission (NRC) in 2009 .The 2010 report will address anticipated comments received from NRC on the 2009 report.</p>	10/01/10	Technical Update

Neutron Absorber Materials Studies

Key Research Question

Neutron absorber materials providing criticality control in fuel storage pools, and in used spent-fuel dry storage and transportation canisters, have experienced some degradation and performance issues .Costs incurred to manage degrading neutron absorber materials can reach in the millions of dollars .It is necessary to collect data regarding existing and proposed neutron absorber materials to assist in the management of existing materials and the development of appropriate manufacturing controls for new neutron absorber materials.

Approach

- Organize annual meetings of neutron absorber material users and manufacturers to share experience and guide future needs.
- Maintain an up-to-date handbook on available neutron absorber material information related to materials properties, manufacturing processes, and field experience.

Impact

Project activities result in more efficient management of existing neutron absorber materials, help maintain choices between available materials, and guide future development of new materials.

How to Apply Results

Material development information can be used by potential new neutron absorber material vendors to establish the necessary quality assurance (QA) program for material property control and by utilities to remain aware of potential neutron absorber materials performance issues .

Future of Nuclear Fuel Cycle Studies (066504)

Key Research Question

Demonstration by the private sector of the cost and schedule for building the new generation of light-water reactors is expected within the next ten to fifteen years .However, the industry, the government, and the public remain uncertain about whether this will indeed come to pass in timely fashion .A remaining major obstacle is the failure to resolve used spent nuclear fuel disposition a decade after the government was obligated to begin taking title to this fuel and still at least a decade away from Yucca Mountain operation.

The need for nuclear energy on one hand and the challenges it faces, particularly in the waste area, have stimulated much discussion on the issues of consolidated interim storage, uranium availability, readiness, cost and environmental benefits of closed fuel cycles, and concomitant proliferation concerns .Pursuit of closed fuel cycles raises even more complex technological and policy challenges concerning introduction at scale of new reactor types (for example, fast spectrum reactors), new fuel forms, new separations technologies, new international institutional arrangements, and new system integration and operational issues.

Approach

These considerations have led the Nuclear Energy Institute (NEI) and the Electric Power Research Institute (EPRI) to support a new interdisciplinary five-year Massachusetts Institute of Technology (MIT) research program to be carried out under the auspices of the MIT Energy Initiative .Although a series of studies over the proposed project period will be conducted, the overwhelming emphasis will be placed on research, analysis, and recommendations for the "back-end" of the fuel cycle, both open and closed, in the context of the same core question addressed in the 2003 Study: *"What actions are needed to enable nuclear power to be an important contributor to electricity supply in a carbon-constrained world for the long term?"*

Impact

The project will be a key element in the development of a sound, technically based strategy for the future of a sustainable nuclear energy fuel cycle.

How to Apply Results

Provide the report to key industry and governmental decisionmakers to assist in long- and short-term strategic planning to begin closing the nuclear fuel cycle.

Advanced Fuel Cycle Modeling and Waste Management (066959)

Key Research Question

Nuclear fuel cycles beyond a "once-through" cycle involve a complex arrangement of many components such as uranium mining and milling; uranium enrichment; uranium dioxide (UOX) fuel fabrication; use of UOX fuel in light-water reactors (LWRs); used UOX storage and transportation; UOX reprocessing; high-level radioactive wastes (HLW) disposal; mixed Pu/U oxide fuel (MOX) fabrication; MOX use in LWRs or fast reactors; used MOX storage and transportation; used MOX reprocessing; and multiple recycle MOX fabrication and use in LWRs or fast reactors .In order to determine how a more "closed" nuclear fuel cycle should be developed and implemented, it is necessary to understand the relevant research and development (R&D) development needs; material and radionuclide tracking; the appropriate mixture of LWR and fast reactors; economics; and start-up issues .Nuclear fuel cycle models are needed for these issues .

Approach

Develop appropriate nuclear fuel-cycle models that track materials and radionuclides through the system; determine the appropriate mixture of LWR and fast reactor technology for both start-up and long-term, steady-state operation; and understand both the health and economic impacts. Almost all of the components for each model are uncertain such that sensitivity and uncertainty analyses will be conducted. Evaluate the readiness of the existing and near-future LWR fleet to utilize MOX fuel.

Impact

The models will be helpful to decisionmakers regarding appropriate research and development (R&D) funding needs, how to begin introducing closed fuel cycle(s) at a commercial scale, and understanding the health and economic risks.

How to Apply Results

Reports provided to industry and federal decisionmakers related to funding decisions and fuel-cycle planning.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
Advanced Fuel Cycle Modeling - 2010 Progress Report: Annual progress report that will describe the model development and results conducted in 2010.	12/17/10	Technical Update

Very Long-Term Used Fuel Storage

Key Research Question

It is likely that used fuel will need to be stored for many decades until either reprocessing or final disposal becomes available. The use of dry used fuel storage technology is now in widespread use. Given the economic and worker dose costs involved in moving used fuel from fuel pools into dry storage, it is in the interest of the utilities and rate payers to be able to continue to store used fuel in the original dry storage systems rather than incurring the additional economic and worker dose related to repackaging the used fuel into a new dry storage system.

Approach

Currently available information on the long-term aging of dry storage systems is enabling some utilities to obtain license extensions for their existing dry storage systems up to approximately 60 years after initial used fuel loading. Given the uncertainty of the availability of options for the ultimate disposition of used fuel, it may be necessary to store used fuel for longer than ~60 years. This project will identify the factors that need to be considered for very long-term storage, such as economics and used fuel and dry storage system aging mechanisms.

Impact

This project will provide the technical bases necessary for continuing to store used fuel in their original dry storage systems for times beyond 60 years.

How to Apply Results

Utilities and dry storage system vendors can use the information with their regulators to obtain license extensions for their dry storage systems beyond 60 years.

2010 Products

Product Title & Description	Planned Completion Date	Product Type
<p>Very Long-term Used Fuel Dry Storage - Aging Management Issues: This report will describe the issues related to the development of a long-term used fuel dry storage system aging management plan and how to deal with those issues (for example, modeling, field and laboratory studies, inspection).</p>	07/30/10	Technical Report

Generic Spent Fuel and High-Level Waste Disposal

Key Research Question

Now that Yucca Mountain has entered the licensing process, Electric Power Research Institute (EPRI) work will focus on disposal issues other than Yucca Mountain. At present, the industry needs for 2010 related to disposal other than Yucca Mountain are not identified pending decisions by the current U.S. administration regarding a new approach to used fuel and high-level radioactive wastes (HLW) management. Furthermore, EPRI's non-U.S. members also may have their own disposal research needs.

Approach

Identify potential generic disposal issues once the new U.S. national policy regarding used fuel and HLW disposition becomes clear. Work with EPRI's international members to identify needs for EPRI-sponsored disposal research and development (R&D).

Impact

- Identification of issues presenting generic challenges to long-term disposal of spent fuel
- Identification of generic research needs related to long-term disposal

How to Apply Results

Research results provide nuclear plant owners and operators with perspective on the viability of long-term disposal options. Such perspective can inform decisions regarding long-term operations and future investments in nuclear power.

Fuel Works/Cask Loader User's Group (052410)

Key Research Question

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 used fuel can be stored outside the reactor building on concrete pads, the data needed to load used 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.

Approach

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 used-fuel assembly for each cask and then prints the utility move sheets and other required forms.

Impact

- Optimize cask loading for cost and schedule
- Maintain data for Department of Energy (DOE) and Nuclear Regulatory Commission (NRC) reporting
- Interact with cask vendor models and technical specifications
- Ease crowding in used 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.