Regulatory Analysis for NUREG-2224, "Dry Storage and Transportation of High Burnup Spent Nuclear Fuel Report"

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ABBREVIATIONS AND ACRONYMS

ADAMS	Agencywide Documents Access and Management System
AMP	aging management program
CFR	*Code of Federal Regulations*
CoC	certificate of compliance
CPI-U	consumer price index for all urban consumers
DSS	dry storage system
EPRI	Electric Power Research Institute
HBU	high burnup
ISFSI	independent spent fuel storage installation
ISG	interim staff guidance
NPV	net present value
NRC	U.S. Nuclear Regulatory Commission
OMB	Office of Management and Budget
PERT	program evaluation and review technique
RAI	request for additional information
SFST	Spent Fuel Storage and Transportation
SNF	spent nuclear fuel
SSA	supplemental safety analysis

1 INTRODUCTION

This document presents the regulatory analysis for NUREG-2224, "Dry Storage and Transportation of High Burnup Spent Nuclear Fuel Report." NUREG-2224 is a new NUREG that provides an engineering assessment of the results of research on the mechanical performance of high burnup (HBU) spent nuclear fuel (SNF) following hydride reorientation. Based on the conclusions of that assessment, NUREG-2224 presents acceptable approaches for licensing and certification of HBU SNF for dry storage (under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 72, "Licensing requirements for the independent storage of spent nuclear fuel, high-level radioactive waste, and reactor-related Greater than Class C waste") and transportation (under 10 CFR Part 71, "Packaging and transportation of radioactive material").

1.1 Background

As required by 10 CFR 72.44(c), a specific license for dry storage of SNF is to include technical specifications that, among other things, define limits on the fuel and allowable geometric arrangements. Further, as required by 10 CFR 72.236(a), a certificate of compliance (CoC) for a dry storage system (DSS) design must include specifications for the type of spent fuel (i.e., boiling-water reactor, pressurized-water reactor, or both), maximum allowable enrichment of the fuel before any irradiation, burnup (i.e., megawatt-days per metric ton uranium), minimum acceptable cooling time of the spent fuel before storage in the spent fuel storage cask, maximum heat designed to be dissipated, maximum spent fuel loading limit, condition of the spent fuel (i.e., intact assembly or consolidated fuel rods), and inerting atmosphere requirements. These specifications ensure that the loaded SNF assemblies remain within the bounds of the safety analyses in the approved design basis.

The regulations in 10 CFR Part 72 include a number of fuel-specific and DSS-specific requirements that may depend on the design-basis condition of the fuel cladding. As required by 10 CFR 72.122(h)(1), the SNF cladding is to be protected against degradation that leads to gross ruptures, or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems when the fuel is removed from storage. In addition, 10 CFR 72.122(l) states that the DSS must be designed to allow ready retrieval of the SNF. According to Spent Fuel Storage and Transportation (SFST) Interim Staff Guidance[1] (ISG) SFST-ISG-2, Revision 2, "Fuel Retrievability in Spent Fuel Storage Applications," issued April 2016 (NRC, 2016), this may be demonstrated by either removing individual or canned SNF assemblies from wet or dry storage (Option A), removing a canister loaded with SNF assemblies from a DSS cask or overpack (Option B), or removing a DSS cask loaded with SNF assemblies from its storage location (Option C). The ready retrieval requirement is defined by the approved design basis for the DSS's CoC or the independent spent fuel storage installation's (ISFSI's) specific license. Therefore, the integrity of the cladding is an important consideration for demonstrating ready retrieval under SFST-ISG-2 Option A. The condition of the fuel cladding may also impact the safety analyses used to demonstrate compliance with DSS-specific requirements in 10 CFR 72.124(a); 10 CFR 72.128, "Criteria for spent fuel, high-level radioactive waste, reactor-related Greater than Class C waste, and other radioactive waste storage and handling"; and 10 CFR 72.236(m).

[1] The staff plans to incorporate the current versions of ISG documents into revised regulatory guides or standard review plans for dry storage and transportation of SNF, as appropriate, and then withdraw the ISGs. Consistent with current agency policy, the revised regulatory guides and standard review plans will be issued for public comment before being finalized.

Similarly, for transportation, the regulations in 10 CFR Part 71 also include a number of fuel-specific and package-specific requirements. The regulations in 10 CFR 71.31, "Contents of application," and 10 CFR 71.33, "Package description," require an application for a transportation package to describe the proposed package in sufficient detail to identify the package accurately and provide a sufficient basis for evaluation of the package, which includes a description of the chemical and physical form of the allowable contents. The regulations in 10 CFR Part 71 also require that (1) the geometric form of the package contents not be substantially altered under the tests for normal conditions of transport (10 CFR 71.55(d)(2)) and (2) a package used for the shipment of fissile material is to be designed and constructed and its contents so limited that under the tests for hypothetical accident conditions specified in 10 CFR 71.73, "Hypothetical accident conditions," the package remains subcritical (10 CFR 71.55(e)). The requirement assumes that the fissile material is in the most reactive credible configuration consistent with the damaged condition of the package and the chemical and physical form of the contents (10 CFR 71.55(e)(1)).

To comply with the above requirements, the fuel cladding generally serves a design function in both DSSs and transportation packages for ensuring that the configuration of undamaged and intact fuel remains within the bounds of the reviewed safety analyses.[2] Therefore, an application should address potential degradation mechanisms that could result in gross cladding ruptures during operations. To assist the safety review of potential degradation mechanisms, the U.S. Nuclear Regulatory Commission (NRC) staff has historically issued guidance on acceptable storage and transport conditions that limit SNF degradation during operations and ensure that the reviewed safety analyses remain valid.

1.2 Statement of the Problem and Objective

1.2.1 Problem Statement

The current NRC guidance in SFST-ISG-11, Revision 3, "Cladding Considerations for the Transportation and Storage of Spent Fuel" (ADAMS Accession No. ML033230335) does not address hydride reorientation failure mechanisms. Hydride reorientation is a process in which the orientation of hydrides precipitated in HBU SNF cladding during reactor operation changes from the circumferential-axial to the radial-axial direction. Research results published over the last decade have shown that hydride reorientation can occur at temperatures and stresses lower than those assumed in the current staff guidance. Therefore, the NRC sponsored additional research to better understand whether hydride reorientation could affect the mechanical behavior of HBU SNF cladding and compromise the fuel configuration analyzed in DSSs and transportation packages.

NUREG-2224 expands the technical basis in support of the SFST-ISG-11, Revision 3, guidance on adequate fuel conditions as it pertains to hydride reorientation in HBU SNF cladding. The existing guidance in SFST-ISG-11, Revision 3, defines adequate fuel conditions, including peak cladding temperatures during short-term loading operations to prevent or mitigate degradation of the cladding. Time-dependent changes in the cladding properties of HBU SNF are primarily driven by the fuel's temperature, rod internal pressure (and corresponding pressure-induced cladding hoop stresses), and the environment during dry storage or transport operations.

[2] If the fuel is classified as damaged, a separate canister (e.g., a can for damaged fuel) that confines the assembly contents to a known volume may be used to provide this assurance.

Historically, safety review guidance has addressed the potential for these changes to compromise the analyzed fuel configuration in DSSs and transportation packages.

1.2.2 Objective

The objective of this regulatory analysis is to assess the benefits and costs of alternatives to issuing NUREG-2224 to ensure that the NRC has chosen the most cost-beneficial (i.e., cost-effective) alternative. This NUREG incorporates the findings from recent NRC-sponsored research to address hydride reorientation in DSSs and transportation packages and improvements to increase the efficiency of the renewal application process.

2 IDENTIFICATION AND ANALYSIS OF ALTERNATIVE APPROACHES

The NRC has identified two alternatives for consideration.

2.1 Alternative 1—Take No Action

Under this alternative, the NRC would not issue new guidance to address the problem of lengthy application reviews due to the lack of submittal standardization or provide expanded technical analysis justifying additional relief from programmatic requirements. This alternative serves as the baseline against which the impacts of Alternative 2 will be measured.

This alternative would pose no incremental burden on licensees, CoC holders, or other entities. The NRC would continue to review renewal applications for dry storage and transportation of HBU SNF on a case-by-case basis. Because the take no action alternative would not make available the most current technical information or incorporate insights from the engineering assessment on hydride reorientation, this alternative would not achieve the NRC's objective to increase the efficiency of the renewal application process.

2.2 Alternative 2—Issue NUREG-2224

Under this alternative, the NRC would issue NUREG-2224. This new guidance document would (1) establish a clear engineering assessment of the safety significance of hydride reorientation during dry storage and transportation conditions for HBU SNF up to 60 years after being removed from the spent fuel pool, and (2) provide guidance for applicants' development of safety analyses submitted by specific licensees or CoC holders of DSSs and transportation packages for HBU SNF.

The NUREG provides current technical reference material in support of the engineering assessment and incorporates insights from the nuclear industry and the public to define various example licensing and certification approaches for dry storage and transportation of HBU SNF. The NUREG also provides NRC-acceptable approaches for the certification of transportation packages to demonstrate adequate cladding ductility during design-basis drop accidents (NRC, 2015). These approaches provide relief from performing the complex calculations and statistical analyses that were previously necessary to demonstrate regulatory compliance. The NUREG also describes approaches for demonstrating the acceptability for transportation of HBU SNF 20 years after being removed from the spent fuel pool. The approaches for dry storage include an NRC-acceptable approach to provide justification for the relief of HBU SNF aging management program (AMP) through the submittal of supplemental safety analyses (SSAs).

As described in Section 3.4, these approaches would benefit applicants (industry) and the NRC by establishing clear guidance and templates, streamlining processes, and documenting the lack of aging management issues based on additional justification provided in the industry's SSAs. The availability of this information promotes a more efficient amendment and renewal application process, if an applicant follows these approaches, without resulting in a substantive change to ongoing costs (i.e., costs associated with fulfilling the requirements of the issued license or CoC).

3 ESTIMATION AND EVALUATION OF BENEFITS AND COSTS

3.1 Affected Entities

Alternative 2 is expected to affect all applicants with DSS designs (site-specific ISFSI licensees and CoC holders) and transportation packages (CoC holders) with HBU SNF from boiling-water reactors, pressurized-water reactors, or both. However, NUREG-2224 is guidance and may not be used by all affected entities.

When submitting a specific license or CoC renewal application for extended periods of dry storage (i.e., beyond 20 years), specific licensee and CoC holder entities provide SSAs to realize efficiencies to their AMPs and submittal processes. The staff anticipates that implementation and operational savings will be realized with the publication of NUREG-2224. The immediate impacts of the guidance could be applicable to 15 specific licensees per the latest ISFSI map (NRC, 2019) and 15 CoC holders per 10 CFR 72.214, "List of approved spent fuel storage casks." The NRC estimates that 10 of these specific licensees and CoC holders will choose to implement the new guidance. The operational cost savings of this guidance also impacts general licensees and specific licensees. There are 65 general licensees (NRC, 2019) associated with dry storage of HBU fuel and 15 specific licensees. The NRC estimates that 25 general licensees and specific licensees will choose to implement the new guidance.

When submitting a CoC amendment to include HBU SNF as allowable contents in a transportation package, CoC holders will immediately benefit from the relief of additional calculations (for directly loaded fuel and previously dry-stored fuel up to 20 years) and clarity on NRC-acceptable approaches for demonstrating acceptability of transport of dry-stored fuel beyond 20 years. The implementation using the NUREG could impact 30 specific licensees and CoC holders. The NRC estimates that 12 specific licensees and CoC holders will choose to implement NUREG-2224 guidance to realize the implementation cost savings associated with the transportation relief for safety analyses and transportation packages of dry-stored fuel beyond 20 years.

3.2 Analytical Methodology

This regulatory analysis follows the guidance in NUREG/BR-0058, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," draft Revision 5, dated January 28, 2020 (NRC, 2020). In addition, the methodology is in accordance with guidance from Office of Management and Budget (OMB) Circular A-4, "Regulatory Analysis," dated September 17, 2003 (OMB, 2013).

In this regulatory analysis, the staff identifies all attributes related to the regulatory action and analyzes them either quantitatively or qualitatively. The benefits include any desirable changes in affected attributes (e.g., monetary savings, improved safety, improved security), while the costs include any undesirable changes in affected attributes (e.g., monetary costs, increased

exposures to radiation or physical hazards). This regulatory analysis estimates the incremental costs resulting from issuing NUREG-2224 relative to a baseline that reflects anticipated behavior if the NRC does not undertake any action (Alternative 1). As part of the regulatory baseline used in this analysis, the staff assumes full compliance with existing NRC regulations.

For the quantified regulatory analysis, the staff developed expected values for each affected benefit and cost. The staff estimated the required level of effort for each activity under Alternative 2 and labor rates for personnel performing those activities. After determining the benefits and costs, the staff discounted the benefits and costs incurred in future years to the current year of the regulatory action. Finally, the staff summed the benefits and costs for Alternative 2 and compared them to the take no action baseline. After performing the quantitative regulatory analysis, the staff addressed qualitative attributes that are difficult to quantify but important to consider.

The staff gathered data from several sources to develop levels of effort and unit cost estimates. It applied several cost estimation methods in this analysis and used professional knowledge and judgment to estimate some of the costs and benefits, using an analogy method or extrapolation techniques.

Using Bureau of Labor Statistics labor rates (BLS, 2019), the staff estimated industry breakdown to support implementation of NUREG-2224 as shown in Table 1. Using this labor breakdown, the CPI-U inflator as shown in Table 2, the staff estimated industry implementation costs as shown in **Error! Reference source not found.**Table 3 and the industry operation costs as shown in Table 4.

Table 1 Industry Labor Breakdown

Labor Category	Percent of Total Time to Complete the Task	Mean Labor Rate	Adjusted Labor Rate
Technician	60%	$109.16	$65.50
Administrative Staff	15%	$84.23	$12.63
Managers	20%	$151.54	$30.31
Executives	5%	$214.63	$10.73
Weighted Industry Labor Rate			**$119.17**

To evaluate the effect of uncertainty in the analysis, the staff employed a Monte Carlo simulation, which is an approach to uncertainty analysis in which input variables are expressed as distributions. The result is a distribution of values for the output variable of interest. With a Monte Carlo simulation, it is also possible to determine the input variables that have the greatest effect on the value of the output variable. Section 3.5 gives a detailed description of the Monte Carlo simulation method and presents the results.

3.2.1 Identification of Affected Attributes

The attributes within the public and private sectors that the analyzed alternatives could affect are presented below. This list was created using the potential attributes provided in NUREG/BR-0058. The basis for selecting these attributes is also presented.

Potential affected attributes include the following:

- Industry Implementation—This attribute accounts for the projected one-time net economic effect on the affected entities related to using the guidance to submit an amendment or renewal application for a specific license or CoC of a DSS design, or an amendment for a CoC of a transportation package. The issuance of NUREG-2224 would affect the efficiency in preparation of these applications for addressing the performance of HBU SNF during the period of operation. NUREG-2224 is expected to improve the efficiency in the preparation of the SSAs by providing various acceptable approaches, which are expected to aid the preparation of applications and reduce NRC staff requests for additional information (RAIs). The NRC assumes that 10 specific licensees and CoC holders will realize the cost savings outlined in NUREG-2224; additional savings will be realized through the transportation relief for safety analyses and transportation guidance greater than 20 years in dry storage. For these later cost savings, the NRC estimates that 12 specific licensees and CoC holders will choose to utilize the guidance.

- Industry Operation—This attribute measures the projected net economic effect of routine and recurring licensee activities that will no longer occur due to the approval of SSAs. Specifically, the expanded engineering analysis in NUREG-2224 provides technical justification for the applicants to show adequate protection otherwise managed through an AMP during dry storage of HBU SNF. This attribute does not account for cost savings associated with the fabrication of transportation packages due to the relief of prior guidance for the transport of HBU SNF in designs that ensured moderator exclusion (NRC, 2015). The latter cost savings are difficult to quantify since fabrication costs are not readily available or tracked by the NRC. The operational cost savings of this guidance impact general licensees and specific licensees. There are 65 general licensees associated with dry storage of HBU fuel and 15 specific licensees. The NRC estimates that 25 general licensees and specific licensees will choose to implement the new guidance.

- NRC Implementation—This attribute accounts for the projected one-time net economic effect per application on the NRC related to using the guidance to review the applicant's SSAs. As stated in the Industry Implementation attribute, the issuance of NUREG-2224 is expected to affect the efficiency of the amendment and renewal process by reducing the number of RAIs. The improved standardization from this guidance is anticipated to significantly reduce the level of effort associated with RAIs. Based on previous application packages, the NRC estimates a mean savings of 368 hours in each of the following areas: (1) dry storage SSAs, (2) transportation relief for safety analyses, and (3) guidance for transportation packages for dry storage greater than 20 years.

- NRC Operations—This attribute measures the projected net economic effect of routine and recurring NRC activities that will occur due to the relief of a licensee's need to conduct an AMP during dry storage of HBU SNF. NUREG-2224 includes licensing and certification approaches acceptable to the staff that remove requirements for the monitoring and surveillance of ongoing HBU SNF activities (EPRI, 2014 and Hanson, 2016) which the NRC would otherwise inspect.

- Regulatory Efficiency—This qualitative attribute accounts for potential nonquantifiable benefits in regulatory and compliance improvements beyond those efficiencies estimated in other attributes. The NRC anticipates that the issuance of the guidance, and the

resulting improved understanding of the performance of HBU SNF during dry storage and transportation operations, would provide efficiency gains by clarifying acceptable approaches for demonstrating that the transportation package or DSS meets all the pertinent regulatory requirements. The staff did not identify any additional nonquantifiable efficiency gains.

3.2.2 Base Year of Analysis

The NRC assumes it will issue NUREG-2224 in 2020, so all quantified benefits and costs are escalated or discounted to 2020 dollars.

3.2.3 Time Horizon

The applicability period for the impacted entities is estimated to be 40 years assuming the implementation period occurs in the 2025 to 2030 time period. A large number of CoC holders and specific licensees have current approved renewal applications for dry storage taking them to 60 years of operation. Another group of CoC holders and specific licensees will be submitting their renewal applications for dry storage within the next 10 years. Due to the ongoing events (EPRI, 2014 and Hanson, 2016) in the dry storage and transportation of HBU SNF, the staff anticipates that CoC holders and specific licensees will wait approximately 5 to 10 years as discussed in Section 3.4.1 to observe the results of ongoing HBU SNF activities and then evaluate the use of SSAs for future license amendments and renewal applications. The staff determined that extending the cost analysis evaluation beyond 40 years has diminishing returns on the estimated benefits and costs resulting from issuing this NUREG. This time horizon addresses all anticipated applications for transportation packages for HBU SNF (aged up to 40 years after removal from the spent fuel pool) and anticipated applications for initial and renewed dry storage (periods of operation up to 40 years).

3.2.4 Cost/Benefit Inflators

The NRC estimated the analysis inputs from various sources, some provided in prior-year dollars. To evaluate the costs and benefits consistently, the staff converted these inputs into base-year dollars using the consumer price index for all urban consumers (CPI-U) developed by the U.S. Department of Labor, Bureau of Labor Statistics. Using the CPI-U, the staff converted prior-year dollars to 2020 dollars, using the formula:

$$\frac{CPI - U_{2020}}{CPI - U_{Base\ Year}}\ x\ Value_{Base\ Year} = Value_{2020}$$

Table 2 summarizes the values of CPI-U used in this regulatory analysis.

Table 2 CPI-U Inflator

Base Year	CPI-U Annual Average[a]
2018	251.1
2019	256.12
2020	263.12

[a] Statistica, 2020

3.2.5 Net Present Value Calculations

The net present value (NPV) calculations determine how much society would need to invest today to ensure that the designated dollar amount is available in a given year in the future. Using discount factors for the costs and benefits allows for future incremental costs and benefits to be valued equally when comparing alternatives. Based on OMB Circular No. A-4, present value calculations are presented using both 3-percent and 7-percent real discount rates, and the decision rationale is based on the 7-percent real discount rate.

3.2.6 Sign Conventions

This analysis uses a sign convention such that all favorable consequences for the alternative are positive and all adverse consequences for the alternative are negative. Negative values are shown using parentheses (e.g., negative $500 is displayed as ($500)).

3.2.7 Assumptions

The analysis uses the assumptions and considerations described below to determine the costs associated with the implementation of the alternatives.

Transportation assumptions:

- CoC holders of transportation packages would review the guidance in preparation for submitting an amendment application to incorporate HBU SNF as allowable contents.

- CoC holders of transportation packages submit the analyses expected per NUREG-2224 at the same time they submit their amendment application.

- The staff estimates that the guidance would result in an overall 368-hour reduction in the amount of time required for applicants to develop their safety analyses for transportation packages and respond to staff RAIs. The NRC also estimates that the guidance will result in a 368-hour reduction in the amount of time required for the staff to review applications, develop RAIs and evaluate responses, and document its safety evaluation. This estimate is based on the staff's experience with prior reviews of safety analyses for transportation packages submitted with prior draft NRC guidance. As noted above, additional cost savings would be realized in the fabrication of transportation packages due to the relief of design features expected per prior NRC guidance (NRC, 2015). The latter cost savings are difficult to quantify since fabrication costs are not readily available or tracked by the NRC.

- CoC holders of transportation packages will use the updated guidance on the performance of HBU SNF to provide justification that the fuel remains in its analyzed configuration during operations, which would also eliminate the need for additional calculations per prior draft guidance (NRC, 2015).

Dry storage assumptions:

- ISFSI specific licensees and CoC holders for DSS designs would review the guidance to prepare for submitting SSAs in their amendment or renewal application.

- ISFSI licensees and CoC holders submit their SSAs at the same time they submit their amendment or renewal application.

- The staff estimates that CoC holders would spend an additional 1-month level of effort to show adequate protection for each SSA in lieu of an AMP. This cost would be realized at the same time as the SSA preparation. The guidance is anticipated to result in a net 368-hour reduction in the time required for applicants to develop their SSAs and respond to staff RAIs. The NRC also estimates that the guidance will result in a 368-hour reduction in the time required for the staff to review applications, develop RAIs and evaluate responses, and document its safety evaluation. This estimate is based on the staff's experience with prior reviews of similar SSAs submitted without any NRC guidance.

- Licensees will use the safety analysis performed through the SSAs to provide justification for not implementing an AMP, which would also eliminate the need to perform subsequent 10-year periodic reviews of their HBU SNF AMPs and NRC inspections of their HBU SNF AMPs.

3.3 Evaluation of Alternative 1—Take No Action

This regulatory analysis measures the incremental impacts of the alternative relative to a baseline, which reflects anticipated behavior if the staff does not issue NUREG-2224. The take no action alternative, the baseline for the analysis, does not result in any change in benefits or costs.

3.4 Evaluation of Alternative 2—Issue NUREG-2224

The evaluation of Alternative 2 for each potential affected attribute is presented below.

3.4.1 Industry Implementation

Following the issuance of NUREG-2224, the NRC anticipates that industry would use the guidance to prepare high-quality safety analyses. Because the guidance was developed with significant input from the nuclear industry, the guidance presents a common understanding of the technical issues associated with potential degradation mechanisms that could result in gross cladding ruptures during operations of transportation packages and DSSs up to 60 years after the HBU SNF is removed from the spent fuel pool. The NRC anticipates that using the acceptable approaches contained in NUREG-2224 would increase the efficiency of the staff's safety analysis reviews and would reduce the number of staff-generated RAIs and redundant, case-by-case reviews of the technical topics that are generically addressed in the NUREG.

NRC-approved SSAs for dry storage of HBU SNF developed per the new guidance would provide reasonable assurance that all pertinent regulatory requirements are met even in the event of potential fuel reconfiguration. This would provide relief from an AMP to surveil and monitor the stored fuel. If this option is chosen by the specific licensee or CoC holder, the time CoC holders spend to develop an application is estimated to increase by 1 month of work, although the streamlined NUREG approach is anticipated to provide an overall reduction in the time required to complete an SSA, as noted in Table 3.

When submitting a specific license or CoC renewal application for extended periods of dry storage (i.e., beyond 20 years), specific licensee and CoC holder entities provide SSAs to

realize efficiencies in their AMPs and submittal processes. The implementation impacts of the guidance will be applicable to 15 specific licensees per the latest ISFSI map and 15 CoC holders per 10 CFR 72.214. The NRC estimates that 10 of these specific licensees and CoC holders will choose to implement the new guidance. The NRC further estimates that within 5 years of publication, three specific licensees/CoC holders will implement the new guidance. Within 10 years of publication, the NRC estimates that an additional seven specific licensees/CoC holders will implement the new guidance as shown in Table 3.

NRC-approved safety analyses of transportation packages developed per the new guidance would provide reasonable assurance that the fuel remains in its analyzed configuration during operations, which would also eliminate the need for additional calculations per prior draft guidance (NRC, 2015). When submitting a CoC amendment to include HBU SNF as allowable contents in a transportation package, CoC holders will immediately benefit from the relief of additional calculations (for directly loaded fuel and previously dry-stored fuel up to 20 years) and clarity on NRC-acceptable approaches for demonstrating acceptability of transport of dry-stored fuel beyond 20 years. The implementation costs impact 30 specific licensees and CoC holders. The NRC estimates that 12 specific licensees and CoC holders will implement NUREG-2224 guidance and realize the implementation cost savings associated with the transportation relief for safety analyses and transportation packages of dry-stored fuel beyond 20 years, as shown in Table 3.

Table 3 shows averted costs (benefits) resulting from the use of the new guidance. These are one-time costs associated with the amendment or renewal application processes.

Table 3 Industry Implementation

Year	Activity	Number Using SSA Approach	Per Entity		Net Benefit (Cost)		
			Labor Hours	Weighted Hourly Rate	Undiscounted	7% NPV	3% NPV
2025	Dry Storage Supplemental Safety Analyses	3	368	119	$131,000	$93,000	$113,000
2030	Dry Storage Supplemental Safety Analyses	7	368	119	$307,000	$156,000	$228,000
				Subtotal:	$438,000	$249,000	$341,000
2025	Transportation Relief for Safety Analyses	6	368	119	$262,000	$187,000	$226,000
2030	Transportation Relief for Safety Analyses	6	368	119	$262,000	$133,000	$195,000
				Subtotal:	$524,000	$320,000	$421,000
2025	Transportation 20+ Year Package	6	368	119	$526,000	$375,000	$454,000
2030	Transportation 20+ Year Package	6	368	119	$526,000	$267,000	$391,000
				Subtotal:	$1,052,000	$642,000	$845,000
				Total	**$2,014,000**	**$1,211,000**	**$1,607,000**

3.4.2 Industry Operation

NRC-approved SSAs for dry storage of HBU SNF would remove the HBU SNF aging management procedure development and maintenance, the training requirement for HBU SNF aging management, the 10-year HBU SNF aging management analysis (referred to as "toll gate") and would eliminate the need for NRC inspection of the HBU SNF AMP.

The operational cost savings of this guidance impact general licensees and specific licensees. There are 65 general licensees associated with dry storage of HBU fuel and 15 specific licensees. The NRC estimates that 25 general licensees and specific licensees will choose to implement the new guidance. The NRC modeled 10 general licensees and specific licensees implementing the guidance in 2025. For the following 40 years, these general licensees and specific licensees realize annual averted costs (benefits) in the relief of HBU SNF AMP implementation and maintenance requirements. Every 10 years, these same general and specific licensees realize averted costs in the relief of the preparation and NRC inspection of their HBU SNF AMP 10-year review ("toll gate"). The NRC estimates that an additional 15 general and specific licensees will implement the guidance outlined in NUREG-2224. The NRC modeled these 15 general and specific licensees implementing the guidance in 2030. For the following 40 years, these general licensees and specific licensees realize annual averted costs (benefits) in the relief of HBU SNF AMP implementation and maintenance requirements. Every 10 years, these same general licensees and specific licensees realize averted costs in the relief of the preparation and NRC inspection of their HBU SNF AMP 10-year review.

Table 4 shows the net benefits (i.e., averted costs) resulting from the use of the new guidance. These are long-term cost savings resulting from changes to the AMP.

Table 4 Industry Operation: Relief of HBU SNF AMP and HBU SNF AMP "Toll Gate"

Year	Activity	General Licensees & Specific Licensees	Hours	Weighted Hourly Rate	Net Benefit (Cost)		
					Undiscounted	7% NPV	3% NPV
2025	Relief of HBU SNF AMP Implementation and Maintenance	10	20	119	$24,000	$17,000	$21,000
2026	Relief of HBU SNF AMP Implementation and Maintenance	10	20	119	$24,000	$16,000	$20,000
2027	Relief of HBU SNF AMP Implementation and Maintenance	10	20	119	$24,000	$15,000	$20,000
2028	Relief of HBU SNF AMP Implementation and Maintenance	10	20	119	$24,000	$14,000	$19,000
2029	Relief of HBU SNF AMP Implementation and Maintenance	10	20	119	$24,000	$13,000	$18,000
2030	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$31,000	$45,000
2031	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$29,000	$43,000

Year	Activity	General Licensees & Specific Licensees	Hours	Weighted Hourly Rate	Net Benefit (Cost)		
					Undiscounted	7% NPV	3% NPV
2032	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$27,000	$42,000
2033	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$25,000	$41,000
2034	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$23,000	$40,000
2035	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$22,000	$39,000
2035	HBU SNF AMP Toll Gate Reviews	10	80	119	$95,000	$34,000	$61,000
2036	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$20,000	$37,000
2037	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$19,000	$36,000
2038	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$18,000	$35,000
2039	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$17,000	$34,000
2040	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$16,000	$33,000
2040	HBU SNF AMP Toll Gate	15	80	119	$143,000	$37,000	$79,000
2041	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$14,000	$32,000
2042	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$14,000	$31,000
2043	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$13,000	$30,000
2044	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$12,000	$30,000
2045	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$11,000	$29,000
2045	HBU SNF AMP Toll Gate	10	80	119	$95,000	$18,000	$45,000
2046	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$10,000	$28,000
2047	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$10,000	$27,000
2048	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$9,000	$26,000

Year	Activity	General Licensees & Specific Licensees	Hours	Weighted Hourly Rate	Net Benefit (Cost)		
					Undiscounted	7% NPV	3% NPV
2049	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$8,000	$25,000
2050	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$8,000	$25,000
2050	HBU SNF AMP Toll Gate	15	80	119	$143,000	$19,000	$59,000
2051	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$7,000	$24,000
2052	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$7,000	$23,000
2053	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$6,000	$23,000
2054	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$6,000	$22,000
2055	Relief of HBU SNF AMP Implementation and Maintenance	25	20	119	$60,000	$6,000	$21,000
2055	HBU SNF AMP Toll Gate	10	80	119	$95,000	$9,000	$34,000
2056	Relief of HBU SNF AMP Implementation and Maintenance	15	20	119	$36,000	$3,000	$12,000
2057	Relief of HBU SNF AMP Implementation and Maintenance	15	20	119	$36,000	$3,000	$12,000
2058	Relief of HBU SNF AMP Implementation and Maintenance	15	20	119	$36,000	$3,000	$12,000
2059	Relief of HBU SNF AMP Implementation and Maintenance	15	20	119	$36,000	$3,000	$11,000
2060	Relief of HBU SNF AMP Implementation and Maintenance	15	20	119	$36,000	$2,000	$11,000
2060	HBU SNF AMP Toll Gate	15	80	119	$143,000	$10,000	$44,000
Subtotal Relief of AMP					$1,860,000	$477,000	$977,000
Subtotal Relief of Toll Gate					$714,000	$127,000	$322,000
Total Industry Operation Cost					**$2,574,000**	**$604,000**	**$1,299,000**

3.4.3 Total Industry Averted Costs

The cost estimates associated with this NUREG result in estimated net benefits (i.e., averted costs) to the industry that range from $1.8 million using a 7-percent NPV to $2.9 million using a 3-percent NPV, when compared to Alternative 1, as shown in Table 5.

Table 5 Total Industry Averted Costs

Attribute	Net Benefit (Cost)

	Undiscounted	7% NPV	3% NPV
Total Industry Implementation Cost	$2,014,000	$1,211,000	$1,607,000
Total Industry Operation Cost	$2,574,000	$604,000	$1,299,000
Total Industry Cost	**$4,588,000**	**$1,815,000**	**$2,906,000**

3.4.4 NRC Implementation

Following the issuance of NUREG-2224, the staff would use this guidance to review the safety analyses for transportation packages and DSSs or ISFSI specific licenses. Because the guidance was developed with significant input from the nuclear industry, it presents a common understanding of the technical issues associated with potential degradation mechanisms that could result in gross cladding ruptures during operations of transportation packages and DSSs after the HBU SNF is removed from the spent fuel pool. The staff anticipates that NUREG-2224 would increase the efficiency of the safety analyses review process by enabling high-quality applications and reducing redundant, case-by-case reviews of the technical topics generically addressed in the NUREG.

The NRC would experience implementation benefits due to an anticipated decrease in the time required to review and approve a license amendment or renewal. The NRC anticipates a reduction in the number of RAIs from the NRC staff due to reducing redundant, case-by-case reviews of the same technical topics. The NRC estimates that the reduction equates to 368 hours. The NRC estimates that this reduction will be realized in three separate areas: (1) dry storage SSAs, (2) transportation relief for safety analyses, and (3) guidance on transportation greater than 20 years.

Relative to dry storage SSAs, the implementation impacts of the guidance will be applicable to 15 specific licensees per the latest ISFSI map and 15 CoC holders per 10 CFR 72.214. The NRC estimates that 10 of these specific licensees and CoC holders will implement the new guidance. The NRC further estimates that within 5 years of publication, the NRC will receive three applications or renewal applications from specific licensees and CoC holders. Within 10 years of publication, the NRC estimates that it will receive an additional seven applications or renewal applications from specific licensees and CoC holders, as noted in Table 6.

Relative to applications related to transportation relief for safety analyses and guidance for transportation greater than 20 years, the implementation impacts the same 30 specific licensees and CoC holders. The NRC estimates that 12 specific licensees and CoC holders will implement NUREG-2224 guidance and realize the implementation cost savings associated with the transportation relief for safety analyses and transportation packages of dry-stored fuel beyond 20 years, as shown in Table 6.

Table 6 shows the net benefits associated with the use of the new guidance. These are one-time costs per application associated with the renewal application process.

Table 6 NRC Implementation (Net Benefit)

Year	Activity	Estimated Number of CoC Holders & Specific Licensees Using SSA Approach	Per Entity		Net Benefit (Cost)		
			Labor Hours	Weighted Hourly Rate	Undiscounted	7% NPV	3% NPV
2025	Dry Storage Supplemental Safety Analyses	3	368	131	$145,000	$103,000	$125,000
2030	Dry Storage Supplemental Safety Analyses	7	368	131	$337,000	$171,000	$251,000
				Subtotal:	$482,000	$274,000	$376,000
Year	**Activity**	**Number of CoC Holders**	**Per Entity**		**Net Benefit (Cost)**		
			Labor Hours	**Weighted Hourly Rate**	**Undiscounted**	**7% NPV**	**3% NPV**
2025	Transportation Relief for Safety Analyses	6	368	131	$289,000	$206,000	$249,000
2030	Transportation Relief for Safety Analyses	6	368	131	$289,000	$147,000	$215,000
				Subtotal:	$578,000	$353,000	$464,000
Year	**Activity**	**Number of CoC Holders**	**Per Entity**		**Net Benefit (Cost)**		
			Labor Hours	**Weighted Hourly rate**	**Undiscounted**	**7% NPV**	**3% NPV**
2025	Transportation 20+ Year Package	6	368	131	$289,000	$206,000	$249,000
2030	Transportation 20+ Year Package	6	368	131	$289,000	$147,000	$215,000
				Subtotal:	$578,000	$353,000	$464,000
				Total:	**$1,638,000**	**$980,000**	**$1,304,000**

3.4.5 NRC Operation

Following the issuance of NUREG-2224, the NRC anticipates changes to the ongoing costs associated with the NRC's oversight of the AMP of dry storage HBU SNF licensees. Provided that the specific license or CoC has an NRC-approved SSA that provides adequate protection for the licensee's aging management for dry storage HBU SNF, the NRC gains ongoing efficiency in the ISFSI inspection program.

The operational cost savings of this guidance impacts general licensees and specific licensees. There are 65 general licensees associated with dry storage of HBU fuel and 15 specific licensees. The NRC estimates that 25 general licensees and specific licensees will choose to implement the new guidance. The NRC modeled 10 general and specific licensees implementing the guidance in 2025. For the following 40 years, these general licensees and specific licensees realize annual averted costs (benefits) in the relief of HBU SNF AMP implementation and maintenance requirements. Every 10 years, these same general and specific licensees realize averted costs in the relief of the preparation and NRC inspection of their HBU SNF AMP 10-year review ("toll gate"). The NRC estimates that an additional 15 general and specific licensees will implement the guidance outlined in NUREG-2224. The

NRC modeled these 15 general and specific licensees implementing the guidance in 2030. For the following 40 years, these general licensees and specific licensees realize annual averted costs (benefits) in the relief of HBU SNF AMP implementation and maintenance requirements. Every 10 years, these same general licensees and specific licensees realize averted costs in the relief of the preparation and NRC inspection of their HBU SNF AMP 10-year review.

The operational savings realized by the NRC are in the area of inspection. Due to the adequate protection justifications provided from the SSA, the NRC will no longer be required to inspect the HBU SNF AMP or the 10-year HBU SNF "toll gate."

Table 7 shows the net benefits resulting from the use of the new guidance. These are long-term cost savings associated with the changes to the AMP.

Table 7 NRC Operation

Year	Activity	General Licensees and Specific Licensees Inspected	Hours	Weighted Hourly Rate	Net Benefit (Cost)		
					Undiscounted	7% NPV	3% NPV
2025	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$2,000
2026	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$2,000
2027	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$2,000
2028	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$2,000
2029	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$2,000
2030	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$1,000
2031	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$1,000
2032	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$1,000
2033	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$1,000
2034	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$1,000
2035	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$1,000
2035	HBU SNF AMP Toll Gate Reviews	10	6	131	$8,000	$3,000	$5,000
2036	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$1,000

Year	Activity	General Licensees and Specific Licensees Inspected	Hours	Weighted Hourly Rate	Net Benefit (Cost)		
					Undiscounted	7% NPV	3% NPV
2037	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$1,000
2038	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$1,000
2039	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$1,000
2040	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$1,000	$1,000
2040	HBU SNF AMP Toll Gate	15	6	131	$12,000	$3,000	$7,000
2041	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$500	$1,000
2042	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$500	$1,000
2043	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$400	$1,000
2044	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$400	$1,000
2045	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$400	$1,000
2045	HBU SNF AMP Toll Gate	10	6	131	$8,000	$1,000	$4,000
2046	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$300	$1,000
2047	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$300	$1,000
2048	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$300	$1,000
2049	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$300	$1,000
2050	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$300	$1,000
2050	HBU SNF AMP Toll Gate	15	6	131	$12,000	$2,000	$5,000
2051	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$200	$1,000
2052	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$200	$1,000
2053	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$200	$1,000

Year	Activity	General Licensees and Specific Licensees Inspected	Hours	Weighted Hourly Rate	Net Benefit (Cost)		
					Undiscounted	7% NPV	3% NPV
2054	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$200	$1,000
2055	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$200	$1,000
2055	HBU SNF AMP Toll Gate	10	6	131	$8,000	$1,000	$3,000
2056	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$200	$1,000
2057	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$200	$1,000
2058	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$200	$1,000
2059	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$100	$1,000
2060	Relief of HBU SNF AMP Implementation and Maintenance	5	2	131	$2,000	$100	$1,000
2060	HBU SNF AMP Toll Gate	15	6	131	$12,000	$1,000	$4,000
Relief of AMP					$72,000	$21,500	$41,000
Relief of Toll Gate					$60,000	$11,000	$28,000
				Total	**$132,000**	**$32,500**	**$69,000**

3.4.6 Future Unmodeled Technology and Innovation

NUREG-2224 provides additional guidance that ultimately could lead to additional cost savings in the fabrication of transportation packages due to the relief of design features expected per prior NRC guidance (NRC, 2015). The NRC cannot predict if industry will realize these potential cost savings in the fabrication of transportation packages, as such packages have never been submitted for construction or consideration. The cost savings with these proposed transportation packages will be quantifiable in the future; however, at present it is difficult to quantify since fabrication costs and transportation packages are not created to reflect this new guidance, nor is the fabrication data readily available or tracked by the NRC.

3.4.7 Total NRC Averted Costs

The cost estimates associated with this NUREG result in estimated averted costs (benefits) to the NRC that range from $1.0 million using a 7-percent NPV to $1.4 million using a 3-percent NPV, when compared to Alternative 1, as shown in Table 8.

Table 8 Total NRC Averted Costs

Attribute	NRC Averted Costs		
	Undiscounted	7% NPV	3% NPV
Total NRC Implementation Cost	$1,638,000	$980,000	$1,304,000

Total NRC Operation Cost	$132,000	$32,500	$69,000
Total NRC Cost	**$1,770,000**	**$1,012,500**	**$1,373,000**

3.4.8 Regulatory Efficiency

The NRC anticipates that the issuance of the guidance, and the resulting improved understanding of the performance of HBU SNF during dry storage and transportation operations, would provide efficiency gains by clarifying acceptable approaches for demonstrating that the transportation package or DSS meets all the pertinent regulatory requirements. The staff did not identify any additional nonquantifiable efficiency gains.

3.4.9 Cost Justification

Relative to Alternative 1, the NRC staff concludes that publication of NUREG-2224 provides substantial averted costs (benefits) to industry and the NRC as shown in Table 9.

Table 9 Total Averted Costs

Attribute	Total Averted Costs		
	Undiscounted	**7% NPV**	**3% NPV**
Industry Implementation	$2,014,000	$1,211,000	$1,607,000
Industry Operation	$2,574,000	$604,000	$1,299,000
Total Industry Cost	*$4,588,000*	*$1,815,000*	*$2,906,000*
NRC Implementation	$1,638,000	$980,000	$1,304,000
NRC Operation	$132,000	$32,500	$69,000
Total NRC Cost	*$1,770,000*	*$1,012,500*	*$1,373,000*
Net	***$6,358,000***	***$2,827,500***	***$4,279,000***

Note: There may be small differences between tables due to rounding.

For Alternative 1, Take No Action, there are no incremental costs or averted costs as there are no changes to current practices. The overall averted costs for the publication of this NUREG range from $2.8 million (7-percent NPV) to $4.3 million (3-percent NPV), as shown in Table 9.

3.5 Uncertainty Analysis

To determine the robustness of the estimated costs and benefits, the NRC examined how costs change due to uncertainties associated with the NRC's analytical assumptions and input data. The NRC used Monte Carlo simulation to examine the impact of uncertainty on the estimated net benefits. These Monte Carlo simulations were performed using the software package @Risk®[3] by Palisade Corporation.

3.5.1 Uncertainty Analysis Results

The NRC staff completed a Monte Carlo sensitivity analysis for this regulatory analysis using the specialty software @Risk®. The Monte Carlo approach answers the question, "What distribution

[3] Information about this software is available at http://www.palisade.com.

of net benefits results from multiple draws of the probability distribution assigned to key variables?"

As this regulatory analysis utilizes estimates of values that are sensitive to licensee-specific cost drivers and installation dissimilarities, the NRC staff provides the following analysis of the variables that have the greatest uncertainty.

Monte Carlo simulations involve introducing uncertainty into the analysis by replacing the point estimates of the variables used to estimate base case costs and benefits with probability distributions. By defining input variables as probability distributions instead of point estimates, the influence of uncertainty on the results of the analysis (in other words, the net benefits) can be effectively modeled.

The probability distributions chosen to represent the different variables in the analysis were bounded by the range-referenced input and the NRC staff's professional judgment. When defining the probability distributions for use in a Monte Carlo simulation, summary statistics are needed to characterize the distributions. These summary statistics include the minimum, most likely, and maximum values of a program evaluation and review technique (PERT) distribution,[4] the minimum and maximum values of a uniform distribution, and the specified integer values of a discrete population. The NRC staff used the PERT distribution to reflect the relative spread and skewness of the distribution defined by the three estimates.

The NRC performed the Monte Carlo simulation by repeatedly recalculating the results, 10,000 times. For each iteration, the values were chosen randomly from the probability distributions that define the input variables. The values of the output variables were recorded for each iteration, and these resulting output variable values were used to define the resultant probability distribution. For each figure below, the staff ran 10,000 simulations in which the key variables were changed to assess the resulting effect on costs and benefits. Figures 1 through 3 are histograms of the Alternative 2 incremental averted costs (benefits) in comparison to the regulatory baseline (Alternative 1) for the industry and NRC, respectively. In each case, histograms are shown for the present value with 3-percent and 7-percent discount rates. Given that positive numbers represent favorable consequences (i.e., savings), the uncertainty analysis shows that there would be a substantial cost savings to both the industry and NRC associated with issuing NUREG-2224.

[4] A PERT distribution is a special form of the beta distribution with specified minimum and maximum values. The shape parameter is calculated from the defined *most likely* value. The PERT distribution is similar to a triangular distribution in that it has the same set of three parameters. Technically, it is a special case of a scaled beta (or beta general) distribution. The PERT distribution is generally considered superior to the triangular distribution when the parameters result in a skewed distribution, as the smooth shape of the curve places less emphasis in the direction of skew. Similar to the triangular distribution, the PERT distribution is bounded on both sides and therefore may not be adequate for some modeling purposes if it is desired to capture tail or extreme events.

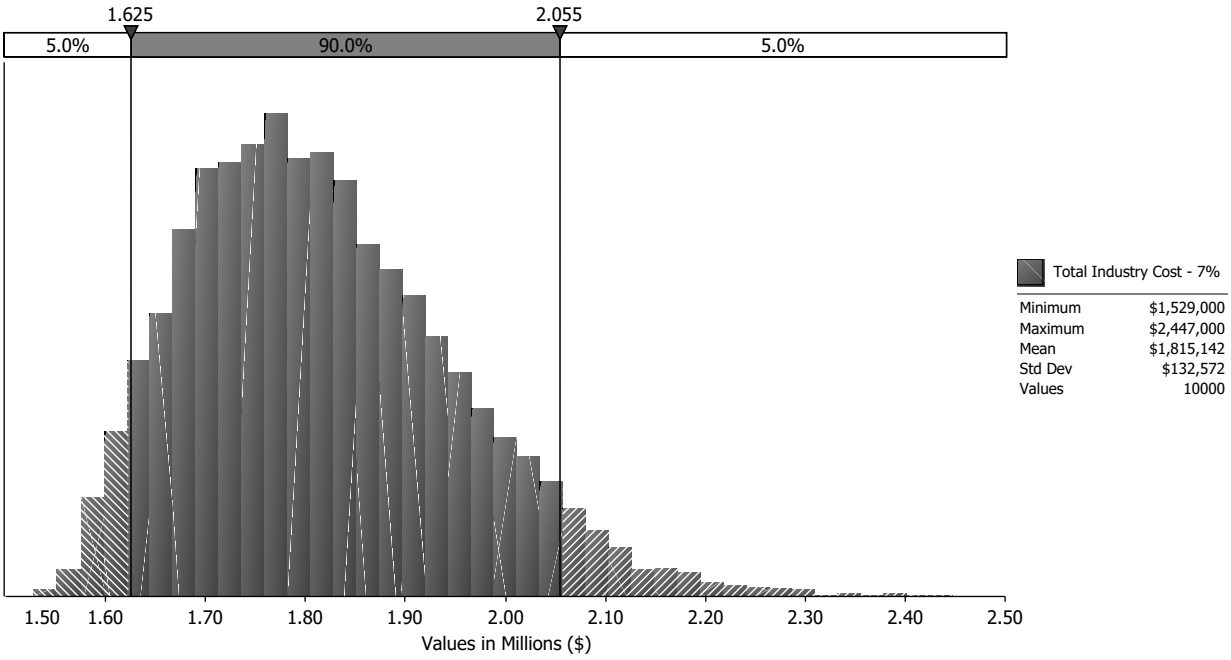

Figure 1 Uncertainty Analysis of Industry Cost Savings—Alternative 2

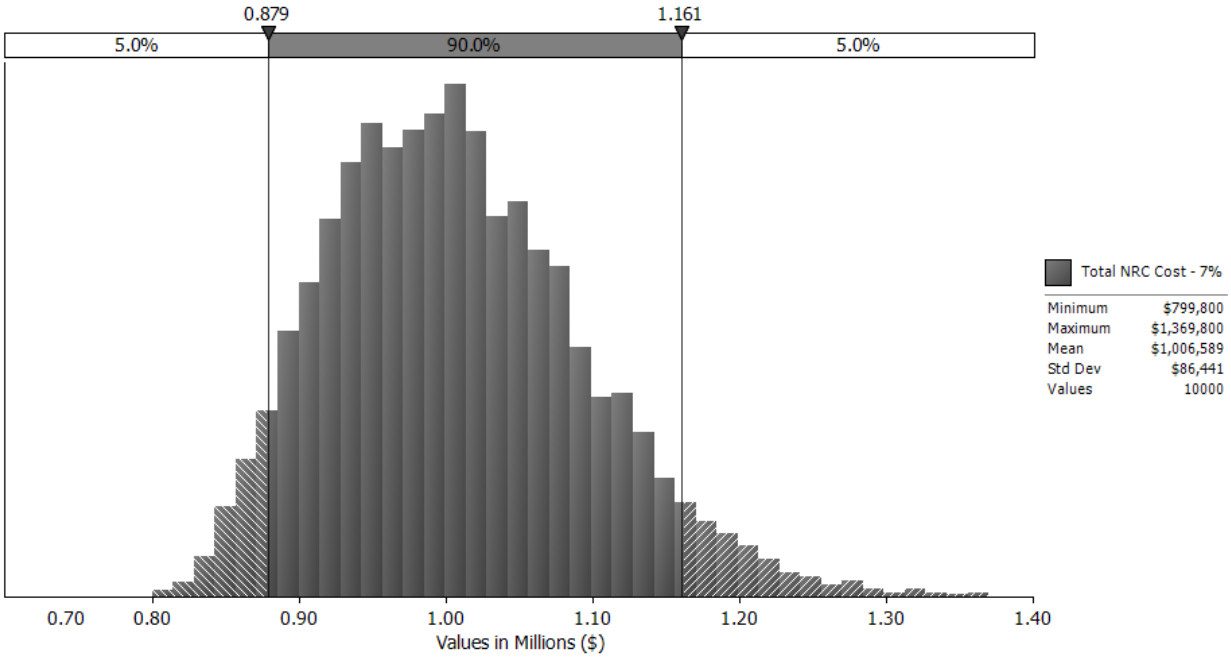

Figure 2 Uncertainty Analysis of NRC Cost Savings—Alternative 2

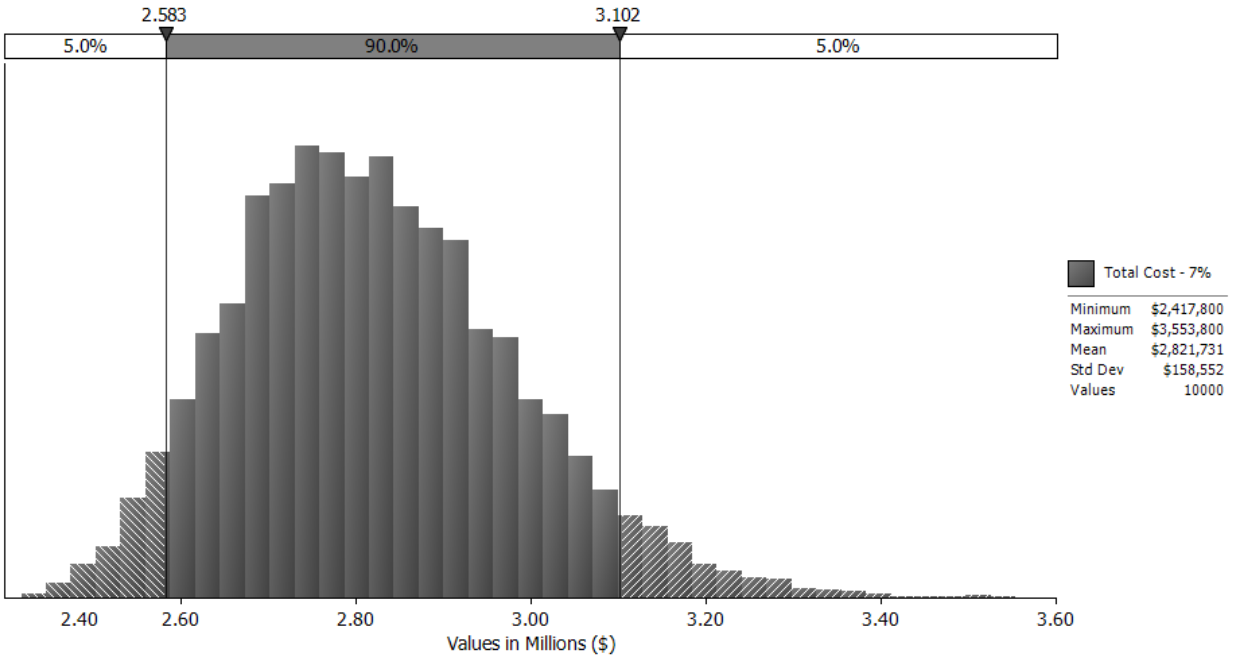

Figure 3 Uncertainty Analysis of Total Net Benefit—Alternative 2

Table 10 displays the key statistical results, including the 90-percent confidence interval in which the net benefits would fall between the 5- and 95-percentile values. Examining the output distribution provided in Table 10 makes it possible to confidently conclude that issuing NUREG-2224 has the potential to result in substantial incremental benefits.

Table 10 Uncertainty Results Descriptive Statistics (7-Percent Discount Factor)

Uncertainty Result	Cost Savings (2020 million dollars)				
	Minimum	**Mean**	**Maximum**	**5%**	**95%**
Total Industry Cost	$1.5	$1.8	$2.4	$1.6	$2.1
Total NRC Cost	$0.8	$1.0	$1.4	$0.9	$1.2
Total	$2.4	$2.8	$3.6	$2.6	$3.1

Note: The total cost is not the total of the above values because these are not normal distributions.

Figure 4 identifies the key variables whose uncertainty has the largest impact on total costs (and averted costs) for this analysis. This figure ranks the variables based on their contribution to cost uncertainty, using a 7-percent discount factor. Five variables drive the most uncertainty in the costs: (1) licensee 20+ year guidance, (2) licensee prepares and submits SSA, (3) NRC 20+ year transportation guidance, (4) NRC 2015 relief requirement (transportation of dry storage casks with ages between 0 and 20 years), and (5) NRC review of SSA. The influence of a variable on the output is not only a function of the value of that variable, but also of the spread of its distribution and the number of licensing actions to which the variable applies.

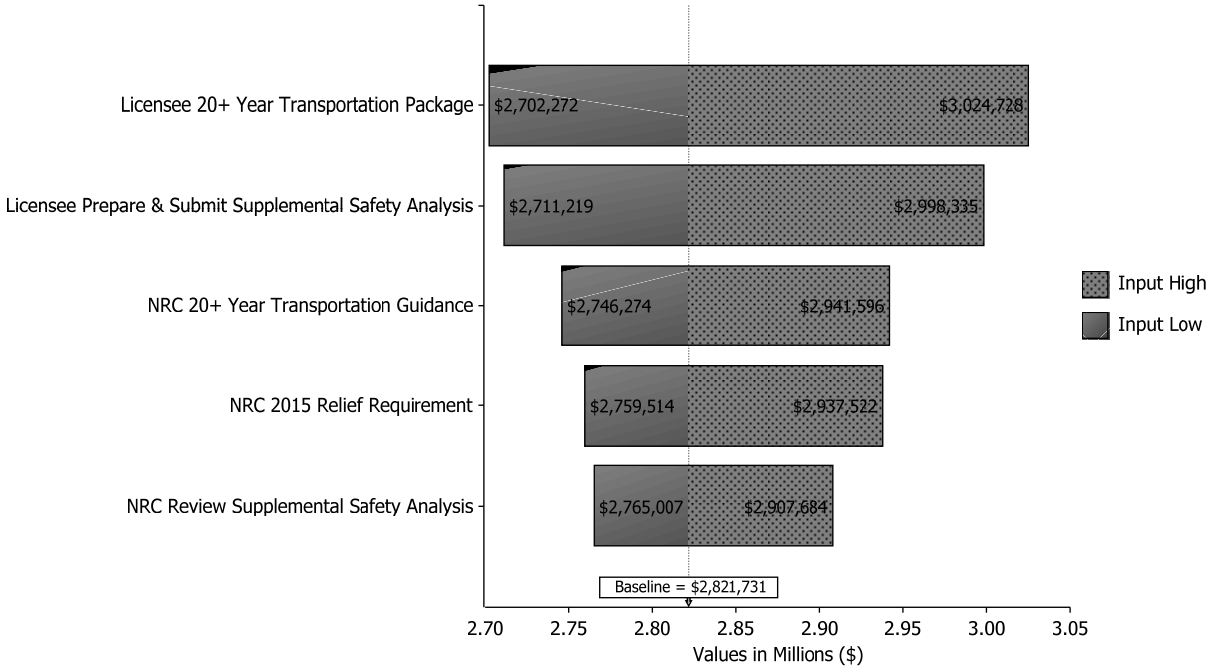

Figure 4 Effect of Uncertainty of Key Variables on Output Mean (7-Percent Discount Factor)

3.5.2 Summary of Uncertainty Analysis

The benefits of issuing NUREG-2224 have a mean value of $2.8 million in net savings at a 7-percent discount rate, with a range between $2.1 million and $3.6 million. The uncertainty analysis shows a 100-percent chance that issuing NUREG-2224 would be cost effective because the minimum calculated result is a positive value.

3.6 Disaggregation

The NRC performed a screening review to determine whether any provisions would be unnecessary to achieve the regulatory objectives. The staff did not identify any unnecessary or unrelated provisions; therefore, it did not perform a disaggregation for this regulatory analysis.

4 PRESENTATION OF RESULTS

Table 11 summarizes both quantifiable and nonquantifiable costs and benefits that would result from issuing NUREG-2224. Although quantifiable costs and benefits appear to be more tangible, the NRC urges decisionmakers not to discount costs and benefits that are nonquantifiable. Such benefits or costs can be just as important as, or even more important than, benefits or costs that can be quantified and monetized.

Table 11 Summary of Net Benefit (or Cost)

Monetary Benefit (or Cost)	Nonmonetary Benefit (or Cost)
Alternative 1—No Action $0	**Alternative 1—No Action** None
Alternative 2—Issue NUREG-2224 **Quantitative Benefit:** Industry Net Benefit: $1.8 million using a 7% discount rate $2.9 million using a 3% discount rate NRC Net Benefit: $1.0 million using a 7% discount rate $1.4 million using a 3% discount rate **Total Quantitative Net Benefit:** $2.8 million using a 7% discount rate $4.3 million using a 3% discount rate	**Alternative 2—Issue NUREG-2224** **Qualitative Benefit:** • Provides the technical basis in support of the NRC's guidance on adequate fuel conditions as it pertains to hydride reorientation in HBU SNF cladding. The guidance defines adequate fuel conditions, including peak cladding temperatures during short-term loading operations to prevent or mitigate degradation of the cladding. • Addresses the problem of lengthy application reviews due to the lack of submittal standardization. • Provides expanded technical analysis documenting a lack of aging management issues when adequate safety analyses are provided in the application. • Makes available the most current technical information or incorporates insights from the engineering assessment, which helps achieve the NRC's objective to increase the efficiency in the renewal application process. • Provides cost savings associated with fabrication of transportation packages due to the relief of prior guidance for the transport of HBU SNF in designs that ensured moderator exclusion (NRC, 2015). The latter cost savings are difficult to quantify since fabrication costs are not readily available or tracked by the NRC. • The issuance of regulatory guidance will enable greater regulatory efficiency, as applicants will be able to more effectively prepare, and the staff efficiently review, license amendments and renewal

Monetary Benefit (or Cost)	Nonmonetary Benefit (or Cost)
	applications because of clarity in the staff's technical position and the need for fewer NRC RAIs. • No significant change in public or occupational radiation exposure. **Total Qualitative Net Benefit:** • Positive qualitative benefit

5 DECISION RATIONALE

The analysis shows that license amendments and renewals of spent fuel dry storage terms from 20 to 60 years would incur substantial benefits from the proposed Alternative 2. The issuance of NUREG-2224 encourages applicants to use a regulatory process that would allow them to submit high-quality applications that would save millions of dollars in renewal application costs over the 40-year regulatory analysis period. The NRC would similarly experience a saving of up to a million dollars, as the time required to review and approve a license amendment or renewal is anticipated to decrease by reducing RAIs from the NRC staff and reducing redundant, case-by-case reviews of the same technical topics.

As noted in Table 9, based solely on quantified costs and benefits, the regulatory analysis shows that the issuance of NUREG-2224 would result in a mean benefit to industry that ranges from $1.8 million (7-percent discount rate) to $2.9 million (3-percent discount rate). The NRC's mean benefit ranges from $1.0 million (7-percent discount rate) to $1.4 million (3-percent discount rate). Therefore, the total quantitative mean net benefit (averted costs) of issuing the guidance would range from $2.8 million (7-percent discount rate) to $4.3 million (3-percent discount rate).

Even if the issuance of NUREG-2224 were found not to be cost beneficial on a monetary basis, the non-quantified costs and benefits in Table 10 show that issuing the guidance document may be justified because it is anticipated to result in net benefits to improvements in knowledge and increases in regulatory efficiency. The knowledge shared by NUREG-2224 is expected to facilitate safety enhancements for long-term storage and transportation of SNF.

Therefore, when considering both quantified and nonquantified costs and benefits, the staff concludes that the issuance of NUREG-2224 is expected to result in a beneficial impact, which provides an adequate basis to conclude that Alternative 2 is the preferred alternative.

The staff recommends Alternative 2, issue NUREG-2224, as this provides the greatest cost benefit.

5.1 Regulatory Flexibility Analysis

The Regulatory Flexibility Act, enacted in September 1980, requires agencies to consider the effect of their regulatory proposals on small entities, analyze alternatives that minimize effects on small entities, and make their analyses available for public comment.

This NUREG primarily affects large entities but does impact one small entity, of which meets the definition of "small entities" set forth in the size standards established by the NRC in 10 CFR 2.810, "NRC size standards." Issuing NUREG-2224 does not have a significant economic impact on this small entity because NUREG-2224 provides guidance that entities may follow for small or large entities to realize incremental savings through the implementation of this NUREG. The NUREG does not impose any additional obligations on entities if they choose not to use the guidance. However, should these entities choose to use this guidance, the analysis shows that there will be an average net savings of $188,000 for most licensees.

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