INTEGRATING MANAGEMENT OF SPENT NUCLEAR FUEL IN THE UNITED STATES BY CONSOLIDATING STORAGE

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The theme of the paper is that consolidated interim storage can provide an important integrating function between storage and disposal in the United States. Given the historical tension between consolidated interim storage and disposal in the United States, this paper articulates a rationale for consolidated interim storage. However, the paper concludes more effort could be expended on developing the societal aspects of the rationale, in addition to the technical and operational aspects of using consolidated interim storage.

I. INTRODUCTION

The Nuclear Waste Policy Act of 1982 (NWPA) generally provides that utility owners are responsible for storage of their commercial spent nuclear fuel (CSNF) until it is accepted by the United States federal government, which is responsible for disposal. This separation of responsibilities makes integration of storage and disposal inherently difficult. The introduction of consolidated interim storage within the US waste management system can mitigate difficulties caused by a lack of integration between storage and disposal of CSNF.

This theme has been expressed before by several commissions and oversight boards such as the Monitored Retrieval Storage (MRS) Review Commission and Nuclear Waste Technical Review board.[1; 2] More recently, the theme was endorsed by the Blue Ribbon Commission on America's Nuclear Future (BRC), formed by Presidential direction to review the current waste management policy.[3] Specifically, the BRC noted in 2012 the need "for improving the overall integration of storage as a planned part of the waste management system without further delay."

Although the theme is not new, there is the periodic need to evaluate past conclusions relative to new information and analysis. This periodic assessment is important especially because changes to the current scheme involve significant challenges because of the large scale of operations required to manage CSNF and high level radioactive waste (HLW) in the US.

II. STORAGE OF RADIOACTIVE WASTE

II.A Current CSNF Storage in the US

Currently, 99 commercial nuclear reactors operate in the US at 61 sites; 65 of the 99 reactors are pressurized water reactors (PWR) and 34 are boiling water reactors (BWR). At the end of 2013 (the period usually discussed in this paper), these operating and previously shutdown reactors had generated ~71,000 metric tons of heavy metal (MTHM) of CSNF, with 49,000 MTHM in wet storage (cooling pools). Most of this wet storage currently resides at operating reactors and, thus, is licensed by the US Nuclear Regulatory Commission (NRC) under 10 CFR 50 as part of the reactor license.

At the end of 2013, the remaining 22,000 MTHM of CSNF was in dry storage. Until recently, 5 years of wet-storage cooling was typically necessary before CSNF could be placed economically in dry storage.[4] High burn-up CSNF (>45 GWd/MTHM) currently being discharged would typically require 7 years of cooling.[5, p. 13]

NRC general requirements for storage of CSNF are in 10 CFR Part 72. The storage methods are usually dry cask storage but can include dry vaults and wet storage. An away-from-reactor wet-storage facility is operated in Morris, IL at the site of an abandoned reprocessing plant.

The storage facility, known as an Independent Spent Fuel Storage Installation (ISFSI), is licensed independently from the nuclear reactor via either a site-specific or general license. If the ISFSI is co-located within the boundaries of a facility already licensed to handle CSNF, then the ISFSI can be authorized by a general license, as found in 10 CFR Part 72 subpart K.[6] Otherwise, it must apply for a site specific license. An ISFSI may be licensed for up to 40 years with options to renew in up to 40-yr increments (10 CFR §72.42).

Although for 20-yr increments prior to 2011, NRC now grants certificates of compliance for the storage casks at an ISFSI in up to 40-yr increments, as well. Dry cask storage systems fall into two categories. The first category is a bare fuel, or direct load, cask in which CSNF is loaded directly into a basket that is an integral part of the cask. These casks are all metal and bolted closed. More common are massive casks or enclosures of concrete that use a thin-walled, internal canister, which is usually welded shut (89% as of 2012).

Most inner canisters in use are dual-purpose, designed for storage and subsequent transportation, but some early designs are single-purpose storage canisters. NRC has approved 34 dry-storage designs, including 5 storage-only casks and 29 dual-purpose canisters (DPCs). Canister capacities currently range from 7 to 37 PWR assemblies and from 52 to 89 BWR assemblies (10 CFR Part 72.214).[6, p. 56794]

CSNF storage is stranded when the site no longer has an operating reactor and other facilities. The current stranded sites include 15 MTHM in dry vault storage at DOE Fort St. Vrain reactor and 2813 MTHM in 383 dry storage casks at 9 shutdown commercial reactor sites.[3]

In the past few years, additional CSNF has been stranded at 4 reactors at 3 sites (Crystal River in 2009, San Onofre (Units 2 and 3) in 2011 and 2012, Kewaunee in 2013). This stranded 3138 MTHM will eventually require ~226 dry storage casks once the CSNF cools. The 12 CSNF stranded sites use 16 different canister designs, 8 different overpack storage cask designs, and would require 7 different overpack transport cask designs. With Vermont Yankee shutting down in December 2014 and Oyster Creek announcing closure, more CSNF will become stranded in the future.

II.B Future CSNF Production in the US

Based on projections of energy demands through 2035 (www.eia.gov), two scenarios are used to assess future CSNF:[3] (1) no new nuclear plants with 60-year plant lifetime; and (2) limited nuclear expansion to add 1000 MW/yr starting in 2015: The projected inventory and number of canisters in dry storage were calculated using the Transportation Storage Logistics (TSL) model.[7]

For no nuclear expansion, there will be ~140,000 MTHM of CSNF, which would require 2 repositories of the size authorized by NWPA. If one assumes no changes in storage practices and disposal has not commenced, the CSNF will be stranded at ~70 decommissioned sites in over 11,000 dry storage casks by 2060, values that are similar to those used several years earlier by the BRC. [3, Fig. 15] With limited nuclear expansion, there will be ~180,000 in ~12,000 casks.

II.C Costs of Storage at Reactors

For this paper, cumulative costs associated with at-reactor dry storage until a repository is available in 2048 were also projected in a TSL analysis (Fig. 1). The costs include dry storage facility construction ($25 million) at each ISFSI, dry storage canister procurement, dry canister loading for storage (~$0.3 million/cask), cask loading for transportation (0.15 million/cask), wet pool operation/ maintenance, and dry storage operation/maintenance. The dry canister procurement and loading costs are based on the number and types of canisters loaded at each site.

The operation/maintenance costs of storing CSNF at an operating site is much lower than the cost of storing CSNF at an shutdown site, because the incremental cost of monitoring dry storage at an operating reactor is minor. Specifically, the annual operating cost for an at-reactor storage facility ranges from $0.2 million/yr to $1 million/yr when the reactor is operating,[8] (analysis used $1 million/yr). The annual costs of dry-storage increases to between $4.5 million/yr and $10 million/yr when the reactor is decommissioned and storage costs can no longer be shared (analysis used $10 million/yr for wet and dry storage or 10 times cost at operating site).[3, p. 35; 4]

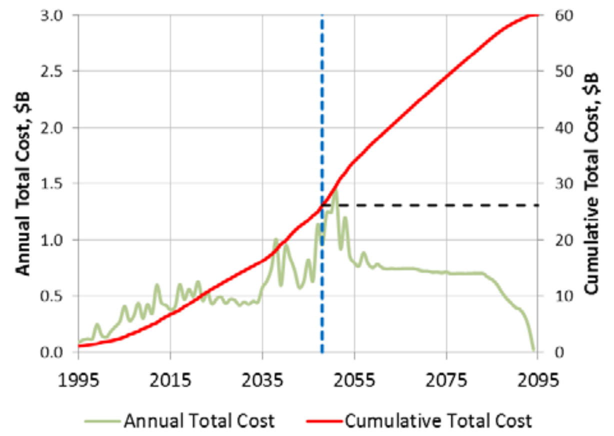

Fig. 1. Annual and Cumulative Costs for At-Reactor Wet and Dry Storage when Repository Available in 2048.

Total annual costs of at-reactor storage begin to accelerate around 2035 when many existing nuclear reactors begin shutting down. In 2048, the cumulative storage costs at reactors are projected to be $26 billion (Fig. 1). The costs continue to grow even after 2048 because it takes time to unload the sites. The analysis used an unloading rate of 3000 MTHM/yr. The final cost is $60 billion in 2095, more than 100 years after storage began at most reactors.

Initially, the pool maintenance and dry-storage construction costs are the major component of the total cost at the reactor. However, the dry-storage maintenance costs are 55% by 2015 and are eventually 84% of the total cost by 2060 (Fig. 2). It is these long-term, dry-storage maintenance costs that are reduced by the ~$1 billion (excluding costs of casks and operation/maintenance) to build the consolidated ISF.

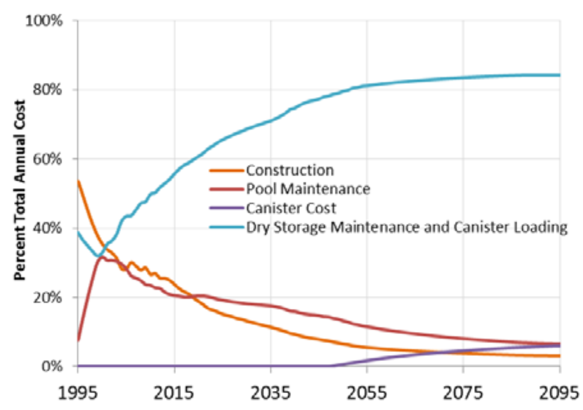

Fig. 2. Contribution of costs from pool maintenance, dry-storage construction, canister/cask procurement, and dry-storage maintenance to total storage costs at reactor sites.

III. BENEFITS OF CONSOLIDATED STORAGE

The long history of resistance to efforts to site consolidated ISFs include the unsuccessful Atomic Energy Commission (AEC) proposal for a 100-yr Retrievable Surface Storage Facility (RSSF) in 1972, the unsuccessful Away-from-Reactor (AFR) Facility proposal by President Carter in 1977, the unsuccessful siting of the Monitored Retrieval Storage (MRS) facility in 1987 in Tennessee, the unsuccessful volunteer siting process for an MRS between 1988 and 1995, and the unsuccessful startup of Private Fuel Storage (PFS) site because of strong opposition in Utah, even though a NRS license was obtained. This historical situation suggests that gaining acceptance of a storage facility will be difficult in the US. Countering this traditional resistance requires articulation of a clear rationale for the movement of CSNF from existing sites to a consolidated ISF, as discussed in subsequent sections.

III.A. Lower Long-Term Costs of Managing CSNF

Protection of public health and safety during storage, transportation, and eventually disposal will always be the primary goal of the waste management system whatever the configuration. Although there is no compelling immediate reason for moving CSNF from existing sites, in view of the *safety* of at-reactor storage, an important question is the cost to provide the required level of safety. As of 2013, CSNF was stranded at 15 reactors at 12 sites. *Constructing and operating consolidated ISFs would cost less than continuing to store at shutdown sites where operations must continue to monitor the CSNF and related nuclear material such as Greater-Than-Class-C low-level waste.* The large, long-term costs as more reactors shutdown will burden future generations.

In early studies comparing consolidated storage to at-reactor storage, the cost comparison was between the money that could be saved by building consolidated storage coupled with disposal at a repository versus using at-reactor storage coupled with repository disposal. As was pointed out in the review for the BRC,[8] however, the situation has dramatically changed because most nuclear power plants have already built at-reactor dry storage and the availability of a repository is still far in the future. Now the most pertinent cost comparison is between at-reactor storage *and eventually stranded storage when reactors are decommissioned* coupled with repository disposal versus consolidated interim storage coupled with repository disposal. The costs of stranded storage are large and become substantial when the availability of a repository is delayed (cumulative cost is $60 billion by 2095 for a repository that opens in 2048—Fig. 1), which makes constructing a consolidated ISF very compelling.

III.B. Security

Consolidated ISF could provide protection from terrorists easier at one site than at 70 stranded sites scattered around the country. Many of the benefits of consolidated storage can be measured in terms of reduced long-term costs. Specifically, security is a major component of at-reactor dry-storage maintenance costs (Fig. 2), even though CSNF in a massive cask would not be considered an attractive theft or terrorist target. None the less, intrinsic benefits also occur and so security is listed separately. For example, radiation from CSNF falls below that which will rapidly disable a potential thief or saboteur after ~100 years of storage, and this period is only slightly longer (120 yr) for high-burnup fuel. A consolidated ISF could more easily combine fuel ages to maintain high radiation during storage and transportation.

III.C. Federal Ownership to Integrate Storage and Disposal Costs

Initially, all costs of storage, transportation, and disposal were paid for by the utility rate payers, but the manner differed. Between 1983 and 2014, most costs to develop a disposal repository were paid by a fee of $1 per MW-hr of energy sold by nuclear utilities, as mandated by NWPA. A portion of the fees were then appropriated by Congress. In contrast, storage costs were subject to utility rate adjustments overseen by the states.

In 1998, utilities began suing the federal government for damages for partial default on the contract for accepting CSNF. Although some suits are still pending, most storage costs are now paid by the Federal government Judgment Fund, funded by all taxpayers as part of the national debt. Also as of 2014, collection of the disposal fee has been suspended by order of the courts.

Consolidated ISF can be constructed sooner (within 10-15 years) to allow federal ownership of CSNF. Federal ownership of CSNF would possibly allow the previously collected fees, paid by utility rate payers, to be used for the costs of storage, rather than use the Judgment Fund, and possibly allow the federal government to resume collecting the disposal fee.

III.D. Integration between Storage and Disposal Agreements and Operations

The standard contract between DOE and nuclear utilities envisions acceptance of bare, uncanisterized CSNF. DOE does not consider CSNF in DPCs to be an acceptable waste form for disposal, absent a mutually agreed contract modification. However, the consolidated ISF could easily accommodate acceptance of both DPCs and uncanisterized CSNF and thereby ease negotiations as to the acceptable waste form.

Furthermore, in the current contractual arrangement between nuclear utilities and the operator of a future repository (currently DOE), the right to ship CSNF is set by the age of fuel residing at the reactor (i.e., oldest fuel first—OFF); however, the utilities may actually ship CSNF of their choice (e.g., youngest fuel first—YFF). Thus, the repository operator has little control over the type and age of CSNF sent to the repository. Instead, repository operations must plan for a variety of receipt scenarios. The inability to plan a receipt schedule is challenging. A consolidated ISF would provide buffer capacity to accommodate the desire of reactor sites to ship thermally hot CSNF directly from the wet storage pool and the need for a repository to dispose of cooled CSNF without renegotiating the existing contract. Hence, a *consolidated ISF would facilitate integration between existing storage and disposal agreements*.

III.E. Put Land to Other Uses

Usually, the only impediment to allowing other uses for the land previously used for a commissioned nuclear power plant is the presence of stranded CSNF in dry storage. *Constructing a consolidated ISF and removing the stranded CSNF would make the property around dismantled reactors, often valuable commercial real estate, available for other uses.*

III.F. Aging Management during Storage

Uncertainties about the state of casks and CSNF after an extended period of storage at reactor sites raise questions about whether the waste management system will be able to transport CSNF far in the future. In addition, there are uncertainties as to whether CSNF that had been stored for an extended period of time and then subjected to transportation loads could then be re-certified for storage.

In 2011, NRC studied aging issues related to extended storage of CSNF.[9] The study identified several material degradation processes that could cause failure of fuel and systems, structures, and components during the extended storage, such as chloride induced stress corrosion cracking (SCC) of canister welds at sites near the ocean or SCC at sites near industrial areas that release corrosive chemicals.

Until research dismisses these degradation processes, one likely approach for aging management of casks would be for every storage site to conduct inspections of a portion of the storage canisters to look for degradation. A consolidated ISF would avoid the added burden of inspecting canisters and casks at shutdown sites.

As with general operational costs and security mentioned earlier, consolidation of CSNF makes inspections conceptually easier. In addition, some economy of scale for inspecting canisters and casks could be realized at a consolidated ISF. More importantly, a consolidated ISF could more easily accommodate any future institutional or technical requirements associated with the long-term storage of spent fuel. For example, consolidating the CSNF at an ISF could facilitate the development of storage systems with features that eased aging monitoring. Storage systems could also be developed that made retrieval easier and more economical.

A research facility co-located with a consolidated ISF would help to rapidly advance the science of aging management since canisters and casks would be readily available to researchers. The laboratory could also develop inspection methods, protocols, and training. Furthermore, the laboratory could participate in the development of a consensus-based standard through American Society of Testing Materials or American Society of Mechanical Engineers with NRC participation. Finally, the research laboratory could evaluate broader issues such as various options for storage and disposal, and alternative methods for managing CSNF and related radioactive materials.

Hence, *a consolidated ISF could more easily monitor the aging of casks and include a research laboratory to study aging of casks and CSNF*. In US national public surveys, the level of support for siting an ISF increased significantly when a research function for the ISF was added (Fig. 3).[10]

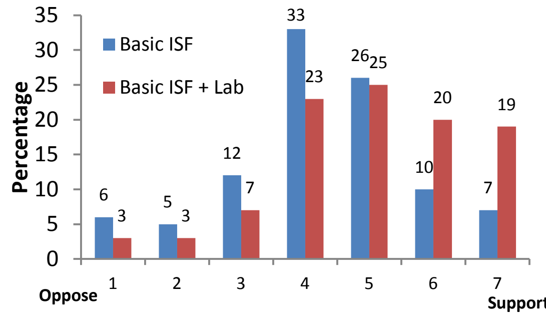

Fig. 3. Increased Public Support for Hosting a Consolidated ISF by Adding Research Laboratory.[10, Fig. 4.3]

III.G. Facilitate Repackaging Should Problems Develop During Storage.

The goal of aging management discussed in the previous section would be to prevent problems during storage. Nonetheless, retrieval of CSNF from long-term storage after 100 years or more could encounter unforeseen problems and require repackaging some CSNF to ensure that it was safe to transport to the disposal repository. In fact, the EIS supporting the NRC waste confidence decision made the assumption that complete repackaging would occur every 100 years.[6] *A consolidated ISF could more easily repackage CSNF should problems develop during storage than at each individual stranded reactor site.*

III.H. Inclusion of Transportation Maintenance and Operation Facilities

Alone with a research laboratory, *a consolidated ISF could include infrastructure to maintain CSNF transportation system*. Specifically, the consolidated ISF could include facilities (1) to maintain the fleet of transportation rail cars and transportation casks, (2) to house personnel and security guards necessary to accompany shipments, (3) for an operations center to coordinate and track CSNF shipments, and (4) to train emergency responders along transportation corridors.

In general, transporting CSNF through communities causes as great a public interest as does the siting of a consolidated ISF (Table I). Hence, identifying the location and facilities for this function may address some of this interest and provide an opportunity to bring the interested public to the consolidated ISF to hear the story of transportation and storage of CSNF in the US.

Table I. Concern for Transportation Similar to Concern for Siting Consolidated ISF in 2013 Survey.[10, Table 8.1]

If a storage site/transportation route for CSNF was proposed within 50 miles of your residence, how likely is it that you would…	**Mean Response** 1~not at all likely 7~extremely likely	
Activity	**Interim Storage**	**Transport Route**
Attend informational meetings	4.37	4.22
Contact your elected representatives	4.20	4.24
Express your opinion on social media	3.96	4.02
Serve on citizen advisory committee	3.92	3.91
Help organize public *support*	3.07	3.09
Help organize public *opposition*	3.05	3.10
Speak at a public hearing in your area	2.97	3.08

III.I. Time for CSNF to Cool

Current DPCs are designed to hold a large number of spent fuel assemblies to minimize the time for loading the canister at the reactor. However, placing a large number of spent fuel assemblies in a single canister increases the temperature and thermal output of the canister. As a result, some stored waste can be too thermally hot to transport because the thermal output of the waste exceeds the NRC Certification of Compliance for the particular transportation cask. Thus, the waste must be stored until it is cool enough to be transported. (Hence, using a rate >3000 MTHM/yr for transporting CSNF from the reactor sometime in the future to compensate for not building a consolidated ISF now cannot substantially reduce the total time to remove CSNF from at-reactor storage).

Even after transport is possible, the thermal output of the large canisters severely limits disposal options and could become a *de facto* siting criterion for a repository and exclude some communities that volunteer to host a disposal facility as a part of a consent-based siting process. To elaborate, even if the standard contract was renegotiated to accept DPCs as a waste form, disposal options for large canisters may be limited to a repository in salt or to repositories that can support extended ventilation (easiest in crystalline rock). For geologic media that do not support extended ventilation, either the large DPCs must be stored for over 100 years to meet disposal thermal limits or the DPCs must be reopened so that thermally hot CSNF can be redistributed to smaller canisters or mixed with cooler CSNF.

Specifically, the thermal power limit per package of the geologic media is an important parameter affecting the amount of CSNF that be emplaced in a given year. The year in which 98% of the total inventory can be emplaced is 2162 for a 6 kW/pkg thermal limit on the geologic media; 2112 for a 10 kW/pkg thermal limit, and 2074 for a 18 kW/pkg thermal limit (Fig. 4). The 6 kW/pkg limit is for sedimentary media, which requires long ventilation-cooling time. The 10 kW/pkg limit is the limit for packages emplaced in salt, based on a 200°C peak salt temperature limit. The 18 kW/pkg limit was used for disposal in a repository in unsaturated, volcanic tuff that could be ventilated.

The long times before emplacement could require excessively long times for storage at stranded sites. *A consolidated ISF would allow the CSNF to cool, without stranding the CSNF at shutdown reactors for over 100 yr.*

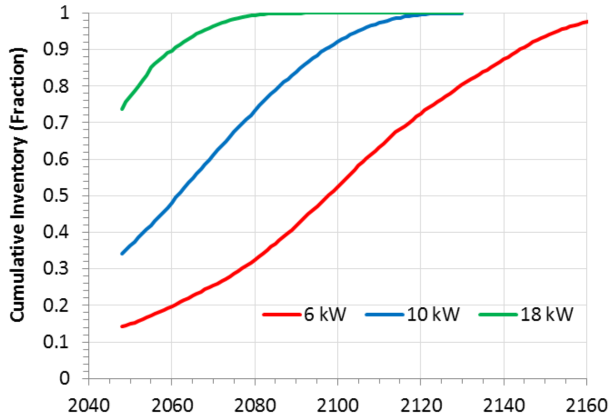

Fig. 4. Cumulative fraction of CSNF inventory available for disposal as a function of the allowable thermal power per package for the geologic media.[11]

III.J. Prepare CSNF for Disposal

The current designs of DPCs limit options for disposal media or complicate the required post-closure performance assessment. *Consolidated ISF could eventually prepare CSNF for shipment and disposal in a repository* to (a) optimize the thermal loading, (b) add neutron-absorbing filler material into canisters to reduce the probability of criticality after disposal, or (c) facilitate disposal handling by using standardized containers.

With respect to size and thermal issues for large DPCs, a consolidated ISF would facilitate the implementation of various solutions necessary to lower the thermal output of DPCs, such as reopening the canisters and redistributing CSNF or placing the CSNF into smaller canisters.

With respect to criticality controls, a consolidated ISF would facilitate the implementation of solutions necessary to lower the probability of criticality during disposal in saturated geologic media. While unnecessary in salt media with its neutron-absorbing chloride, the possible solutions include adding robust criticality controls, repackaging CSNF into smaller canisters, or repackaging into new canisters built with robust, long-lived criticality controls. Also, a research facility co-located with a consolidated interim storage facility could advance the science in designing corrosion-resistant criticality controls in various geologic media.

III.K. Reduced Risk from Flooding

A consolidated ISF would reduce the number of at-reactor ISFSIs, many of which are near rivers and oceans where some risk of flooding, though small, is possible.

Because of the need for cooling water, nuclear reactors are usually near rivers or the ocean where flooding is possible. As demonstrated by continued safe dry storage of CSNF at the Fukushima Dalichi reactor site after the tsunami, flooding cannot damage the massive units used for dry cask storage and thereby, cause health risks. Furthermore, dry storage is designed to provide passive cooling for the CSNF, without supplemental power. However, restoration of essential power for security, restoration of guard facilities, and cleanup of the stranded site would require expenditures that could be avoided by consolidating the CSNF at an ISF far from rivers and oceans.

III.L. Early Implementation of Consent-Based Siting and Licensing

Licensing a first of a kind facility for nuclear waste can involve uncertainty. The uncertainty in licensing a consolidated ISF has been reduced somewhat because of the successful effort expended by PFS to license the away-from-reactor ISFSI for 40,000 MTHM of CSNF under 10 CFR 72 in 2005. However, the PFS ultimately failed in 2006 through strong opposition by the State of Utah and its Congressmen, accompanied by the refusal of the Department of Interior to authorize the lease between the Goshute Indian Tribe and PFS. The lack of an inclusive consent-based siting approach contributed to this failure.

Although inclusive consent-based approach will be needed for siting either a consolidated ISF or repository, the consolidated ISF could be sited and built years before a future repository. Because the consolidated ISF would involve limited characterization, the steps in the consent-based process will require only years rather than decades to implement. *The consolidated ISF offers the opportunity to learn early from the implementation of a consent-based siting process and licensing proceedings in a US setting.*

III.M. Integration of Deterministic and Probabilistic Container Requirements

Because of the separation of legislation in the US, there are separate regulatory frameworks for reactor operations (10 CFR Part 50), storage (10 CFR Part 72), transportation (10 CFR Part 71), and disposal (10 CFR Part 60 and 10 CFR Part 63) that were developed over time with a different philosophy of regulation.[12]

For the previously proposed US repository in volcanic tuff, for example, the probabilistic approach in 10 CFR Part 63 in conjunction with NRC staff guidance placed a high regulatory burden on the surface operations at the repository in comparison with the deterministic approach for storage (10 CFR Parts 50 and 72), and transportation (10 CFR Part 71). The ease of the deterministic approach strongly favored conducting as many operations away from the repository as possible under Parts 50, 71, and 72. Specifically, the manufacture's QA program, the nuclear power plant QA program in loading the casks, and NRC audits could be used to demonstrate compliance with storage regulations; however, the probability of errors had to be propagated for showing compliance with disposal regulations.

Yet, not all repository issues could be resolved by moving operations to the reactor sites. For example,

1. QA controls on (a) fabrication of DPCs, or (b) possible damage in transit from the manufacturer are sufficient for NRC to find reasonable assurance that DPCs are acceptable for use in the reactor fuel pool, at-reactor storage, and for transportation. However, NRC was unreceptive to accepting the manufacturing QA controls for repository operations without further estimates of the reliability.
2. Using the drying procedure specified by NRC for existing DPCs at the reactor site were sufficient to satisfy NRC that DPCs could be certified with no concern for hydrogen generation via radiolysis. However, the NRC drying process could not be shown to have a probability less than 1 in 10^4 (beyond a Category 2 event specified in 10 CFR 63 disposal regulations) using a fault tree analysis; hence, the repository was expected to include the possibility of water in canisters when evaluating hazards during operations at the repository (i.e., canister drops, internal radiolysis, steam buildup).

Granted, developing uniform regulatory requirements for CSNF canisters for storage, transportation, and repository would eliminate these issues. Yet, *a consolidated ISF that conducted packaging functions for the repository would diminish the influence of deterministic approaches for cask storage and probabilistic approaches for waste package disposal*. For example, the agency jointly responsible for consolidated ISF and disposal should be able to work through integration issues related to canister requirements for storage and disposal by developing a topical report for the NRC. In other words, a subtle benefit of a consolidated ISF is that the same organization would be responsible for storage and disposal such that resolving integration issues would be both more feasible and have a higher priority.

III.N. Consolidation to Facilitate Flexible Decisions

A consolidated ISF would decouple long-term storage and disposal operations from nuclear reactor operations such that a more flexible integrated waste management system could develop. Contingencies that require flexible planning and decision-making include the ability to accommodate

1. Uncertainty in the availability and timing of new repositories and any operational constraints (e.g. capacity limits) that may be imposed in a consent-based siting process
2. Necessary maintenance, desirable upgrades, and operatational changes to a licensed repository.
3. Uncertainties about future nuclear fuel cycles and the associated amounts, types, and timing of waste forms requiring storage and disposal.

4. Constrained and/or uncertain funding.

An attempt to develop a waste management system that is optimized for a particular postulated reference operating scenario that aims for just-in-time delivery of waste would likely produce a design that does not perform as well as expected if actual conditions deviate from the reference operating scenario. To reduce this risk, flexibility is an important criterion for the waste management system.

One prominent issue is scheduling receipt of different waste types at a repository. A consolidated ISF within the waste management system would provide the necessary flexibility to accommodate the desire of reactor sites to ship certain types of waste (such as thermally hot CSNF directly from the wet storage pool as mentioned in §III.D) and the desire for a repository to receive certain types of waste for disposal (such as cooled CSNF).

Similarly, maintenance and/or desirable upgrades to surface and underground facilities over the course of a repository's 50 year operating life might stop CSNF shipments from reactors for a period unless a consolidated ISF is available. This possibility emphasizes the need for flexibility in the waste management system even after a repository is available.

In the late 1980s, DOE issued a formal position supporting development of an MRS facility "as an integral part of the waste-management system because an MRS facility would allow DOE to better meet its strategic objectives of timely disposal, timely and adequate waste acceptance, schedule confidence, and system flexibility."[13] In 1996, the Nuclear Waste Technical Review Board supported storage capacity to provide flexibility.[2] In 2003, the National Academy of Sciences (NAS) noted that storage "…provides a flexible mechanism to separate waste acceptance from waste disposal…"[14] Finally, the BRC recommended consolidated storage for the flexibility it provides to the waste management system.[3, p. 32]

III.O. Consolidated ISF Can be Located Separate from Repository

Some arguments for consolidated storage do not depend upon separating the ISF functions from the operation of the repository. However, lower costs (argument in III.A), early federal ownership of CSNF (argument in III.C), early implementation of consent-based siting (argument in III.L), and resolution of deterministic and probabilistic regulatory requirements (argument in III.M), and to some extent flexibility (argument in III.N) suggest that benefits accrue for an ISF if easier to build sooner than a future repository.

Another policy question is how many waste management facilities should be built. Though far from settled, the public generally favors more storage/ repository facilities,[15] which favors separating the ISF from the repository, even though cost considerations might favor one centralized waste management facility if both elements could be rapidly deployed.[4]

Public Perceptions of Consolidated ISF

As discussed elsewhere in the literature and panel sessions of this conference, the arguments in the previous sections cause a general uneasiness with surface storage at current and former reactor sites and modest support for consolidated storage among the US public (Fig. 5).

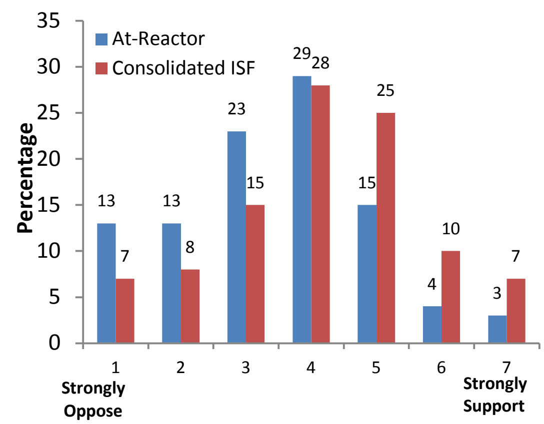

Fig. 5. Uneasiness with At-Reactor Storage and Modest Support for Consolidated Storage in 2013 US National Public Survey.[10, Fig. 4.2; 15, Table 1]

In a 2012 US National Public Survey, the efficacy of three arguments was evaluated for a consolidated ISF built solely to receive stranded CSNF.[10] The three supplemental arguments evaluated, beyond the intrinsic argument for building an ISF for stranded CSNF, were (1) allow valuable properties to be used for other purposes (argument of §III.E); (2) readily allow inspection and repackaging of CSNF, when necessary, for shipment to a repository for disposal (succinct combination of arguments of §III.G and §III.H); or (3) reduce costs of storing stranded CSNF (argument of §III.A). Of the three supplemental arguments, only reducing the costs of storing stranded CSNF made a statistical difference in the level of support (Table II). This finding does not imply that the public only values lower costs, for as discussed earlier, the public also values distributing waste management facilities, which increases costs.

Table II. Support for Consolidated ISF for Stranded CSNF with Supplemental Arguments.[10, Table 5.1]

	Response				
Rationale (4 groups)	**Oppose (1-3)**	**Unsure (4)**	**Support (5-7)**	**Mean**	**%Δ**
Base case ISF	22	29	49	4.45	—
+Release Property, or	20	28	52	4.45	0.0
+Repack CSNF, or	21	33	46	4.48	+0.6
+Reduce costs	19	24	57	4.68	+5.2

IV. INSIGHTS

The tension between the desire to include substantial storage capacity as a way to provide flexibility in the waste management system and the concern that such capacity would reduce the national urgency for a repository and, thereby, delay availability of disposal capability has been a constant theme in the US. Furthermore, no immediate *safety* reason exists for moving CSNF from existing sites. However, unless the federal government implements a solution to the current situation, US nuclear utilities will be forced to make decisions based on their current needs which will result in substantial quantities of stranded CSNF stored at former reactor sites with potentially no easy path to disposal.

Assuming a consolidated ISF is constructed separate from and can be constructed sooner than a repository, the rationale for the moving CSNF from existing sites to a consolidated ISF include reduced costs of long-term storage, integration of existing storage and disposal costs through sooner federal ownership of CSNF, learning from early implementation of a consent-based siting process, and mitigating differences in deterministic and probabilistic regulatory approaches for storage and disposal. Other points include adding buffer capacity to the system, freeing up property at former reactor sites, ease of aging management inspections coupled with laboratory research, co-location of transportation infrastructure, ease in repackaging CSNF should problems occur during long-term storage, reduce risks of cleanup costs from flooding at-reactor sites, and preparing CSNF for disposal. Many of these benefits greatly enhance flexibility of the waste management system.

Most of the arguments for integrating the waste management system through consolidated storage have been discussed before with technical audiences. What has not been done extensively is describing the value of consolidated storage to wider audiences, as recently recommended by the Government Accountability Office.[16] Hence, more effort should be expended on developing the societal aspects of the rationale of why the US should move CSNF into consolidated interim storage.

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