Used Fuel Disposition Campaign

Interim Storage Mock-Up Discussion

David Enos and Charles Bryan
Sandia National Laboratories

UFD Working Group Meeting
June 5th, 2014
SAND2014-15020 PE
Considerable work has been done on 304SS to demonstrate that it is susceptible to chloride induced stress corrosion cracking.

Work of particular relevance to interim storage relies on bend bars to provide the stress state:
- Is this representative?
- What can these tell us and what are their limitations?

Recall – SCC requires three things:
- Environment (EPRI work, etc.)
- Susceptible material – Mockup (sensitization)
- Stress – Mockup (weld residual stress)
Goals for a Mock Container

- Want to replicate fielded structures in order to assess the susceptibility stress corrosion cracking initiation and propagation
- Welding parameters, joint designs, etc. are all held proprietary by the vendors
- NEUP program (R. Ballinger) approached three vendors last year and received quotes from each of them.
- We attempted to do the same with varying degrees of success
  - NAC – still waiting…
  - Holtec – no response.
  - Areva-TN - Ranor
General Info on the Mock-up

- **Wall material:** 304 SS
- **Wall thickness, overall diameter, weld joint geometry:** standard geometry for NUHOMS 24P
- **Welds:**
  - Specific design not specified by manufacturer.
  - Welds to be full penetration and inspected per ASME B&PVC Section III, Division 1, Subsection NB (full radiographic inspection)
  - Double-V joint design
  - Weld procedure: Submerged Arc
Mock-Up Design

Circumferential weld

Two longitudinal welds, 180 degrees apart
Mock-Up Design

Two Circumferential welds

Three longitudinal welds, 180 degrees apart

67.25 in.

48 in.  48 in.  48 in.
What do we want to do with the mockup?

- Comments on the design – anything we should add/remove?
  - Baseplate?
  - Simulated repairs?
  - Stress mitigation?
  - Others?

- What do we want to measure?
  - Weld residual stress state
  - Extent of sensitization

- What samples do we want to make?
  - Subdividing the mock-up will impact the stress state – need to determine how much
  - Sample geometry that we need?
Integrating Management of Spent Nuclear Fuel from Generation to Disposal in the United States

Rob P. Rechard
Laura L. Price
Elena Kalinina
Sandia National Laboratories

Storage and Transportation Workshop between Sandia and BAM
Albuquerque, New Mexico
7-8 October 2014
SAND2014-18539 PE
US History of Commercial Power Reactors

130 Commercial Nuclear Power Plants Built

- 9 Early Prototypes
  - No fuel on site
- 1 Never Operated
- 1 Disabled (Three Mile Island)
  - Fuel moved to DOE
- 1 Demonstration High Temperature Gas Reactor (Fort St. Vrain in Colorado)
- 18 Ceased Operations
  - Fuel on site
  - 3 reactors on sites with ongoing nuclear operations
  - 15 reactors on 12 sites with no other nuclear operations
- 100 Operating Reactors
- 6 New Reactors at Existing Sites Under Construction
Current waste management system uses at-reactor storage

• 100 operating reactor at 62 sites in 2014
  – 65 pressurized water reactors (PWR)
  – 35 boiling water reactors (BWR)

• 71,000 tonnes heavy metal radioactive waste in 2013
  – 49,000 tonnes in wet storage
  – 22,000 tonnes in dry storage
Licensing of storage is deterministic and rule-based in US

- Wet storage licensed as part of reactor operations
  - Reactor license for up to 60 y, with 20 y renewal
  - 10 CFR 50

- Dry storage licensed separately
  - 69 Independent Spent Fuel Storage Installations (ISFSI) in 2013
  - Licensed up to 40 y with up to 40 y extensions
  - 10 CFR 72

- 2 types of ISFSI licenses
  - 54 General licenses
    - Co-located with operating reactor
    - 3.5 y to complete application
  - 15 Site-specific licenses
    - Separate from reactor or reactor is shut down
    - 6 y to complete application
Several types of ISFSI designs in US

- Vertical above ground
- Vertical below ground
- Horizontal bunker
- 1 Vault: DOE site in Colorado for Fort St. Vrain SNF (high temperature gas cooled reactor)
Dry Storage Inventory

- Majority is in Large Welded Canisters
- Current dry storage inventory is diverse
- Trend toward higher capacities

- 1,655 Welded Metal Canisters In Vented Concrete Overpacks
  65,102 Assemblies, 87.5% of Dry
  Transnuclear (34%)
  Holtec (41%)
  NAC (10%)

- 183 Bare Fuel Casks
  8,406 Assemblies, 11.3% of Dry

- 12 Welded Metal Canisters in Transport Overpacks
  866 Assemblies, 1.2% of Dry

- Transnuclear TN-32
- Holtec Hi-Star 100

World Institute for Nuclear Security, June 10-12, 2014
Shutdown Reactor Sites Use Several Different Storage Designs

498 Fuel Casks, ~25 GTCC Casks
5,561 MT, 14,266 Assemblies

Early Shutdown Reactor Fuel Cask
250 Fuel Casks, ~10 GTCC Casks,
2,747 MT, 6,617 Assemblies

Stranded Reactor Fuel Casks
248 Fuel Cask, 15 GTCC Casks,
2,813 MT, 7,649 Assemblies

Humboldt Bay, Holtec below grade
Rancho Seco, TN horizontal
Maine Yankee, NAC vertical
Two categories of casks for dry storage

• Bare fuel (also called direct load)
  – 11% in 2012
  – All metal containers
  – Bolted closed

• Canister, thin-walled inner stainless steel container
  – 89% in 2012
  – Overpack of concrete (or sometimes metal)
  – Welded closed

• Licensed for up to 20 yr with 20 yr renewal increments

• 10 CFR 71

• Current assumption in environmental impact statement (EIS) is that casks will be reloaded after 100 y
NRC has approved 34 designs

- Many more versions because of license revisions and amendments
  - 5 storage only designs (316 total casks)
  - 29 dual-purpose designs (licensed for storage and transportation which started in late 1980s)

- Cask certification mostly based on modeling

- QA program adequate for certification supplemented by observation from an approved aging management program
NRC certifies compliance of transportation casks through 3 tests

Impact
- 9 m drop onto unyielding surface

Puncture
- 1 m drop onto 15 cm steel bar

Fire
- 800 °C fully engulfing fire for 30 minutes
Modeling has progressed such that numerical simulations usually sole basis of certification.
New railcars necessary for transporting massive casks on large scale basis

- Without new railcars, US has no capability to move massive dual-purpose casks
- Association of American Railroads sets the standard for the specialized railcars
- Developing new compliant railcars is long and detailed process of analysis and testing
- DOE currently developing a request for proposals (RFP) to design, test, and certify new railcars
Dedicated train for rail transportation

**Locomotive**
- Two 4000 HP
- Electronically controlled pneumatic brakes

**Cask Car**
- Carry casks and cradle from 25 to 160 ton
- 17 ft long, 12 ft wide, <15 ft tall

**Buffer Car**
- Spread axle loads for bridges
- Provide distance to protect locomotive and escort car
- Carry spare parts

**Escort Car**
- Carry security and technical personnel
- Provide location monitoring, and security/emergency communications
Concern for transportation route as great as concern for siting a consolidated storage facility

If storage / transportation route for SNF was proposed within 50 miles of your residence, how likely is it that you would …

<table>
<thead>
<tr>
<th>Likelihood of Activities</th>
<th>Interim Storage</th>
<th>Transportation Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attend informational meetings held by authorities (E75/T)</td>
<td>4.37</td>
<td>4.22</td>
</tr>
<tr>
<td>Write or phone your elected representatives (E78S/T)</td>
<td>4.20</td>
<td>4.24</td>
</tr>
<tr>
<td>Express your opinion using social media (E77S/T)</td>
<td>3.96</td>
<td>4.02</td>
</tr>
<tr>
<td>Serve on a citizens’ advisory committee (E81S/T)</td>
<td>3.92</td>
<td>3.91</td>
</tr>
<tr>
<td>Help organize public support (E80S/T)</td>
<td>3.07</td>
<td>3.09</td>
</tr>
<tr>
<td>Help organize public opposition (E79S/T)</td>
<td>3.05</td>
<td>3.10</td>
</tr>
<tr>
<td>Speak at a public hearing in your area (E76S/T)</td>
<td>2.97</td>
<td>3.08</td>
</tr>
</tbody>
</table>
Public comments on National Transportation Plan for SNF ask for full-scale testing to address risk concerns

Sandia truck cask test at 130 km/h in 1978

BAM CASTOR side impact test (BAM public website)
Possible full-scale testing

• NRC recommendations
  – Impact test of a rail cask into an unyielding target at 96 to 144 km/h (60 to 90 mph)
  – “Back breaker” impact test of a truck cask onto a rigid semi-cylinder where impact limiters are by-passed and the full impact of the test is on the cask itself
  – Fully engulfing fire tests for a duration beyond the 30 minute limit specified in 10 CFR 71.73

• National Academy of Science recommendations
  – Very long duration fire test with a well-instrumented package to provide validation-quality data
  – Regulatory and credible, extra-regulatory impact testing to support integrated analytical, simulation, and scaled testing efforts
Stranded SNF storage at shutdown nuclear reactors big issue

• Costs of storing SNF at a shutdown reactor are large and provide large impetuous for consolidated interim storage facility

• Prior to 2000, focus of cost comparisons were between
  – (a) at-reactor storage (at operating reactor) then repository disposal and
  – (b) consolidated interim storage then repository disposal

• By 2013, at-reactor storage had been implemented but a repository was far in the future

• By 2013, focus of cost comparisons were between
  – (a) at-reactor storage followed by stranded storage then repository disposal and
  – (b) at-reactor storage followed by storage at consolidated interim storage then repository disposal
Combined cost of storage at reactor followed by stranded storage was ~$35 billion in 2012

- Annual cost for storage is 10 greater at shut down site versus operating site (i.e., ~$6 million/y versus ~$0.6 million/y)
- Costs increase around 2035 when many reactors shut down
- Cost has increased to ~$50 billion based on higher costs for preparing fuel for storage and annual costs for storage at shutdown reactors
Consolidated interim storage is path to integrating US waste management system

Consolidated interim storage facility could

- Facilitate more flexible siting criteria by implementing schemes to lower thermal output by
  - Buffer storage of hot canisters, or
  - Mixing SNF fuel in disposal canister
- Ease burden of aging inspections at shutdown sites and operating sites
- Accommodate shipment of bare fuel in wet storage
- Make same national organization responsible for long-term storage and disposal (versus current scheme of private utilities for storage and federal government for disposal)

Consolidated interim storage facility way for the US waste management system to be more flexible to changing situations (e.g., different repository media, emergency closure of reactor, and temporary closure of repository for upgrades)
Blue Ribbon Commission on America’s Nuclear Future Reviewed the Back End of the Cycle

• Emphasized Interim Storage as Part of an Integrated Waste Management System

• Consolidated Storage would...
  – Allow for the removal of ‘stranded’ spent fuel from shutdown reactor sites
  – Enable the federal government to begin meeting waste acceptance obligations
  – Provide flexibility to respond to lessons learned from Fukushima and other events
  – Support the repository program
  – Provide options for increased flexibility and efficiency in storage and future waste handling functions

• The Administration agrees that interim storage should be included as a critical element in the waste management system

• The Administration supports a pilot interim storage facility initially focused on serving shut-down reactor sites.
Pilot Storage Facility Concept

- 5,000 to 10,000 tonne capacity with a receipt rate of 1,500 tonne/y
  - Accept dry storage containers from stranded sites
  - Transport fuel dual purpose canisters (DPC) in approved transportation overpack casks
  - Transfer the DPC to a new storage overpack cask approved for each DPC
  - 9 stranded sites use 13 canister designs, 8 storage, and 7 transport overpack designs
    - Transition from short-term storage to transportation to long-term storage
    - Aging Management Plans expected

**Facilities will include:**

- Rail yard and associated maintenance equipment
- Cask-handling building for transfer of the DPC from transportation to storage overpacks
- Storage pads with multiple vertical and horizontal storage overpack designs
- Security facilities
- Infrastructure and balance of plant facilities
Pilot Alternative Design
(Flexible, Adaptable, and Expandable)

- **Dry Storage Alternatives**
  - Vented concrete at grade in horizontal and vertical vendor specific systems currently in use
  - Vaults for dry canisters
  - Universal storage overpacks
  - Universal underground systems

- **Required Support Systems/Facilities**
  - Cask-handling facility
    - Large shielded cell vs. transfer cask may offer time in motion and ALARA advantages
  - Storage overpack fabrication
  - Rail and cask maintenance
  - Security systems, infrastructure, and balance of plant

- **Potential Co-located Systems**
  - Laboratory for supporting long-term storage and developing repackaging techniques
  - Fuel remediation capability for damaged or failed fuel
  - Related manufacturing facilities
Larger ISF Concept

- **DOE Strategy document provides guidance**
  - ISF starts operations in 2025
  - 20,000 tonne or greater
  - Receipt rate is greater than the U.S. discharge rate (~2000 tonne/y), working basis is 3,000 tonne/y
  - Repository starts operation in 2048
  - Modular approach for functional capability and capacity increases and provide flexibility

- **Assumed ISF capacity is about 70,000 tonnes**
  - Based on 3,000 tonnes/y receipt rate and schedule in DOE Strategy (2048 repository)

- **Continued DPC storage using the storage method selected for the Pilot**

- **Significant bare fuel receipt and storage capability may be needed for efficient acceptance from reactors**

- **Pilot and ISF licensed as ISFSI (10 CFR 72)**
For Full ISF Design Bare Fuel Storage May be Included

- **Bare fuel receipt and storage systems**
  - Pools – technically mature, but expensive
    - Choice for Central Interim Storage in Sweden (CLAB)
  - Continue to load dry canisters
    - decay heat per package may limit transportation and disposal
    - DPC may become LLW if repackaging for disposal is required
  - Vaults
    - approach used in Spain

- **Dry storage continues using technologies selected for the Pilot**

- **Support facility capacity increases**
  - Examine a range of receipt rates

- **Potential packaging facility to disposal if required**
Why has Germany abandoned Consolidated Interim Storage?

- Transportation risks have been cited, but how extensive was the public discussion?
- Will the prospect of 80 y long term storage cause Germany to re-examine decision?
Knowledge Preservation for Repository Systems

Kevin McMahon
Sandia National Laboratories

Presented to the
SNL-BAM Workshop
October 6-8, 2014
Albuquerque, NM
Outline

- Knowledge Management vs Knowledge Preservation
- Yucca Mountain Project Knowledge Preservation – case study
- Sandia National Laboratories (SNL) Knowledge Preservation for Nuclear Weapons – case study
- NEA-OECD Sponsored Records, Knowledge and Memory (RK&M) Project Overview
- NEA-OECD Sponsored Repository Metadata (RepMet) Project Overview
- Conclusion
Knowledge Management

- Knowledge Management:
  - Encompasses efforts directed at compiling, organizing, and leveraging an organization’s knowledge to support organizational goals, (continuity, profitability, efficiency, etc.)
  - For repository systems, includes the following:
    - Technical, well understood, (certain) physical/chemical characteristics (waste packages materials, waste forms, corrosion, and waste locations);
    - Less well understood (uncertain) characteristics, (natural fluid flow, volcanism, other low probability events);
    - Very poorly definable characteristics, (cultural influences, societal characteristics)
Knowledge Preservation

- For repository systems envelops both classic subdivisions of knowledge; *explicit* knowledge, and *tacit* knowledge
  - *Explicit* knowledge includes information that is readily codified into a tangible form, i.e., documentary material (reports, analyses, memos, videos, email, databases, etc.) that may be retained in a wide variety of media (paper, film, electronic, etc.)
  - *Tacit* knowledge is knowledge that we as individuals possess, but is not readily codified.
    - More difficult to codify, if possible at all
    - Examples include technical, societal, or cultural processes that pertain to substantial organized efforts (large engineering projects)
Media for Knowledge Preservation

- Pervasive problem that overshadows all attempts at knowledge preservation, especially those attempting to preserve knowledge for centuries or even millennia as in the case of repository post-closure information\(^1\)
- Paper objects have traditionally served as the media for important information.
- Technological advances are clearly directing preservation efforts to electronic forms...but these are not immune to obsolescence.
  - While ease of web-based publishing has greatly enhanced the dissemination of information, inevitable changes in the web construct lead to international efforts to secure continued access to scientific and technical literature in the nuclear field\(^2\)

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2. IAEA, 2008, Web Harvesting for Nuclear Knowledge Preservation, IAEA Nuclear Energy Series No. NG-T-6.6, Vienna
Yucca Mountain (YM) Project
Knowledge Preservation Case Study

- June of 2008 the U.S. Department of Energy (DOE) submitted a license application to the U.S. Nuclear Regulatory Commission for a high-level waste repository located at YM
  - > 20 years of scientific investigations into the feasibility and safety of disposal of high-level radioactive waste and commercial spent nuclear fuel at YM
- March of 2010 DOE began to terminate YM activities per the direction of the current Administration
  - July 2010, all YM site-related technical studies were ended
- Because licensing proceeding had not come to a clear cut conclusion, several organizations, including Sandia National Laboratories, moved to preserve the scientific, technical and procedural information from the YM Project
Yucca Mountain (YM) Project
Knowledge Preservation Case Study - Continued

- NRC’s rules required population of a Licensing Support Network (LSN) to facilitate legal discovery for the adjudicatory licensing hearing.
  - LSN is an electronic system, established by the NRC and operated by the NRC's Atomic Safety and Licensing Board (ASLAB) panel.
  - Purpose to provide internet access to documents that may be used as evidence in the NRC's review process and licensing proceedings.
- Information to support licensing was preserved by NRC, in addition to the DOE and support organizations.
- Rigorous records management provisions were imposed by DOE throughout the project.
  - Collection of information maintained by DOE’s Legacy Management office is the most comprehensive YMP collection.
Yucca Mountain (YM) Project
Knowledge Preservation Case Study - Continued

- Knowledge Preservation Systems for the Yucca Mountain Project that preserve *Explicit* knowledge include:
  - NRC ADAMS (Agency Document and Management System) Collection
  - NRC ASLAB LSN (Licensing Support Network) Collection
  - DOE Legacy Management Collection
  - Sandia National Laboratories (Yucca Mountain Project Lead Laboratory)

- Time constraints did not permit collection, codification or preservation of the *Tacit* knowledge of the hundreds of participants in the YM project.
SNL Nuclear Weapons

Knowledge Preservation Case Study

- SNL emerged from World War II’s Manhattan project\(^3\)
- Through the 1940’s, nuclear stockpile was small, consisting of a few hand-crafted devices modeled on the Fat Man design used in World War II.
  - As cold war progressed from the 1950’s through the end of the 20\(^{th}\) century, the US developed a larger stockpile of nuclear weapons of multiple designs
  - SNL primary mission continues to be to provide the science and technology to maintain and certify the nuclear stockpile
- Ability to certify safety, security and operational capabilities of the stockpile are made even more difficult since the banning of nuclear weapon testing in 1996

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1990’s, SNL recognized there were no new weapons designs on the horizon and designers of the weapons over the prior 40+ years were leaving SNL and entering retirement.

- Challenge to maintain expertise to sustain the nuclear stockpile and the capability to respond to changes in the threat environment.
- SNL and DOE require storage and maintenance of all design and test drawings and documents (Explicit knowledge), but SNL had no way of capturing and preserving Tacit knowledge of the weapons designers.
- In the 1990’s and early 2000’s, much of this Tacit knowledge of retiring weaponeers >1,500 hours of video was gathered and placed on the Sandia Classified Network.
- For over a decade, this captured Tacit knowledge resided on servers, available but unused.

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In 2012, retirees reviewed the lengthy tapes, identifying and categorizing short (5-10 minute) synopses (video clips) for inclusion into a web based “YouTube” like application

Sandia Weapons Channel created

SNL Nuclear Weapons
Knowledge Preservation Case Study - Continued
SNL Nuclear Weapons
Knowledge Preservation Case Study - Continued

Sandia Weapons Channel
SNL Nuclear Weapons
Knowledge Preservation Case Study - Continued

- Sandia Weapons Channel, while an important component of the knowledge preservation at SNL, is not the only component of the Knowledge Preservation Project.

- All phases of the Nuclear Weapon Knowledge Cycle are currently being addressed in SNL’s knowledge preservation activities.

- As a weaponeer passes through early, middle and senior stages of their career, the Nuclear Weapon Knowledge Cycle repeats itself.
  - Goal to minimize lost knowledge that would be leaving the organization.
  - Nuclear Weapon Knowledge Cycle shown in next slide.
SNL Nuclear Weapons
Knowledge Preservation Case Study - Continued

Nuclear Weapon Knowledge Cycle

- Culture
  - History
  - Context
  - Values
  - Folklore
  - Process
  - Procedures
  - Programs
- Nuclear Weapons Knowledge Artifacts
- Hardware
  - Tooling
  - Product
  - Prototypes
  - Test Items
  - Sites
- Recorded Information
  - Documents
  - Media
  - SW code
  - Data
- Tacit/Implicit (memories, skills)
  - Staff
  - Retirees
  - Contractors

Tasks
- R&D & E
- Design
- Prototypes
- Testing
- Assessments
- Analysis
- Software
- Manufacturing
- Surveillance
- Programs
- Services
- Management

Knowledge, skills, abilities

New Hire
 Preparation in NW -> Weaponeer Role
 Early       Mid       Senior

Weaponeer/Other Role(s)

Retire

Lost Knowledge
Records, Knowledge & Memories
NEA-OECD RK&M Sponsored Project

- International consensus that geologic repositories represent the best known method for permanently disposing of used nuclear fuel and high-level radioactive waste, without putting a burden of continued care on future generations.\(^5\)

- Repositories are conceived to be intrinsically safe, there should be no intention to forgo, at any time, knowledge and awareness of the repository or waste that it contains.\(^6\)

- The OECD sponsored “*Project on Preservation of RK&M Across Generations,*” initiated in 2010, identified specific products and actions over the years 2010-2014


Preservation of records, knowledge and memory (RK&M) need to be integral parts of the phases of repository development process from pre-siting all the way through site characterization, licensing, operations of waste emplacement and post-closure monitoring and management.

Challenge to knowledge preservation for repository development phases is exacerbated by the time frames from start to finish, which may extend over hundreds of years.
Repository Metadata Project
NEA-OECD Sponsored RepMet Project

- October 2012, Integration Group for the Safety Case of Radioactive Waste (IGSC) 14th Annual Meeting in Paris:
  - Proposal for data management was made.
  - Identified usefulness of a review of the data types and preservation methods that different national programs are currently using.
  - DaMa project initiated.

- September 2013, Data Management (DaMa) project held first meeting:
  - Participation included Belgium, France, Germany, Hungary, Japan, Spain, Sweden, the United Kingdom and the United States
  - “...Aim of this project is to create a metadata registry that can be used by national programmes to manage their repository data and records in a way that is harmonized internationally and is suitable for long-term management...”
January of 2014, the first RepMet meeting was held in Paris

The scope of the RepMet project includes:

- Id of methods and protocols for repository data and metadata
- Justification of sufficiency of metadata
- Relationship to safety assessment models
- The role of metadata in 'handshake' between data providers and data users
- Id of methods, protocols to guarantee persistence of procedures in time
- Guideline for proposed data/metadata management
- Data auditability, verification methods
Conclusion

- Knowledge Preservation related to an eventually successful nuclear repository project will be of inestimable value.
- Projects like this require a historian or knowledge management entity that is explicitly responsible for Knowledge Management and Knowledge Preservation, as well as, a defined process for capturing not only Explicit, but also Tacit knowledge from participants.
- We should not leave future generations wondering: ‘How did they move those enormous stones into place to build the pyramids?’
Public Acceptance and Preferences for Used Nuclear Fuel Management in the U.S.

Hank C. Jenkins-Smith
Kuhika Gupta
Center for Energy, Security & Society
University of Oklahoma
Research Goals and Methods

♦ CES&S: Partnership between University of Oklahoma and Sandia National Labs
♦ Goal: track and analyze the evolution of public perceptions about UNF management in the U.S.
♦ Methods: complementary streams of data, such as:
  • Public opinion surveys
    » Annual surveys since 2006, totaling > 19,000 participants
    » Latest survey fielded on 27-28 June 2014, n=1,610
  • Social media and big data platforms
    » Analyzing the co-evolving public and elite narratives using data collected via Twitter, Google News, and Google Trends
  • Qualitative focus groups
    » Studying group deliberation to assess the kinds of information that stakeholders would like to see when evaluating a prospective UNF management policy
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Preferred Energy Sources

What percent of our energy should come from nuclear energy, which currently provides about 8% of total U.S. energy?

Renewables: 0.0%
Fossil: +27.6%
Nuclear: −31.8%

Fukushima (e18A, 19A, 20A)
As nuclear fuel is used to generate electricity, it becomes contaminated with radioactive byproducts. When it can no longer efficiently produce electricity, it is called “used” or “spent” nuclear fuel. To the best of your knowledge, what currently is being done with most of the used nuclear fuel produced in the U.S.? (response options randomized)
Current On-Site Storage

**Arguments FOR**
- Move radioactive materials only once to permanent repository
- Packing & transporting materials to ISF is risky
- Less expensive in short-term; buys time for permanent solution
- No harm yet; risks of terrorism and flooding can be reduced

**Arguments AGAINST**
- Improving protections from terrorism and flooding expensive
- Near large populations; UNF has leaked into pools
- Quantities of UNF increasing with no permanent solution
- UNF at “stranded” sites expensive to secure and protect

- Visual representation of public opinion with a mean value of 3.57

![Bar chart showing public opinion with mean value of 3.57](chart.png)
Interim Storage

**Arguments FOR**
- Construct sooner than repository; store UNF up to 100 yrs.
- Better protection from terrorists; allows packaging for repository
- Reduce UNF storage near pop. centers; reduce risks of flooding
- Eliminate stranded fuel; savings help offset costs of ISF

**Arguments AGAINST**
- Could delay decision on permanent disposition
- Risks of transportation > risks of on-site storage
- Cheaper & politically more acceptable than new facilities
- No public harm yet; risks of terrorism, flooding can be addressed

![Bar Chart with Mean = 4.04](chart.png)
Now assume that this interim storage facility is to be located [50, 100, 150, 200, 250, or 300] miles from your primary residence. (distances randomized)

**Distance in Miles**

- **Not Stated**: 4.04
- **50 miles**: 3.34 \( (p < .0001) \)
- **100 miles**: 3.64 \( (p = .0006) \)
- **150 miles**: 3.50 \( (p < .0001) \)
- **200 miles**: 3.73 \( (p = .0619) \)
- **250 miles**: 3.98 \( (p = .6118) \)
- **300 miles**: 3.85 \( (p = .1190) \)

**Not Stated**

1. Strongly Oppose
2. Not Stated
3. Not Stated
4. Strongly Support

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Energy 2014: 8
The UNIVERSITY of OKLAHOMA
On the evening of February 14, 2014, trace amounts of airborne radioactive materials were discovered above ground near the facility. It was determined that 21 workers were exposed to trace levels of radiation. No deaths or serious injuries have been reported, and no one is known to have been exposed to harmful levels of radiation. Pictures from the underground facility show the lid of a drum of waste burst open in a room that is partially filled with containers of radioactive waste. An open drum could release radioactive material into the air flowing through the repository. The cause of the burst lid in an unsealed room is under investigation.

**Implications of WIPP Incident for Support of ISF**

<table>
<thead>
<tr>
<th>Effect</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Reduced</td>
<td>31%</td>
</tr>
<tr>
<td>No Effect</td>
<td>50%</td>
</tr>
<tr>
<td>Strongly Increased</td>
<td>19%</td>
</tr>
</tbody>
</table>

Mean = \(-1.87\) (e41)
Valuing UNF Storage Options

Government officials are deciding how to proceed on storing used nuclear fuel in the U.S. Their decision on how these materials should be stored could cost you money. For example:

- Continuing to store used nuclear fuel at nuclear power plants would require heightened security measures and expanding current practices, which is expensive and could mean higher taxes.
- Construction of interim storage facilities and transportation of used nuclear fuel to the facilities is expensive and could mean higher taxes.

(a) Base ISF Track

(b) Enhanced ISF Track
ISF Siting Process: Who Should Have Vito Power?

Select all of the following that you think should be allowed to block or veto construction of a proposed interim storage facility for used nuclear fuel.

<table>
<thead>
<tr>
<th>Option</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>A majority of citizens, including those in Native American communities, residing within 50 miles of the proposed facilities</td>
<td>66</td>
</tr>
<tr>
<td>A majority of voters in the host state, including affected Native American communities</td>
<td>64</td>
</tr>
<tr>
<td>The host state’s environmental protection agency or its equivalent</td>
<td>55</td>
</tr>
<tr>
<td>The Governor of the host state</td>
<td>52</td>
</tr>
<tr>
<td>The US Environmental Protection Agency</td>
<td>50</td>
</tr>
<tr>
<td>The US Department of Energy</td>
<td>44</td>
</tr>
<tr>
<td>The US Nuclear Regulatory Commission</td>
<td>43</td>
</tr>
<tr>
<td>Either of the two US senators representing the host state</td>
<td>39</td>
</tr>
<tr>
<td>The US congressperson representing the host district</td>
<td>39</td>
</tr>
<tr>
<td>The leaders of the host state’s legislature</td>
<td>39</td>
</tr>
<tr>
<td>Tribal authorities of affected Native American communities</td>
<td>38</td>
</tr>
<tr>
<td>Nongovernmental environmental interest groups in the host state</td>
<td>26</td>
</tr>
</tbody>
</table>
**ISF Siting Process: Likely Modes of Participation**

Assuming construction of an ISF is proposed within 50 miles of your residence, how likely is it that you would . . .

(1 = Not At All Likely—7 = Extremely Likely)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Unlikely (1–3)</th>
<th>Unsure (4)</th>
<th>Likely (5–7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attend informational meetings on the proposed ISF held by authorities</td>
<td>33</td>
<td>18</td>
<td>50</td>
</tr>
<tr>
<td>Contact your elected representatives expressing your opinion regarding</td>
<td>38</td>
<td>19</td>
<td>43</td>
</tr>
<tr>
<td>the proposed ISF</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Express your opinion on the proposed ISF using social media</td>
<td>40</td>
<td>16</td>
<td>44</td>
</tr>
<tr>
<td>Speak at a public hearing about the ISF</td>
<td>58</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>Help organize public opposition to the proposed ISF</td>
<td>56</td>
<td>20</td>
<td>24</td>
</tr>
</tbody>
</table>
Willingness to Engage: ISF Citizens’ Advisory Committee

If invited, how likely is it that you would participate as a member of a citizens’ committee asked to provide advice and oversight to authorities developing the proposed ISF if it required about [5, 10, 20] hours of your time monthly for a year? (times randomized)

(1 = Not At All Likely—7 = Extremely Likely)

Means

- 5 Hours: 3.81
- 10 Hours: 3.83
- 20 Hours: 3.70
Conclusions

- Preferences for nuclear in future energy mix have been declining since Fukushima
  - But current percentage (8%) is lower than preferred (15%)
- Mixed understanding of current UNF management policy
- Support for interim storage is higher than support for current on-site storage
  - Support for ISF decreases with proximity
  - WIPP incident has potential to decrease support for ISF
- Non-market value of an ISF is higher than non-market value of continued on-site storage
  - Inclusion of a research lab and repackaging facility increases non-market value of an ISF
- Local residents most likely to have initial NIMBY response
  - Substantial fractions of population willing to engage
  - Absent state level opposition, engagement can reverse NIMBY