**Regulatory Analysis for Proposed Rulemaking 10 CFR 50.46c:**
**“Emergency Core Cooling System Performance during Loss-of-Coolant Accidents”**

**March 24, 2014**

U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation
Division of Policy and Rulemaking

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## Abbreviations

ADAMS – Agencywide Documents Access and Management System

ANL – Argonne National Laboratory

AOR – Analysis of Record

BWR – Boiling Water Reactor

CFR – Code of Federal Regulations

CP-ECR – Cathcart-Pawel – Equivalent Cladding Reacted

DG – Draft Regulatory Guide

ECCS – Emergency Core Cooling System

ECR – Equivalent Cladding Reacted

FR – Federal Register

FRN – Federal Register Notice

FTE – Full-time Equivalent

GDC – General Design Criterion

GSI – Generic Safety Issue

LAR – License Amendment Request

LTC – Long-Term Cooling

LOCA – Loss-of-Coolant Accident

LWR – Light Water Reactor

NEI- Nuclear Energy Institute

NRC – United States Nuclear Regulatory Commission

PCT – Peak Cladding Temperature

PQD – Post Quench Ductility

PRA – Probabilistic Risk Assessment

PRM – Petition for Rulemaking

PWR – Pressurized Water Reactor

RIL – Research Information Letter

RIN – Regulation Identifier Number

RG – Final Regulatory Guide

SRM – Staff Requirements Memorandum

SOC – Statement of Considerations

STPNOC – South Texas Project Nuclear Operating Company

UFSAR – Updated Final Safety Analysis Report

TR – Topical Report

# 1. Introduction

This document presents a regulatory analysis of a proposed rule (and implementing regulatory guidance) that would amend Title 10 of the *Code of Federal Regulations* (10 CFR) by establishing new, performance-based requirements for emergency core cooling systems (ECCS) for light water nuclear power reactors.

## 1.1 Background

In SECY-98-300, "Options for Risk-Informed Revisions to 10 CFR Part 50-'Domestic Licensing of Production and Utilization Facilities,'" dated December 23, 1998 (the U.S. Nuclear Regulatory Commission's (NRC) Agencywide Documents Access and Management Systems (ADAMS) Accession No. ML992870048), the NRC began to explore approaches to risk-informing its regulations for nuclear power reactors. One alternative (termed "Option 3") involved making risk-informed changes to the specific requirements in the body of 10 CFR Part 50. As the NRC began to develop its approach to risk-informing these requirements, it sought stakeholder input in public meetings. Two of the regulations identified by industry as potentially benefitting from risk-informed changes were §§ 50.44 and 50.46. Section 50.44 specifies the requirements for combustible gas control inside reactor containment structures, and § 50.46 specifies the requirements for light-water power reactor emergency core cooling systems. For § 50.46, the potential was identified for making risk-informed changes to requirements for both ECCS cooling performance and ECCS analysis acceptance criteria in § 50.46(b).

On March 14, 2000, as amended on April 12, 2000, the Nuclear Energy Institute (NEI) submitted a petition for rulemaking (PRM) requesting that the NRC amend its regulations in §§ 50.44 and 50.46 (PRM-50-71) (ADAMS Accession No. ML003723791). The NEI petition noted that these two regulations apply to only two specific zirconium-alloy fuel cladding materials (zircaloy and ZIRLO™). The NEI stated that reactor fuel vendors[1] had subsequently developed new cladding materials other than zircaloy and ZIRLO™ and that, in order for licensees to use these new materials under the regulations, licensees had to request NRC approval of exemptions from §§ 50.44 and 50.46.

On May 31, 2000, the NRC published a notice of receipt in the *Federal Register* (65 FR 34599) and requested public comment. The public comment period ended on August 14, 2000, and the NRC received 11 public comment letters from public citizens and the nuclear industry. Although the majority of the comments generally supported the requests of the PRM, one commenter suggested that the enhanced efficiency of the proposal would be at the expense of public health and safety. The NRC disagrees with that commenter and notes that, while the petition's proposal would remove specific zirconium-alloy names from the regulation, the NRC review and approval of specific zirconium-alloys for use as reactor fuel cladding would be required prior to their use in reactors (with the exception of lead test assemblies permitted by technical specifications). A detailed discussion of the public comments submitted on PRM-50-71 is contained in a separate document (*see* Section IX of the proposed rule Statement of Considerations (SOC), "Availability of Documents.")

After evaluating the petition and public comments received, the NRC decided that PRM-50-71 should be considered in the rulemaking process. The NRC's determination was published in the *Federal Register* on November 6, 2008 (73 FR 66000). Because most of the issues raised in this PRM pertain to § 50.46, the PRM is addressed in this proposed rule. The PRM also requested changes to § 50.44. Those changes were addressed in a rulemaking that revised that section (68 FR 54123; September 16, 2003) to include risk-informed requirements

[1] For the purpose of this analysis, the term "vendor" refers to manufacturers of NRC approved fuel assembly designs. To support implementation of the proposed requirements on individual plant dockets, fuel vendors would submit for NRC review alloy-specific hydrogen uptake models and LOCA model updates.

for combustible gas control. The regulation was also modified to be applicable to all boiling or pressurized water reactors regardless of the type of fuel cladding material used.

On March 31, 2003, in response to SECY-02-0057, "Update to SECY-01-0133, 'Fourth Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.46 (ECCS Acceptance Criteria)'" (ADAMS Accession No. ML020660607), the Commission issued a staff requirements memorandum (SRM) (ADAMS Accession No. ML030910476) directing the NRC staff to move forward to risk-inform its regulations in a number of specific areas. Among other things, this SRM directed the staff to modify the ECCS acceptance criteria to provide a more performance-based approach to the ECCS requirements in § 50.46.

Separate from the effort to modify the regulations to provide a more risk-informed, performance-based regulatory approach, the NRC had also undertaken a fuel cladding research program to investigate the behavior of high-exposure fuel cladding under accident conditions. This research program included an extensive loss-of-coolant accident (LOCA) research and testing program at Argonne National Laboratory (ANL), as well as jointly-funded programs at the Kurchatov Institute (supported by the French Institute for Radiological Protection and Nuclear Safety and the NRC) and the Halden Reactor project (a jointly-funded program under the auspices of the Organization for Economic Cooperative Development – Nuclear Energy Agency, sponsored by national organizations in 18 countries), to develop the body of technical information needed to support the new regulations.

The effects of both alloy composition and fuel burnup (the extent to which fuel is used in a reactor) on cladding embrittlement (i.e., loss of ductility) under accident conditions were studied in these research programs. The research programs identified new cladding embrittlement mechanisms and expanded the NRC's knowledge of previously identified mechanisms. The research results revealed that alloy composition has a minor effect on embrittlement, but that the cladding corrosion that occurs as fuel burnup increases has a substantial effect on embrittlement. One of the major findings of the NRC's research program was that hydrogen, which is absorbed in the cladding as a result of zirconium oxidation (i.e., corrosion) under normal operation, has a significant influence on embrittlement during a postulated LOCA. Increased hydrogen content increases both the solubility of oxygen in zirconium and the rate at which it is diffused within the metal, thus increasing the amount of oxygen in the metal during high temperature oxidation in LOCA conditions. Further, the NRC's research program found that oxygen from the oxide fuel pellets enters the cladding from the inner surface if a bonding layer exists between the fuel pellet and the cladding, in addition to the oxygen that enters from the oxide layer on the outside of the cladding. Moreover, under some small-break LOCA conditions (such as extended time-at-temperature around 1,000 degrees Celsius (°C) (1832 degrees Fahrenheit (°F))), the accumulating oxide on the surface of the cladding can break up, allowing large amounts of hydrogen to diffuse into the cladding, exacerbating the embrittlement process.

The research results also confirmed a previous finding that if cladding rupture occurs during a LOCA, large amounts of hydrogen from the steam-cladding reaction can enter the cladding inside surface near the rupture location. These research findings have been summarized in Research Information Letter (RIL)-0801, "Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46" (ADAMS Accession No. ML081350225), and the detailed experimental results from the program at ANL are contained in NUREG/CR-6967, "Cladding Embrittlement during Postulated Loss-of-Coolant Accidents" (ADAMS Accession No. ML082130389). Since the publication of NUREG/CR-6967 and RIL-0801, additional testing was conducted related to the embrittlement phenomenon, which was documented in supplemental reports. Where the additional testing relates to conclusions and recommendations in RIL-0801, RIL-0801 has been supplemented to reference the additional reports and incorporate findings (ADAMS Accession No. ML113050484).

The NRC publicly released the technical basis information in RIL-0801 on May 30, 2008, and NUREG/CR-6967 on July 31, 2008. Also on July 31, 2008, the NRC published in the *Federal Register* a notice of availability of the RIL and NUREG/CR-6967, together with a request for comments (73 FR 44778). In that notice, the NRC stated that these documents and comments on the documents would be discussed at a public workshop to be scheduled for September 2008. The public workshop was held on September 24, 2008, and included presentations and open discussion among representatives of the NRC, international regulatory and research agencies, domestic and international commercial power firms, fuel vendors, and the general public. A summary of the workshop, including a list of attendees and presentations, is available in ADAMS under Accession No. ML083010496. The NRC has not prepared responses to comments received on the technical basis information as a result of the July 31, 2008, *Federal Register* notice (FRN) (including comments received at the September 2008 public workshop), because: 1) the public workshop was held, in part, to discuss public comments on the technical basis information; and 2) further opportunity to comment is available during the proposed rule's formal public comment period.

Based upon a preliminary safety assessment in response to the research findings in RIL-0801, the NRC determined that immediate regulatory action was not required, and that changes to the ECCS acceptance criteria to account for these new findings could reasonably be addressed through the rulemaking process. Recognizing that finalization and implementation of the new ECCS requirements would take several years, the NRC completed a more detailed safety assessment which confirmed current plant safety for every operating reactor. See Section III.A of the proposed rule SOC for further information.

On March 15, 2007, Mark Leyse (the petitioner) submitted a PRM to the NRC (ADAMS Accession No. ML070871368) requesting that all holders of operating licenses for nuclear power plants be required to operate such plants at operating conditions (e.g., levels of power production, and light-water coolant chemistries) necessary to effectively limit the thickness of crud[2] and/or oxide layers on fuel rod cladding surfaces. The petitioner requests that the NRC conduct rulemaking in the following three specific areas:

1) Establish regulations that require licensees to operate light-water power reactors under conditions that are effective in limiting the thickness of crud and/or oxide layers on zirconium-clad fuel in order to ensure compliance with § 50.46(b) ECCS acceptance criteria;

2) Amend appendix K to 10 CFR part 50 to explicitly require that steady-state temperature distribution and stored energy in the reactor fuel at the onset of a postulated LOCA be calculated by factoring in the role that the thermal resistance of crud deposits and/or oxide layers plays in increasing the stored energy in the fuel (these requirements also need to apply to any NRC-approved, best-estimate ECCS evaluation models used in lieu of appendix K to 10 CFR part 50 calculations); and

3) Amend § 50.46 to specify a maximum allowable percentage of hydrogen content in (fuel rod) cladding.

On May 23, 2007, the NRC published a notice of receipt for this petition in the *Federal Register* (72 FR 28902) and requested public comment. The public comment period ended on August 6, 2007. Comments in support of PRM-50-84 were provided by the Union of Concerned Scientists, two individuals, and the petitioner. The NEI and Strategic Teaming and Resource Sharing organization submitted comments in opposition to the petition. After evaluating the

[2] For the purpose of this discussion, the NRC defines "crud" as any foreign substance deposited on the surface of the fuel cladding prior to the initiation of a LOCA. It is known that this layer can impede the transfer of heat.

public comments, the NRC resolved PRM-50-84 by deciding that each of the petitioner's issues should be considered in the rulemaking process. The NRC's determination, including the NRC's response to public comments received on the petition, was published in the *Federal Register* on November 25, 2008 (73 FR 71564). Because the issues raised in the petition pertain to ECCS analysis and acceptance criteria, the need for rulemaking to address each of the petitioner's concerns will be addressed in this proposed rule.

The proposed rule would provide a risk-informed approach to address the effects of debris on long-term cooling. This approach could be used to close all actions related to Generic Safety Issue (GSI)-191, "Assessment of Debris Accumulation on Pressurized Water Reactor Sump Performance," which concluded that debris could clog the containment sump strainers in pressurized water reactors (PWRs) leading to the loss of net positive suction head for the ECCS and containment spray system pumps. The NRC issued Generic Letter (GL) 2004-02, "Potential Impact of Debris Blockage on Emergency Recirculation During Design Basis Accidents at Pressurized-Water Reactors," dated September 13, 2004 (ADAMS Accession No. ML042360586), requesting that licensees address the issues raised by GSI-191. The staff also prepared several Commission papers on GSI-191 and had numerous public interactions on the same subject. For additional background information, please see SECY-12-0093, "Closure Options for Generic Safety Issue – 191, Assessment of Debris Accumulation on Pressurized-Water Reactor Sump Performance," dated July 9, 2012 (ADAMS Accession No. ML121320270).

## 2. Statement of the Problem and Objective

### 2.1 Statement of the Problem

The proposed action is needed in response to recent research by ANL, the Kurchatov Institute, and the Halden Reactor project into the behavior of fuel cladding under accident conditions, mainly a LOCA. This research indicated that the current combination of peak cladding temperature (PCT) (2200 °F (1204 °C)) and local cladding oxidation criteria (17 percent) do not always ensure post quench ductility (PQD) following a postulated LOCA. The proposed action would replace the limits on PCT and local oxidation with specific cladding performance requirements and acceptance criteria that ensure that an adequate level of cladding ductility is maintained throughout the postulated LOCA. The NRC developed three draft regulatory guides (DGs) that provide acceptable means of meeting the proposed performance requirements. The three DGs are: DG-1261, "Conducting Periodic Testing for Breakaway Oxidation Behavior" (ADAMS Accession No. ML12284A324); DG-1262, "Testing for Post Quench Ductility" (ADAMS Accession No. ML12284A325); and DG-1263, "Establishing Analytical Limits for Zirconium-Based Alloy Cladding" (ADAMS Accession No. ML12284A323).

The proposal to expand applicability to all light-water nuclear power reactors, regardless of fuel design or cladding material used, is necessary to account for the development of new fuel designs and cladding materials other than zircaloy and ZIRLO™. Under the current rule, licensees that use different types of cladding material are required to request NRC approval for an exemption from the rule.

The proposal would also require licensees to evaluate thermal effects of crud and oxide layers that accumulate on fuel cladding. This proposed amendment would address one of the requests of PRM-50-84.

Lastly, the NRC identified the need for an approach that would allow entities to address the effects of debris on long-term cooling in a manner that would be more timely and cost-effective for some licensees than the current use of deterministic methods. The proposed rule would contain a provision that would allow licensees to use an alternative risk-informed approach to evaluate the effects of debris for long-term cooling (LTC).

## 2.2 Objectives

The principal objectives of the proposed revision to the requirements for ECCS performance for light-water nuclear power reactors are to provide more performance-based criteria and also account for the new research information. Further, the NRC intends to expand the applicability of the rule to all fuel design and fuel cladding materials. In addition, this proposed rule would address the issues raised in PRM-50-71 and PRM-50-84. This proposed rule would also provide an alternative approach for addressing the effects of debris on long-term cooling.

As noted in Section V of the proposed rule SOC, and expanded upon in Section XVIII of the SOC, "Backfitting and Issue Finality," this rulemaking is proposed because of the NRC's position that it is necessary to ensure adequate protection to the public health and safety. The proposed rule would ensure that the level of protection intended to be achieved by the current rule is maintained. Regulatory guidance, in the form of three DGs, were developed in order to: (1) provide a clear, acceptable methodology for supporting and establishing the performance-based regulatory limits called for in § 50.46c; (2) simplify the NRC staff's review process; and (3) reduce regulatory uncertainty and thereby help to minimize the costs associated with the implementation of the regulatory requirements proposed for § 50.46c.

This regulatory analysis was developed following the "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission"[3] (Guidelines). In particular, with regard to adequate protection, the Guidelines state that, "The level of protection constituting 'adequate protection' is

[3] NUREG/BR-0058, Revision 4, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," Office of Nuclear Regulatory Research, September 2004 (http://www.nrc.gov/reading-rm/doc-collections/nuregs/brochures/br0058/#pub-info).

that level which must be assured *without regard to cost"* (emphasis added). The Guidelines also state that " . . . a proposed backfit to one or more of the facilities regulated under 10 CFR part 50 does not require a regulatory analysis if the resulting safety benefit is required for purposes of compliance or adequate protection under 10 CFR 50.109(a)(4)." However, the Guidelines note that if there is more than one way to achieve compliance or reach a level of adequate protection, costs may be a factor in that decision. With respect to the regulatory guides, the NRC believes that the development of such guidance for § 50.46c is desirable in order to ensure a consistent means of generating and using experimental data to establish regulatory limits.

### 2.3 Disaggregation

In order to comply with the guidance provided in Section 4.3.2 ("Criteria for the Treatment of Individual Requirements") of the Guidelines, the NRC conducted a screening review to determine if any of the individual requirements (or set of integrated requirements) of the proposed rule are unnecessary to achieve the objectives of the rulemaking. The NRC determined the objectives of the rulemaking are to: 1) incorporate recent research findings; 2) establish performance-based requirements for ECCS in the event of a LOCA; 3) expand the regulation's applicability; 4) incorporate the requests of two PRMs; and 5) include a provision to allow risk-informed submittals to evaluate the effects of debris on long-term cooling. Furthermore, the NRC concluded that each of the proposed rule's requirements is necessary to achieve one or more objectives of the rulemaking. The results of this determination are set forth in the following table.

**Table 1 - Disaggregation**

| Regulatory Goals for 10 CFR 50.46c | 1) Revise the ECCS acceptance criteria to reflect recent research findings | 2) Establish performance-based requirements | 3) Expand applicability of10 CFR 50.46 to all fuel types and cladding materials | 4) Incorporate requests of two PRMs | 5) Include a provision to allow risk-informed approach for addressing the effects of debris on long-term cooling |
|---|---|---|---|---|---|
| Paragraph (a) Applicability. | | | X | X | |
| Paragraph (b) Definitions. | X | | | | |
| Paragraph (d) Emergency core cooling system design. | | X | | | |
| Paragraph (g) Fuel system designs: uranium oxide or mixed uranium-plutonium oxide pellets within cylindrical zirconium-alloy cladding. | X | | | | |
| Paragraph (k) Use of NRC approved fuel in reactor. | | | X | X | |
| Paragraph (m) Reporting. | X | | | | X |
| Paragraph (d)(2)(iii) Core Geometry and Coolant Flow. | | | | | X |
| Paragraph (e) Alternate Risk-Informed Approach for | | | | | X |

| Regulatory Goals for 10 CFR 50.46c | 1) Revise the ECCS acceptance criteria to reflect recent research findings | 2) Establish performance-based requirements | 3) Expand applicability of10 CFR 50.46 to all fuel types and cladding materials | 4) Incorporate requests of two PRMs | 5) Include a provision to allow risk-informed approach for addressing the effects of debris on long-term cooling |
|---|---|---|---|---|---|
| Addressing the Effects of Debris on Long-Term Core Cooling. | | | | | |

## 3. Identification and Preliminary Analysis of Alternative Approaches

Given the existing data and information, this proposed rule and the no-action alternative (described below as addressing the embrittlement and risk-informed alternative by a case-by-case method) are considered by the NRC to be the only credible regulatory actions to maintain adequate protection. Consequently, a rulemaking is the only regulatory action alternative considered other than the no-action alternative.

### 3.1 No-Action Alternative

The no-action alternative is used only as a basis against which to measure the costs and benefits of the proposed rule. The no-action alternative requires that the embrittlement issue and the risk-informed approach to evaluating the effects of debris on long-term cooling be resolved on a case-by-case basis (e.g., license amendments, orders). This would require exemption requests and other administrative costs that are shown in the attributes as negative costs (i.e., savings) for the proposed rule.

In light of recent research findings that indicate that the current regulations do not always ensure PQD following a LOCA, this proposed rule is necessary to ensure adequate protection to the public health and safety by maintaining that level of protection (i.e., reasonable assurance of adequate protection) that the NRC thought previously would be achieved (throughout the entire term of licensed operation). However, based upon a preliminary safety assessment in response to the research findings in RIL-0801, the NRC determined that immediate regulatory action was not required, and that changes to the ECCS acceptance criteria to account for these new findings could reasonably be addressed through the rulemaking process. Recognizing that finalization and implementation of the new ECCS requirements would take several years, the NRC completed a more detailed safety assessment that confirmed current plant safety for every operating reactor. See Section II.A of the proposed rule SOC for further information.

### 3.2 Proposed Rule Alternative

The proposed rule alternative would amend the current regulations for ECCS acceptance criteria, found in § 50.46(b), by establishing performance-based requirements. The proposed rule would expand applicability to all light water reactors (LWRs), regardless of fuel design or cladding materials. It should be noted that this amendment would satisfy a request of PRM-50-71. The proposed rulemaking would also incorporate recent research findings that identified previously unknown cladding embrittlement mechanisms and expanded the NRC's knowledge of previously identified mechanisms. Specifically, the research identified that hydrogen, which is absorbed in the cladding during normal operation, has a significant influence on embrittlement during a postulated accident. The proposed rule would also require licensees to evaluate the thermal effects of crud and oxide layers that may have developed on the fuel cladding. It should be noted that this amendment would satisfy a request of PRM-50-84. Finally, the proposed rule alternative would allow licensees to use an alternative risk-informed approach to evaluate the effects of debris on long-term cooling. Including the risk-informed alternative in this proposed rule would alleviate the need for a GSI-191 related rulemaking and would decrease the NRC and Industry implementation costs in relation to developing another rule. Including the risk-informed alternative is also based on the SRM on the proposed rule, SRM-SECY-12-0034, “Proposed Rulemaking – 10 CFR 50.46c: Emergency Core Cooling System Performance During Loss-of-Coolant Accidents (RIN 3150-AH42),” which directed: “Regarding Generic Safety Issue 191, the 10 CFR 50.46c proposed rule should contain a provision allowing NRC licensees, on a case-by-case basis, to use risk-informed alternatives without an exemption request.”

### 3.3 Regulatory Guidance

Because the proposed rule would be performance-based, three companion DGs were developed. The proposed rule calls for measurement of the onset of breakaway oxidation for a zirconium cladding alloy based on an acceptable experimental technique. The proposed rule also calls for the evaluation of the measurement relative to emergency core cooling system performance, and periodic testing and reporting of the values measured. Draft Guide-1261 describes an experimental technique acceptable to the NRC staff to measure the onset of breakaway oxidation in order to support a specified and acceptable limit on the total accumulated time that a cladding may remain at high temperature, as well as a method acceptable to the NRC to implement the periodic testing and reporting requirements in the proposed rule.

The proposed rule also calls for the establishment of analytical limits on peak cladding temperature and time at elevated temperature that correspond to the measured ductile-to-brittle transition for the zirconium-alloy cladding material. Draft Guide-1262 describes an experimental technique that is acceptable to the NRC for measuring the ductile-to-brittle transition for a zirconium-based cladding alloy. Draft Guide-1263 provides a method of using experimental data to establish regulatory limits. These DGs will be published for comment along with the proposed rule.

With regard to the risk-informed alternative to address the effects of debris on long-term cooling, South Texas Project Nuclear Operating Company (STPNOC) submitted a letter of intent to pilot a risk-informed approach for addressing GSI-191 (ADAMS Accession No. ML103481027) in December 2010. Subsequently, the NRC received a pilot submittal from STPNOC on January 31, 2013 (ADAMS Accession No. ML13043A013), supplemented June 19, 2013 (ADAMS Accession No. ML131750250). In parallel with the NRC's review of the application, the NRC will develop draft guidance for the risk-informed alternative to address the effects of debris on long-term cooling. That draft guidance will be published for comment upon completion, which is currently anticipated for early- to mid-calendar year 2015. The NRC will then evaluate public comments received on the draft guidance, and develop the final guidance on a timeline that ensures all guidance (both for the risk-informed alternative and the new proposed embrittlement criteria) is available when the NRC staff provides the final § 50.46c rule to the Commission (currently scheduled for February 2016).

## 4. Estimation and Evaluation of Values and Impacts

This section identifies the components of the public and private sectors, commonly referred to as attributes, that are expected to be affected by this rulemaking. An inventory of the impacted attributes was developed using the list provided in Chapter 5 of the NRC's "Regulatory Analysis Technical Evaluation Handbook"[4] (Handbook). The identified impacts are quantified where possible.

[4] NUREG/BR-0184, "Regulatory Analysis Technical Evaluation Handbook," U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research, 1997.

## 4.1 Assumptions

All 100 currently operating light-water nuclear power reactors[5] would be affected by this proposed rule. The quantifiable impacts (i.e., those that are able to be monetized), are the implementation and operation costs for both industry and the NRC. All monetized costs are expressed in 2017 dollars, the year the rule is assumed to be implemented. Other than for operating reactors that have indicated they would not seek a license renewal, this analysis assumes that remaining operating reactors' life expectancy would include a 20-year license extension, unless stated otherwise.[6] As a result, the average license would expire in 2039. Given that the rule is assumed to be implemented in 2017, the average remaining life would be 22 years from implementation and any recurring costs would be discounted over that time period. Any costs incurred over future years would be discounted back to 2017 values at both a 3 percent and 7 percent discount rate. Based on the most recent NRC labor rates, using the methodology described in NUREG/CR-6967, Revision 2, "Generic Cost Estimates: Abstracts from Generic Studies for Use in Preparing Regulatory Impact Analyses," dated February 1992, an NRC staff-year is valued at $173,000, while an annual industry staff labor rate of $200,000 is assumed.

There are currently two design certifications that are expected to be renewed. For the regulatory analysis, the NRC assumes that these are the only design certifications that would be submitted.

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[5] The NRC does not consider San Onofre Nuclear Generating Station, Units 2 and 3, Crystal River Nuclear Plant, Unit 3 and Kewaunee Nuclear Power Plant because they have submitted their certification of permanent cessation of power operations per § 50.82(a)(1)(i). The NRC continues to consider Vermont Yankee Nuclear Power Station in the regulatory analysis because, while Vermont Yankee submitted a notification of permanent cessation of power operations under § 50.82(a)(1)(i) (see ADAMS Accession No. ML13273A204), that notification contained only an estimate of the date of cessation. Vermont Yankee plans to supplement that letter with a (firm) date of cessation, as required per §§ 50.82(a)(1)(i) and 50.4(b)(8). The final regulatory analysis will reflect that data.

[6] Oyster Creek Nuclear Power Plant is planned to close in 2019. See http://www.exeloncorp.com/PowerPlants/oystercreek/Pages/profile.aspx.

The NRC assumes that there are six future operating light-water nuclear power reactors that would be affected by this rule. The nuclear power reactors are: Watts Bar Nuclear Power Plant, Unit 2, with an assumed beginning of operations date in 2015; Vogtle Electric Generating Plant (Vogtle), Units 3 and 4, with an assumed beginning of operations date of 2017; Virgil C. Summer Nuclear Station, Units 2 and 3, with an assumed beginning of operations dates of 2017 and 2019, respectively; and Bellefonte Nuclear Station Unit 1, with an assumed beginning of operations date of 2020.[7]

The NRC assumes that other new design certifications could be submitted to the NRC for approval and has developed a hypothetical design certification to analyze the costs and benefits of the proposed rule on a design certification.

The NRC also assumes that other new light-water nuclear power reactors could begin to operate in the future and has developed a hypothetical light-water nuclear power reactor to analyze the costs and benefits of the proposed rule on a new light-water nuclear power reactor. The NRC assumes that no other types of reactors would be built and that there would be no significant differences between the future operating reactors and the hypothetical reactor.

Another assumed difference in this analysis is that industry implementation costs are separated into direct and indirect costs. This difference is explained further in Section 4.2, "Industry Implementation".

The NRC assumes that the final rule is published on January 1, 2017. It would then take vendors approximately 1 year to submit their revised models. The NRC assumes that nine alloy-specific cladding hydrogen uptake models would need to be developed and 12 existing LOCA models would need to be revised in order to implement the proposed rule. (To facilitate this analysis, and the assumptions within, the LOCA models are distinguished between

[7] Bellefonte Nuclear Station, Unit 2, as well as all other combined license applications submitted to the NRC are too speculative in nature to be included in the regulatory analysis.

PQD/Breakaway and LTC.) Next, the NRC assumes 1 year for the NRC review and comment of the nine vendor cladding hydrogen uptake models, and 2 years for the NRC review and comment of the twelve vendor LOCA models. Next, the 64 plants in Track 1 would demonstrate compliance within 24 months by providing a letter report to the NRC. No NRC review of these letters would be necessary. Finally, the remaining 36 plants in Tracks 2 and 3 would demonstrate compliance within 48 months and 60 months, respectively, by submitting a new LOCA analysis of record (AOR).

### 4.2 Industry Implementation

This attribute is composed of indirect and direct licensee implementation costs for operating reactors, design certifications and future operating reactors. The proposed rule would require licensees of operating reactors, design certifications, and future operating reactors to make use of revised ECCS analysis models based upon the new required acceptance criteria. The revised ECCS models and alloy-specific cladding hydrogen uptake models would be developed by vendors, at the request and expense of the licensees. Because the vendors are not licensed by the NRC and are developing the revised ECCS models because of the new requirements being imposed upon licensees, these costs are considered to be *indirect industry implementation costs*. The vendors would also produce licensing topical reviews describing the new models for NRC review and approval. The vendors would also produce test data to characterize alloy performance and develop analytical limits based on this test data to be included within each alloy's topical review.

After NRC approval in relation to operating reactors, the models would be run to perform plant-specific analyses, demonstrate compliance with the proposed acceptance criteria, and to employ PQD analytical limits. Costs incurred by licensees under these three tracks are considered direct industry implementation costs.

The NRC assumes that some entities will decide to implement the risk-informed alternative to the proposed rule (12 analyses of record (AOR)), based on initial industry estimates. The NRC assumes that the entities will submit the alternative in accordance with their compliance demonstration dictated by track assignment, but the NRC will support early implementation of the alternative approach, if desired. However, the NRC assumes that each entity will expend the same level of effort to develop and submit the alternative. The use of this alternative approach would obviate the need for licensees to submit four exemption requests: § 50.46c, General Design Criterion (GDC)-35, GDC-38, and GDC-41. This benefit is recognized in the same year that the licensees' submittal is received for the alternative approach.

Sixty-four operating plants under Track 1 and five future operating plants with similar implementation steps as Track 1 would complete any necessary engineering calculations, update their plant updated final safety analysis report (UFSAR), and provide a letter report to the NRC documenting compliance with § 50.46c. The plants in Track 1 meet the new requirements without new analysis or model revisions (beyond use of Cathcart-Pawel – Equivalent Cladding Reacted (CP-ECR)) to integrate time-at-temperature and hydrogen uptake models to establish PQD analytical limits), and thus would meet the new requirements with a low level of effort. The 15 operating plants in Track 2 are PWR plants using realistic evaluation models, as well as BWR/2 plants, which will require new analyses or model revisions to demonstrate compliance. The NRC anticipates that Track 2 plants will exert a medium level of effort to comply with the proposed regulation. The 21 operating plants in Track 3 are pressurized water reactor (PWR) plants using appendix K of 10 CFR part 50 evaluation models, as well as boiling water reactor (BWR)/3 plants, which will require new analyses or model revisions to demonstrate compliance. The NRC anticipates that Track 3 plants will exert a medium – high level of effort to comply with the proposed regulation. Track 2 and Track 3 plants would be required to conduct a new ECCS evaluation, and submit a new LOCA AOR. The vendors would also conduct initial breakaway testing on all cladding alloys. Again, because the vendors are not licensed by the NRC, and would be conducting initial breakaway tests because of the new requirements imposed on the licensee, these costs are considered indirect costs.

The proposed rule would require licensees to evaluate the thermal effects of crud and oxide layers that accumulate on the fuel cladding during plant operation. Because licensees are required to account for various thermal parameters under the current regulation, the NRC's position is that the proposed requirement to evaluate crud is a clarification of the current requirement. As such, there would be no additional cost incurred as a result of the rule.

Although multiple designs for new reactors have been certified by the NRC, only one type of design is currently in the construction phase in the United States, the Westinghouse Electric Company's AP1000. The AP1000 uses the same fuel design as the current fleet and, therefore, will have no effect in relation to the attributes. As no other construction has begun, all other reactor designs would be too speculative to evaluate within the Regulatory Analysis.

The current ECCS performance regulation applies to "each boiling or pressurized light-water nuclear power reactor fueled with uranium oxide pellets within cylindrical zircaloy or ZIRLO™ cladding." As such, licensees must request an exemption to use fuel designs consisting of materials other than those stated. The proposed rule would extend applicability to all LWRs, regardless of fuel design. This would eliminate the need for exemption requests, and represents a benefit.

### 4.3 NRC Implementation

The NRC would incur several implementation costs. The first set of costs is for the development of the regulatory guides and final rule. Once the rule is implemented, the NRC would review and approve the approximately 21 vendor licensing topical reviews that provide the revised ECCS analysis models. The NRC would have to review all of the risk-informed alternatives submitted by the licensees (12 AORs). Because the use of this alternative approach would obviate the need for licensees to submit four exemption requests, the NRC would no longer need to review four exemption requests for each of the alternatives submitted. Next, the NRC would need to review the approximately 25 revised ECCS AORs in Tracks 2 and 3 (due to multiple unit sites that share common analyses, this total number of AORs covers 36 plants). Lastly, the proposed rule alternative would eliminate the need for licensees to submit an exemption request to use materials other than "uranium oxide pellets within cylindrical zircaloy or ZIRLO™ cladding." The NRC would no longer be required to review such exemption requests, which results in a benefit.

### 4.4 Industry Operation

Industry would incur annual costs in performing the periodic breakaway tests. These tests involve the performance of the required breakaway oxidation tests as performed by vendors and, as a result, are considered indirect costs. These costs would be incurred for plants that are both currently operating or operating in the future (does not apply to design certifications). The NRC notes that the proposed rule would require licensees to report errors in calculated equivalent cladding reacted (ECR) in concert with reported changes in peak cladding temperature (PCT). For the purposes of this analysis, the NRC assumes that the cost of reporting ECR is negligible since licensees calculate ECR under the current regulation and are already required to report changes to or errors in ECCS evaluation models with respect to calculated PCT.

The NRC notes that the proposed reporting criteria are restructured and rewritten to provide clarification on which items need to be reported, and the timeframe for reporting. The proposed additional language clarifies the intent of the current regulation. As such, the proposed revision does not constitute a change in burden to the NRC or the industry.

Licensees that elect to use the risk-informed alternative to address the effects of debris in the long-term would be required to periodically update their probabilistic risk assessments (PRA) every 4 years. Additionally, those licensees would be required to report errors or changes in their submittals. The NRC assumes that industry would submit one error per year.

### 4.5 NRC Operation

The NRC would experience recurring costs as a result of the industry's periodic breakaway tests by analyzing the test results. The NRC would also incur annual costs as a result of reviewing reported errors in calculated ECR. However, the current regulation requires licensees to report errors in calculated PCT, and the actions the NRC would take for an error in ECR are the same as those actions for errors in calculated PCT. Additionally, errors in calculated ECR would have an associated error in calculated PCT. For all of these reasons, the NRC assumes that the change in annual costs between the current regulatory baseline and the proposed rule alternative, with respect to reporting ECR, are negligible. With respect to the risk-informed alternative, the NRC would review updates to the PRAs and errors and changes to the submittal.

### 4.6 Improvements in Knowledge

The proposed rule alternative incorporates research findings that identified new cladding embrittlement mechanisms. As a result, future LOCA analyses will improve the predictions of cladding embrittlement.

## 4.7 Regulatory Efficiency

Expanding the applicability of this rule to different fuel designs and additional cladding materials would contribute to regulatory efficiency by eliminating the need for licensees to submit exemption requests for different fuel designs or cladding material. As a result, the proposed rule alternative would improve regulatory efficiency.

## 4.8 Public Health (Accident)

As noted above, the NRC is initiating these new requirements so that the risk of accidental radiation exposure to the public would remain at the previously assumed level. Therefore, there would be an insignificant difference in public health (accident) costs or benefits between the regulatory baseline and the proposed rule alternative.

## 4.9 Occupational Health (Accident)

Similarly, the NRC assumes that the risk of an accidental radiation exposure would remain at the level it was assumed to have been prior to the proposed rule. Therefore, there would be an insignificant difference in occupational health (accident) costs or benefits between the regulatory baseline and the proposed rule alternative.

## 4.10 Onsite Property

Likewise, the NRC assumes that the risk of damage to onsite property would remain at the level it was assumed to have been prior to the proposed rule. Therefore, there would be an insignificant difference in offsite property costs or benefits between the regulatory baseline and the proposed rule alternative.

### 4.11 Offsite Property

The NRC also assumes that the risk of damage to offsite property would remain at the level it was assumed to have been prior to the proposed rule.

### 4.12 Attributes Not Affected

Attributes that are not expected to be affected under the proposed rulemaking include the following: public health (routine); occupational health (routine); other government; general public; antitrust considerations; safeguards and security considerations; and environmental considerations.

## 5. Presentation of Results

This section presents the quantitative results by attribute. Values are shown in 2017 dollars. The tables, unless provided within the body of the section, are located in Appendix B, “Tables”.

### 5.1 Industry Implementation Costs

The industry implementation costs are spread among operating reactors, design certifications, and future operating reactors. As noted above, the proposed rule would require licensees to make use of revised ECCS analysis models based upon the new required acceptance criteria. The revised ECCS models would be developed by vendors, at the request and expense of the licensees. These models are the cladding hydrogen uptake models and the LOCA model updates. The vendors would also produce test data to characterize alloy performance and develop analytical limits based on this test data. The vendors would produce licensing topical reviews regarding the new models, which would require NRC review and approval. After NRC approval, vendors would run the models under contract to licensees to perform plant-specific analyses and demonstrate compliance with the proposed acceptance criteria. The costs associated with implementation assume the use of the Regulatory Guides (RGs) developed for this proposed rule and include the costs of the testing as outlined in the RGs.

As shown in Table 2 - Industry Implementation Costs for Operating Reactors, the first component is the indirect costs resulting from vendor implementation. As noted above, because the vendors are not licensed by the NRC and are developing the revised ECCS models because of the new requirements being imposed upon licensees, these are considered to be indirect industry implementation costs. The cladding hydrogen uptake models are assumed to be performed in a 1-year period in 2017 and the LOCA models (PQD and Breakaway) are assumed to be performed in a 2-year period between 2016 and 2017. The LOCA Models (long-term cooling) are assumed to be performed in a 2-year period from 2016 to 2017). The Initial Breakaway Tests are assumed to be performed in 2017. The nine cladding hydrogen uptake models are assumed to require 0.75 full-time equivalent (FTE)/year/alloy. (For this analysis, the NRC assumes an industry labor rate of $200,000/year.) The 12 LOCA models (PQD and breakaway) are assumed to require 0.75 FTE/year/alloy. The 12 LOCA models (long-term cooling) are assumed to require 0.5 FTE/year/alloy. There are also assumed to be nine Initial Breakaway Test Models requiring a third of an FTE each and that the tests would be performed in 2017. The 9 models of Cladding Alloys cost an estimated $1.4 million. Further, the 24 LOCA models, including both the PQD and breakaway and long-term cooling models, (which include estimates for the completion of the topical reports) are estimated to cost $3.0 million total.[8] The Initial Breakaway Test is expected to occur in 2017 and is estimated to cost $600,000.

Additionally, the NRC assumes that a number of licensees would implement the risk-informed alternative within three different tracks. The NRC assumes that there would be

[8] In this analysis, where activities occur in or before 2017, no discounted values are provided.

10, 1, and 1 AORs in Track 1, Track 2, and Track 3, respectively, and each AOR would require 2.5 FTE. Also, because each unit would not be required to submit an exemption request in the same year that the AOR is submitted, not preparing and submitting this document would be a negative cost (savings) of 100 hours per exemption request. The number of exemption requests saved would be 56, 4, and 4 for Tracks 1, 2, and 3, respectively. Track 1, Track 2, and Track 3 would implement the risk-informed alternative and not implement the exemption requests in years 2018, 2019, and 2020, respectively. Therefore, the NRC estimates the total costs for these tracks and exemption request savings range from $3.4 million (7 percent) to $3.7 million (3 percent). Without the exemption request savings, Track 1 has values ranging from $4.7 million (7 percent) to $4.9 million (3 percent). Track 2 has values ranging from $440,000 (7 percent) to $470,000 (3 percent). Track 3 has values ranging from $440,000 (7 percent) to $470,000 (3 percent).

Adding to the previous implementation costs are the Track 1, Track 2, and Track 3 activities. The NRC assumes that there would be 49, 12, and 13 revised AORs in the three tracks, respectively. Due to multiple unit sites that share common analyses, the number of AORs is less than the 100 plants. Track 1 actions would require 0.5 FTE over a 2-year period (0.25 FTE/year); Track 2 actions would require 1.5 FTE over a 3-year period (0.5 FTE/year); Track 3 actions would require 2.25 FTE over a 3-year period (0.75 FTE/year). The NRC estimates the total costs for these tracks range from $13 million (7 percent) to $14 million (3 percent). Track 1 has values ranging from $4.8 million (7 percent) to $4.9 million (3 percent). Track 2 ranges from $3.0 (7 percent) to $3.4 (3 percent). Similarly, for Track 3, the cost estimate ranges from $4.8 million (7 percent) to $5.3 million (3 percent).

Another potential indirect licensee cost for operating reactors would be the development of new PQD analytical limits in place of utilizing the acceptable PQD analytical limits provided in the regulatory guide. For the purpose of this regulatory analysis, the NRC assumes that the industry would elect to establish new PQD analytical limits for two cladding alloys requiring a quarter of an FTE per year. It is also assumed that this test would be accomplished in 2017, and the estimated cost would be $100,000. The remaining seven cladding alloys would utilize the PQD analytical limits in the RG. The NRC assumes that, due to the high cost of establishing a new experimental technique (outside the acceptable experimental technique in the RG), no vendor will choose that method.

Another licensee implementation test is the LTC test. The NRC assumes that nine cladding alloys would need to be tested, requiring 0.15 FTE per year. It is also assumed that this test would be accomplished in 2017. The total cost for the long-term cooling testing is estimated to be $270,000.

The proposed rule would reduce licensee implementation cost by eliminating the need for exemption requests to use materials other than uranium-oxide fuel pellets within cylindrical zircaloy or ZIRLO™ cladding. The NRC assumes that 50 plants (5 per year over a 10-year period, beginning in 2017) would request an exemption if the proposed rule did not extend applicability. It is also assumed that the exemption requests would require 0.2 FTE per exemption request. This would result in an estimated total savings (negative cost) ranging from $1.5 million (7 percent) to $1.8 million (3 percent). The estimated total implementation cost for operating reactors ranges from $20 million (7 percent) to $21 million (3 percent).

As shown in Table 3 - Industry Implementation Costs for Design Certifications, the costs come from an analysis of the design certifications. The Track 2[9] cost is an indirect cost that would occur for both design certifications in 2020. The NRC assumes that the design certifications would require 1.5 FTE per design certification. Track 2 has an estimated cost

[9] Although labeled "Track 2," the NRC assumes that design certifications will not be a part of Track 2, but will have characteristics similar to Track 2 and are, therefore, labeled as "Track 2."

range from $490,000 (7 percent) to $549,000 (3 percent). The estimated implementation costs for design certification ranges from $490,000 (7 percent) to $549,000 (3 percent).

Table 4, Industry Implementation Costs for Future Operating Reactors, provides costs for the initial breakaway test, the track designation that most closely matches implementation required for the reactors, and the LTC test that each reactor would use. The initial breakaway test, which would occur for Watts Bar in 2017, the Summer and Vogtle future operating reactors in 2022 and Bellefonte 1 in 2023, has an estimated cost range from $36,000 (7 percent) to $43,000 (3 percent).

The Track 1[10] costs, which would occur for Watts Bar in the years 2020 and 2021, Vogtle and Summer in years 2024 and 2025, and Bellefonte in years 2026 and 2027, would require 0.25 FTE for each AOR. The Watts Bar Track 1 estimated cost ranges from $79,000 (7 percent) to $94,000 (3 percent). The Summer and Vogtle future operating reactors Track 1 estimated cost ranges from $240,000 (7 percent) to $351,000 (3 percent). The Bellefonte 1 Track 1 estimated cost ranges from $52,000 (7 percent) to $75,000 (3 percent). The total cost estimate for Track 1 ranges from $370,000 (7 percent) to $490,000 (3 percent).

The LTC Test cost would be incurred in years 2020 for Watts Bar, Vogtle Units 3 and 4, and Summer, Unit 2; 2025, for Summer, Unit 3; and 2026, for Bellefonte 1. The LTC requires 0.04 FTE per reactor and has an estimated total cost range from $43,000 (7 percent) to $46,000 (3 percent).

The total estimated industry implementation cost for future operating reactors ranges from $460,000 (7 percent) to $580,000 (3 percent).

[10] Although labeled “Track 1,” the NRC assumes that future operating reactors will not be a part of Track 1, but will have characteristics similar to Track 1 and are, therefore, labeled as “Track 1.”

The total estimated industry implementation cost for operating reactors, design certifications and future operating reactors ranges from $21 million (7 percent) to $22 million (3 percent).

## 5.2 Industry Operation Costs

The NRC assumes that, once all licensees of operating reactors have implemented the proposed rule, 60 periodic breakaway tests will be submitted to the NRC each year (based on distribution between 18 month and 24 month operating cycles). However, between publication and full implementation, the NRC estimates the number of periodic breakaway tests will be as indicated for operating reactors:

| | | |
|---|---|---|
| 2019 | Periodic Breakaway Tests | 60 |
| 2020 | Periodic Breakaway Tests | 0 |
| 2021 | Periodic Breakaway Tests | 60 |
| 2022 | Periodic Breakaway Tests | 44 |
| 2023 | Periodic Breakaway Tests | 60 |

Table 5 - Industry Operation Costs for Operating Reactors shows the costs for both the risk-informed alternative and the periodic breakaway test. For the risk-informed alternative, for the Track 1 AOR, starting in 2021, and every 4 years, 10 AORs would be updated, requiring 0.05 FTE/AOR. For the Track 2 AOR, starting in 2022, and every 4 years, 1 AOR would be updated, requiring 0.050 FTE/AOR. For the Track 3 AOR, starting in 2023, and every 4 years, 1 AOR would be updated, requiring 0.05 FTE/AOR. Also, the NRC assumes that, starting in 2021, one error would be found and require change each year and would require 0.050 FTE/error. The total industry operation cost for the risk-informed alternative ranges from $370,000 (7 percent) to $550,000 (3 percent).

For the periodic breakaway tests, in 2019, the majority of Track 1 plants would have conducted periodic breakaway tests. As such, in 2020 those plants would not have to re-test for breakaway oxidation, and neither Track 2 nor Track 3 plants would have implemented the rule. By 2021, a portion of Track 1 plants would re-test for breakaway oxidation, as well as a portion of Track 2 plants. The 2022 value also reflects the total resulting from a portion of Track 1 and Track 2 plants. In 2023, Track 3 plants would begin their periodic breakaway tests, and a portion of Track 1 and Track 2 plants would conduct testing. Starting in 2023, and annually thereafter through the average remaining life, the NRC assumes that a total of 60 breakaway oxidation tests will be submitted per year. The total estimated discounted cost range of the periodic breakaway testing for operating reactors is $4.9 million (7 percent) and $7.0 million (3 percent). Therefore, the total industry operation costs for operating reactors ranges from $5.3 million (7 percent) to $7.6 million (3 percent).

Table 6 - Industry Operation Costs for Future Operating Reactors shows the industry operation costs for future operating reactors. The NRC assumes that Watts Bar Unit 2, Vogtle Units 3 and 4, and Summer Unit 2 will perform a periodic breakaway test in 2021 during refueling and every 2 years thereafter. Watts Bar Unit 2 would stop performing periodic breakaway tests in year 2073 and Vogtle Units 3 and 4, and Summer Unit 2 would stop performing periodic breakaway tests in year 2075. Summer, Unit 3 would begin performing periodic breakaway tests in 2023 and would continue performing the test every other year until 2077. Bellefonte Unit 1 would begin performing periodic breakaway tests in year 2022 and would continue performing the test every other year until 2078. Each periodic breakaway test would require an average FTE requirement of 0.05 FTE. The estimated total cost for the industry operation costs for future operating reactors ranges from $380,000 (7 percent) to $780,000 (3 percent).

The total estimated industry operation cost for operating reactors, design certifications and future operating reactors ranges from $5.3 million (7 percent) to $7.8 million (3 percent).

### 5.3 Total Industry Costs

Table 7 - Total Industry Costs shows the total industry costs broken down between direct and indirect costs as well as by implementation and operation costs. The total industry costs range from $26 million (7 percent) to $31 million (3 percent).

#### 5.3.1 Industry Average Implementation Costs per Designated Unit

Table 8 - Industry Average Implementation Cost per Designated Unit provides the estimates of the various average costs per designated unit, by type of cost for operating reactors, design certifications and future operating reactors. As shown, the largest average designated unit cost contributors for operating reactors and future operating reactors are the 3 Track Activities. Almost all of the average designated unit cost contributors for design certifications are from the initial breakaway test. The total industry operating reactor implementation cost per AOR estimate ranges from $260,000 (7 percent) to $280,000 (3 percent). The total industry design certification implementation estimated cost per reactor or design certification ranges from $250,000 (7 percent) to $280,000 (3 percent). The total industry future operating reactor implementation cost per reactor/AOR estimate ranges from $190,000 (7 percent) to $280,000 (3 percent).

### 5.4 NRC Implementation Costs

Table 9 - NRC Implementation Costs Affecting Operating Reactors, Design Certifications, and Future Operating Reactors shows the NRC implementation costs that affect

operating reactors, design certifications and future operating reactors[11]. Four RGs would be published as a result of this rule (both draft and final versions). The first relates to analytical limits, the second and third to test procedures, and the fourth RG relates to the risk-informed alternative. As shown in Table 9 - NRC Implementation Costs Affecting Operating Reactors, Design Certifications, and Future Operating Reactors, the NRC estimates the costs to be approximately $1.7 million. This is based upon the assumptions of 10 NRC staff-years to complete the regulatory guides, with an NRC yearly rate of $173,000. The NRC also assumes that it will take approximately 2 calendar years to complete the guides.

The NRC would also need to develop and issue a revision to NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition." The cost estimates for this action would require one FTE and is estimated to be $173,000.

The NRC would also incur costs reviewing and commenting on the cladding hydrogen uptake models and the LOCA models. For the cladding hydrogen uptake models, the NRC estimates that it would take 2 FTE at $173,000 annually, be implemented in 2018, and, therefore, range from $330,000 (7 percent) to $340,000 (3 percent). The NRC review of the LOCA models (PQD, breakaway) is estimated to take 2 FTE/year over a 2-year period, beginning in 2018. The cost for this activity is estimated to be from $640,000 (7 percent) to $670,000 (3 percent). The NRC review of the LOCA models (long-term cooling) is estimated to take 1 FTE/year over a 2-year period, beginning in 2018. The cost for this activity is estimated to be from $310,000 (7 percent) to $330,000 (3 percent). Next, the NRC estimates that this final rule development would take approximately 6 FTE over 3 years, beginning in 2014, and have a cost of approximately $1 million.

Table 10 - NRC Implementation Costs for Operating Reactors shows the NRC implementation costs for operating reactors. The NRC's break-away test review is assumed to

[11] In relation to totaling costs, these costs are part of the operating reactor costs.

require one FTE in the year 2018. The resulting cost estimate ranges from $160,000 (7 percent) to $170,000 (3 percent).

Table 10 - NRC Implementation Costs for Operating Reactors provides the estimated NRC costs for the risk-informed alternative. The NRC implementation costs related to the risk-informed alternative are related to reviewing the risk-informed alternative submittals and the negative costs (savings) from not needing to review exemption requests. The estimated NRC effort for each AOR review is 0.56 FTE and the estimated NRC effort for each exemption request review is 0.40 FTE. Therefore, the estimated NRC implementation costs for the risk-informed alternative ranges from $580,000 (7 percent) to $720,000 (3 percent).

Table 10 - NRC Implementation Costs for Operating Reactors also provides estimated implementation costs for operating reactors for analysis of record reviews for Tracks 2 and 3. (Track 1 compliance for operating reactors is demonstrated through a letter report – no NRC review would be necessary.) These efforts would take place over a 2-year period and begin in the years 2019, 2021, and 2022 for the Tracks 1, 2, and 3, respectively. Because Track 1 would require no NRC review, there would be no cost associated with this track. For Track 2, the range is $520,000 (7 percent) to $610,000 (3 percent). For Track 3, the values range from $480,000 (7 percent) to $590,000 (3 percent). Therefore, the total estimated NRC implementation cost for the amendment reviews ranges from $1.0 million (7 percent) to $1.2 million (3 percent). The next NRC implementation costs for operating reactors are a result of PQD Tests. As mentioned, the assumption is that only two cladding alloys would need to be done under the so-called “redone NRC Version.” Each cladding alloy is assumed to require 0.25 FTE, beginning in 2015. The resulting estimates are calculated to be $81,000 (7 percent) to $84,000 (3 percent).

There are also NRC implementation costs associated with LTC tests. The assumption is that the NRC review would require 0.15 FTE for each of the 9 cladding alloys, beginning in

2015. The resulting estimates are calculated to be $210,000 (7 percent) to $220,000(3 percent).

The proposed rule would eliminate the need for the NRC to review licensee exemption requests to use materials other than uranium-oxide fuel pellets within cylindrical zircaloy or ZIRLO™ cladding; this represents a cost savings. The NRC assumes that 50 plants (five per year over a 10-year period, beginning in 2014) would request exemptions if the proposed rule did not extend applicability to other materials. It is also assumed that NRC review of the exemption requests would require 0.1 FTE per exemption request. This would result in a total savings ranging from $650,000 (7 percent) to $770,000 (3 percent).

Therefore, the total NRC Implementation costs for operating reactors, including those implementation costs that affect both design certifications and future operating reactors, are estimated to range from $5.6 million (7 percent) to $5.9 million (3 percent).

Table 11 - NRC Implementation Costs for Design Certifications shows the NRC implementation costs for design certifications. The NRC assumes that, in 2021, the NRC will conduct a review of the certification amendment analysis for both design certifications, requiring 0.27 FTE each, resulting in an estimated cost range from $70,000 (7 percent) to $82,000 (3 percent). The total NRC implementation costs for design certifications range from $70,000 (7 percent) to $82,000 (3 percent).

Table 12 - NRC Implementation Costs for Future Operating Reactors shows the NRC implementation costs for future operating reactors. An initial breakaway test review would be performed in 2018 by the NRC for Watts Bar, Vogtle Units 3 and 4, and Summer Unit 2, and would require 0.01 FTE per review, and has an estimated cost range from $7,000 (7 percent) to $8,000 (3 percent). The initial NRC breakaway test review for Summer Unit 3 would be conducted in 2020 would require requiring 0.01 FTE, and has an estimated cost of $2,000. The initial NRC breakaway test review for Bellefonte 1 would be conducted in 2021 would require

0.01 FTE, and has an estimated cost of $2,000. Also, as all future operating reactors are assumed to be submitting LARs following the Track 1 methodology, no NRC review would be required. The last implementation cost is the LTC review costs. The NRC would review the Watts Bar LTC test in 2018, requiring 0.04 FTE for an estimated cost of $7,000. The NRC would perform the Summer and Vogtle units LTC test reviews in 2020, requiring 0.04 FTE per reactor for an estimated cost range from $19,000 (7 percent) to $23,000 (3 percent). The NRC would perform the Bellefonte 1 LTC test review in 2021, requiring 0.04 FTE for an estimated cost range from $4,000 (7 percent) to $6,000 (3 percent). The total NRC implementation costs for future operating reactors ranges from $46,000 (7 percent) to $51,000 (3 percent).

The total NRC implementation costs range from $5.8 million (7 percent) to $6.2 million (3 percent).

## 5.5 NRC Operation Costs

As noted above, the NRC would experience recurring costs for operating reactors and future operating reactors as a result of the industry’s periodic breakaway tests and review of the industry PRA submittals and changes to errors. As shown in Table 13 - NRC Operation Costs for Operating Reactors, for operating reactors, the NRC assumes that the NRC’s analysis of the periodic breakaway tests would require 0.15 FTE per year every other year until 2039 and that the update to PRA reviews will be conducted the year following the industry submittal starting in 2022 and continues until 2039. The NRC estimates that it would require 0.56 FTE per PRA review. The effort per year is based on the number of PRA reviews submitted by industry the year before. The NRC, beginning in 2022 and continuing until 2039, would spend 0.029 FTE reviewing an error and respective change each year. Therefore, the estimated NRC operation costs for operating reactors ranges from $2.7 million (7 percent) to $4.2 million (3 percent).

Table 14 - NRC Operating Costs for Future Operating Reactors outlines the NRC operating costs for future operating reactors. The periodic breakaway test reviews will be performed for Watts Bar (requiring 0.01 FTE per review) until 2022, when future operating reactor reviews will be conducted (requiring 0.04 FTE per year). The estimated NRC operating costs for future operating reactors ranges from $62,000 (7 percent) to $130,000 (3 percent).

The total NRC operating costs ranges from $880,000(7 percent) to $1.1 million (3 percent).

## 5.6 Total NRC Costs

Table 15 - Total NRC Costs shows the total NRC costs broken down by implementation and operation costs. As stated above, the estimated NRC implementation costs range from $5.7 million (7 percent) to $6.0 million (3 percent) and the NRC operating costs range from $2.8 million (7 percent) to $4.3 million (3 percent). The total NRC cost estimate ranges from $8.5 million (7 percent) to $10 million (3 percent).

## 5.7 Total Rule Costs

Table 16 - Total Costs shows the total cost estimates, including both industry and the NRC, range from $35 million (7 percent) to $41 million (3 percent). As shown in Table 16 - Total Costs they are composed of implementation costs of $27 million (7 percent) to $29 million (3 percent) and operating costs of $8.1 million (7 percent) to $12 million (3 percent).

Lastly, the average implementation costs per AOR are estimated to range from $150,000 (7 percent) to $190,000 (3 percent).

## 5.8 Future Design Certifications

As there are potential design certifications that may come into the NRC for review, but are too uncertain regarding likelihood and timing to be properly added into the regulatory analysis, the NRC assumes a hypothetical design certification beginning in a hypothetical year (year X), based on 2017 dollars, to determine the cost to the industry and the NRC for the future design certifications.

As shown in Table 17 - Industry Costs for Future Design Certifications, the Industry would incur costs in relation to implementation costs. One industry cost would be the initial breakaway test in year X that would require 0.04 FTE and provide an estimated cost of $8,000. The other industry cost would come from the PQD test, which is assumed to be a redone NRC version. This cost would occur in year X, would require 0.01 FTE of effort and provide an estimated cost of $2,000.The total estimated industry cost for a hypothetical design certification is $10,000.

As shown in Table 18 - NRC Costs for Future Design Certifications, the NRC would incur costs in relation to the review of the initial breakaway test and the PQD test for a hypothetical design certification. The breakaway test review, which would occur in year X+1, would require 0.01 FTE of effort and have an estimated cost of $2,000. The PQD test review, which would also occur in year X+1, would require 0.005 FTE of effort and have an estimated cost of $1,000.

The total estimated NRC cost for a hypothetical design certification is $3,000.

### 5.9 Hypothetical Future Operating Reactors

As there are future operating reactors that are also too uncertain regarding likelihood and timing to be properly added into the regulatory analysis, the NRC assumes a hypothetical future operating reactor (a single reactor at a new site) beginning operation in a hypothetical year (year X), based on 2017 dollars, to determine the cost to the industry and the NRC for the future operating reactor.

As shown in Table 19 - Industry Costs for Hypothetical Future Operating Reactor the Industry would incur both implementation and operating costs in relation to a hypothetical reactor. One industry implementation cost would be a breakaway test in year X that would require 0.04 FTE and provide an estimated cost of $8,000. Another implementation cost would be for Track 1, which would be over 2 years (X and X+1) and would require a total FTE of 0.5, spread between the 2 years and having a total estimated cost of $100,000. The final implementation cost would be for the LTC test, which would occur in year X and would require 0.04 FTE and provide a total cost of $8,000. The total industry hypothetical future operating implementation cost is estimated at $116,000. The industry operating costs for the periodic breakaway test for the hypothetical operating reactor would occur during the first reload and each subsequent reload, and would require 0.05 FTE for the expected life of the reactor. The total industry estimated cost for the periodic breakaway test is $390,000.

The total cost for the industry hypothetical future operating reactor is estimated at $506,000.

As shown in Table 20 - NRC Costs for Hypothetical Future Operating Reactor, the NRC incurs both implementation and operating costs due to this rulemaking for a hypothetical future operating reactor. The implementation costs are divided into breakaway test review, Track 1 review and LTC test review. The breakaway test review would occur in year X+1 and would require 0.08 FTE for an estimated cost of $14,000. For the Track 1 review, the NRC would not incur any costs as no FTE would be required. For the LTC review, the review would occur in year X+1 and would require 0.04 FTE for the unit for an estimated cost of $7,000. The total NRC hypothetical future operating reactor implementation cost is estimated at $21,000. The NRC would incur an operation cost starting in year X+2.5 for the periodic breakaway test review. The FTE requirement per year would be 0.002 and would occur for through the expected life of the reactor, providing a total estimated cost of $20,000.

The total NRC hypothetical future operating reactor cost is estimated at $41,000.

## 6. Decision Rationale

As noted above, this rulemaking is predicated upon the belief that this proposed action falls under the adequate protection justification. The Regulatory Analysis Guidelines state that, "The level of protection constituting 'adequate protection' is that level which must be assured *without regard to cost"* (emphasis added). The Guidelines also state that, ". . . a proposed backfit to one or more of the facilities regulated under 10 CFR Part 50 does not require a regulatory analysis if the resulting safety benefit is required for purposes of compliance or adequate protection under 10 CFR 50.109(a)(4)."

## 7. Implementation

### 7.1 Proposed Rule

It is assumed that the rule would initially take effect 30 days after publication of the final rule in the *Federal Register.* The rule would establish a staged implementation approach to improve the efficiency and effectiveness of the migration to the new ECCS requirements. The staged implementation plan would have a duration of 5 years. As the first step, vendors would develop, and submit to the NRC for review via topical reports, hydrogen pick up models and LOCA model updates. This is expected to occur during the first year. Also, during the first year, the vendors would obtain PQD analytical methods by either: 1) using the analytical limits provided in an NRC RG, or 2) using an NRC-approved experimental method provided in an RG. (A third option, which involves the vendors developing their own experimental method for NRC approval, is available but, due to the high cost and burden of this option, the NRC assumes that no vendors will develop their own experimental method.) The PQD analytical limits that are obtained via the approved experimental method would be submitted for NRC review in the form of a topical report. Also, the vendors would perform long-term cooling tests to determine the long-term cooling limit for each of the nine cladding alloys. Finally, during the first year after the rule becomes effective, the vendors would perform initial breakaway testing. The results of the initial breakaway tests would be submitted by the licensee via their license amendment request (LAR) which is necessary to demonstrate compliance with the proposed rule.

As part of this implementation plan, licensees will be divided among three implementation tracks based upon existing margin to the revised requirements and anticipated level of effort to demonstrate compliance. The purpose of the staged implementation approach is to bring licensees into compliance as quickly as possible, while accounting for: 1) more effort and longer schedules will be necessary for plants that require new LOCA analyses with revised LOCA models; and 2) differences between realistic and appendix K to 10 CFR part 50 LOCA models.

Lastly, the tracks will begin to conduct periodic breakaway testing 1 year after they are in full compliance. (Track 1 to being periodic breakaway testing in Year 3, Track 2 in Year 5 and Track 3 in Year 6.) The results of these tests will be included in the annual ECCS submittal. The proposed rule would allow licensees to use an alternative risk-informed approach to evaluate the effects of debris on long-term cooling. The NRC would allow partial early implementation of the proposed requirements of § 50.46c, limited to the alternate approach. However, the NRC assumes in this analysis that the alternatives would be submitted the same year as compliance with the embrittlement criteria is demonstrated. Entities that choose this approach would submit the alternative approach to the NRC for review and approval. Additionally, the licensees would have to submit all changes to the approved alternatives to the NRC for review.

## 7.2 Regulatory Guidance

There are three DGs developed along with the proposed rule. The three DGs are: DG-1261, "Conducting Periodic Testing for Breakaway Oxidation Behavior" (ADAMS Accession No. ML12284A324); DG-1262, "Testing for Post Quench Ductility" (ADAMS Accession No. ML12284A325); and DG-1263, "Establishing Analytical Limits for Zirconium-Based Alloy Cladding" (ADAMS Accession No. ML12284A323). These RGs would be available for use as guidance immediately upon their issuance in final form; issuance in final form may pre-date the necessary date for compliance with the rule as specified in § 50.46c(o). The NRC will develop draft guidance for the risk-informed alternative to address the effects of debris on long-term cooling. The draft guidance will be published for comment upon completion, which is currently anticipated for early- to mid-calendar year 2015. The NRC will then evaluate public comments received on the draft guidance, and develop the final guidance on a timeline that ensures all guidance (both for the risk-informed alternative and the new proposed embrittlement criteria) is available when the NRC staff provides the final § 50.46c rule to the Commission (currently scheduled for February 2016).

## Appendix A – References


NUREG/BR-0058, Revision 4, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," dated September 2004, available at http://www.nrc.gov/reading-rm/doc-collections/nuregs/brochures/br0058/br0058r4.pdf and ADAMS Accession No. ML042820192.

NUREG/BR-0184, "Regulatory Analysis Technical Evaluation Handbook," dated January 1997, available at http://pbadupws.nrc.gov/docs/ML0501/ML050190193.pdf and ADAMS Accession No. ML050190193.

NUREG/CR-4627, "Generic Cost Estimates: Abstracts from Generic Studies for Use in Preparing Regulatory Impact Analyses," dated February 1992, available at http://pbadupws.nrc.gov/docs/ML1313/ML13137A259.pdf and ADAMS Accession No. ML13137A259.

NUREG-1409, "Backfitting Guidelines," dated July 1990, available at http://pbadupws.nrc.gov/docs/ML0322/ML032230247.pdf and ADAMS Accession No. ML032230247.

Section 50.109 of Title 10 of the *Code of Federal Regulations*, "Backfitting," available at http://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0109.html.

SECY-98-300, "Options for Risk-Informed Revisions to 10 CFR Part 50-'Domestic Licensing of Production and Utilization Facilities,'" dated December 23, 1998, available at http://www.nrc.gov/reading-rm/doc-collections/commission/secys/1998/secy1998-300/1998-300scy.pdf and ADAMS Accession No. ML992870048.

SECY-02-0057, "Update to SECY-01-0133, 'Fourth Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.46 (ECCS Acceptance Criteria),'" dated March 29, 2002, available at http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2002/secy2002-0057/2002-0057scy.pdf and ADAMS Accession No. ML020660607.

SRM-SECY-02-0057, "Staff Requirements – SECY-02-057 – Update to SECY-01-0133, 'Fourth Status Report on Study of Risk-Informed Changes to the Technical Requirements of 10 CFR Part 50 (Option 3) and Recommendations on Risk-Informed Changes to 10 CFR 50.46 (ECCS Acceptance Criteria)," dated March 31, 2003, available at http://pbadupws.nrc.gov/docs/ML0309/ML030910476.pdf and ADAMS Accession No. ML030910476.

SRM-SECY-12-0034, "Staff Requirements – SECY-12-0034 – Proposed Rulemaking – 10 CFR 50.46c: Emergency Core Cooling System Performance During Loss-of-Coolant Accidents (RIN 3150-AH42)," dated January 7, 2013, available at http://pbadupws.nrc.gov/docs/ML1300/ML13007A478.pdf and ADAMS Accession No. ML13007A478.

Section 50.44 of Title 10 of the *Code of Federal Regulations*, "Combustible Gas Control for Nuclear Power Reactors," available at http://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0044.html.

Section 50.46 of Title 10 of the *Code of Federal Regulations*, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors," available at http://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0046.html.

Section 50.46a of Title 10 of the *Code of Federal Regulations*, "Acceptance Criteria for Reactor Coolant System Venting Systems," available at http://www.nrc.gov/reading-rm/doc-collections/cfr/part050/part050-0046a.html.

DG-1261, Draft Regulatory Guide for "Conducting Periodic Testing for Breakaway Oxidation Behavior," ADAMS Accession No. ML12284A324.

DG-1262, Draft Regulatory Guide for "Testing for Post Quench Ductility," ADAMS Accession No. ML12284A325.

DG-1263, Draft Regulatory Guide for "Establishing Analytical Limits for Zirconium-Based Alloy Cladding," ADAMS Accession No. ML12284A323.

RIL-0801, "Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46," dated May 30, 2008, available at http://pbadupws.nrc.gov/docs/ML0813/ML081350225.pdf and ADAMS Accession No. ML081350225.

NUREG/CR-6967, "Cladding Embrittlement during Postulated Loss-of-Coolant accidents," dated July 7, 2008, available at http://pbadupws.nrc.gov/docs/ML0817/ML081780360.pdf and ADAMS Accession No. ML081780360.

65 FR 34599, PRM-50-71, "Nuclear Energy Institute; Receipt of Petition for Rulemaking," dated May 31, 2000, available at http://www.gpo.gov/fdsys/pkg/FR-2000-05-31/pdf/00-13515.pdf.

73 FR 66000, PRM-50-71, "Anthony R. Pietrangelo, Nuclear Energy Institute; Consideration of Petition in the Rulemaking Process," dated November 6, 2008, available at http://www.gpo.gov/fdsys/pkg/FR-2008-11-06/pdf/E8-26463.pdf.

72 FR 28902, PRM-50-84, "Mark Edward Leyse; Receipt of Petition of Rulemaking," dated May 23, 2007, available at http://www.gpo.gov/fdsys/pkg/FR-2007-05-23/pdf/E7-9901.pdf.

73 FR 71564, PRM-50-84, "Mark Edward Leyse; Consideration of Petition in Rulemaking Process," dated November 25, 2008, available at http://www.gpo.gov/fdsys/pkg/FR-2008-11-25/pdf/E8-27938.pdf.

"NRC Workshop Summary of September 24, 2008 Public Meeting," dated October 29, 2008, available at http://pbadupws.nrc.gov/docs/ML0830/ML083010496.pdf and ADAMS Accession No. ML083010496.

# Appendix B - Tables

## Table 2 - Industry Implementation Costs for Operating Reactors

**Industry Implementation Costs (Indirect - Vendor Implementation Costs)**

| Year | Activity | Number of Models/Cladding Alloys | Per Model/Cladding Alloy | | Cost per year | | |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | Undiscounted | 3% NPV | 7% NPV |
| 2019 | Cladding Hydrogen Uptake Models (Including Topic Rpts) | 9 | 0.75 | $200,000 | $1,400,000 | $1,400,000 | $1,400,000 |
| 2016 | LOCA Models (PQD, Breakaway) | 6 | 0.75 | $200,000 | $900,000 | $900,000 | $900,000 |
| 2017 | | 6 | 0.75 | $200,000 | $900,000 | $900,000 | $900,000 |
| 2016 | LOCA Models (LTC) | 6 | 0.50 | $200,000 | $600,000 | $600,000 | $600,000 |
| 2017 | | 6 | 0.50 | $200,000 | $600,000 | $600,000 | $600,000 |
| 2017 | Initial Breakaway Test | 9 | 0.33 | $200,000 | $600,000 | $600,000 | $600,000 |
| | | | | **Total:** | **$5,000,000** | **$5,000,000** | **$5,000,000** |

**Industry Implementation Costs: Risk-Informed Alternative**

| Year | Activity (Alternative Approach) | Number of AOR/Unit | Per AOR/Unit | | Cost per year | | |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | Undiscounted | 3% NPV | 7% NPV |
| 2018 | Track #1 | 10 | 2.5 | $200,000 | $5,000,000 | $4,900,000 | $4,700,000 |
| 2018 | Exemption Request (ER) Preperation and Submission | 56 | 0.18 | $200,000 | ($2,000,000) | ($1,900,000) | ($1,900,000) |
| 2019 | Track #2 | 1 | 2.5 | $200,000 | $500,000 | $470,000 | $440,000 |
| 2019 | Exemption Request (ER) Preperation and Submission | 4 | 0.18 | $200,000 | ($140,000) | ($130,000) | ($120,000) |
| 2020 | Track #3 | 1 | 2.5 | $200,000 | $500,000 | $460,000 | $410,000 |
| 2020 | Exemption Request (ER) Preperation and Submission | 4 | 0.18 | $200,000 | ($140,000) | ($130,000) | ($110,000) |
| | | | | **Total:** | **$3,700,000** | **$3,700,000** | **$3,400,000** |

**Industry Implementation Costs**

| Year | Activity (Includes PQD, Breakaway, LTC) | Number of AOR | Per AOR | | Cost per year | | |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | Undiscounted | 3% NPV | 7% NPV |
| 2017 | Track #1 | 49 | 0.25 | $200,000 | $2,500,000 | $2,500,000 | $2,500,000 |
| 2018 | | | 0.25 | | $2,500,000 | $2,400,000 | $2,300,000 |
| 2018 | Track #2 | 12 | 0.50 | $200,000 | $1,200,000 | $1,200,000 | $1,100,000 |
| 2019 | | | 0.50 | | $1,200,000 | $1,100,000 | $1,000,000 |
| 2020 | | | 0.50 | | $1,200,000 | $1,100,000 | $980,000 |
| 2019 | Track #3 | 13 | 0.75 | $200,000 | $1,950,000 | $1,800,000 | $1,700,000 |
| 2020 | | | 0.75 | | $1,950,000 | $1,800,000 | $1,600,000 |
| 2021 | | | 0.75 | | $1,950,000 | $1,700,000 | $1,500,000 |
| | | | | **Total:** | **$14,000,000** | **$14,000,000** | **$13,000,000** |

**Industry Implementation Costs: Exemption Request Savings**

| Year | Activity | Number of Exemption Requests | Per Exemption Request | | Cost per year | | |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | Undiscounted | 3% NPV | 7% NPV |
| 2017 | Exemption Requests (ER) Preparation and Submission | 5 | 0.2 | $200,000 | ($200,000) | ($200,000) | ($200,000) |
| 2018 | Exemption Requests (ER) Preparation and Submission | 5 | 0.2 | $200,000 | ($200,000) | ($190,000) | ($190,000) |
| 2019 | Exemption Requests (ER) Preparation and Submission | 5 | 0.2 | $200,000 | ($200,000) | ($190,000) | ($170,000) |
| 2020 | Exemption Requests (ER) Preparation and Submission | 5 | 0.2 | $200,000 | ($200,000) | ($180,000) | ($160,000) |
| 2021 | Exemption Requests (ER) Preparation and Submission | 5 | 0.2 | $200,000 | ($200,000) | ($180,000) | ($150,000) |
| 2022 | Exemption Requests (ER) Preparation and Submission | 5 | 0.2 | $200,000 | ($200,000) | ($170,000) | ($140,000) |
| 2023 | Exemption Requests (ER) Preparation and Submission | 5 | 0.2 | $200,000 | ($200,000) | ($170,000) | ($130,000) |
| 2024 | Exemption Requests (ER) Preparation and Submission | 5 | 0.2 | $200,000 | ($200,000) | ($160,000) | ($120,000) |
| 2025 | Exemption Requests (ER) Preparation and Submission | 5 | 0.2 | $200,000 | ($200,000) | ($160,000) | ($120,000) |
| 2026 | Exemption Requests (ER) Preparation and Submission | 5 | 0.2 | $200,000 | ($200,000) | ($150,000) | ($110,000) |
| | | | | **Total:** | **($2,000,000)** | **($1,800,000)** | **($1,500,000)** |

**Industry Implementation Option Costs: PQD Tests**

| Year | Activity | Number of Cladding Alloys | Per Cladding Alloy | | Undiscounted | 3% NPV | 7% NPV |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | | | |
| 2017 | PQD Test - Accepted NRC Reg Guide | 7 | 0 | $200,000 | $0 | $0 | $0 |
| 2017 | PQD Test - Redone NRC Version | 2 | 0.25 | $200,000 | $100,000 | $100,000 | $100,000 |
| 2017 | PQD Test - Industry Version | 0 | 0.5 - 2.5 | $200,000 | $0 | $0 | $0 |
| | | | | **Total:** | **$100,000** | **$100,000** | **$100,000** |

**Industry Implementation Option Costs: LTC Tests**

| Year | Activity | Number of Cladding Alloys | Per Cladding Alloy | | Undiscounted | 3% NPV | 7% NPV |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | | | |
| 2017 | LTC Tests | 9 | 0.15 | $200,000 | $270,000 | $270,000 | $270,000 |
| | | | | **Total:** | **$270,000** | **$270,000** | **$270,000** |

| | Undiscounted | 3% NPV | 7% NPV |
|---|---|---|---|
| **Total Industry Operating Reactor Cost (Direct):** | **$16,000,000** | **$16,000,000** | **$15,000,000** |
| **Total Industry Operating Reactor Cost (Indirect):** | **$5,000,000** | **$5,000,000** | **$5,000,000** |
| **Total Industry Operating Reactor Implementation Cost:** | **$21,000,000** | **$21,000,000** | **$20,000,000** |

## Table 3 - Industry Implementation Costs for Design Certifications

**Industry Implementation Costs: Design Certification**

| Year | Activity | Number of Design Certifications | Per Design Certification | | Cost per year | | |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | Undiscounted | 3% NPV | 7% NPV |
| 2020 | Track #2 | 2 | 1.50 | $200,000 | $600,000 | $550,000 | $490,000 |
| | | | | **Total:** | **$600,000** | **$550,000** | **$490,000** |
| | | **Total Industry Design Certification Cost:** | | | **$600,000** | **$550,000** | **$490,000** |

## Table 4 - Industry Implementation Costs for Future Operating Reactors

**Industry Implementation Costs (Indirect - Vendor Implementation Costs): Future Operating Reactors**

| Year | Activity | Number of Reactor | Per Reactor | | Cost per year | | |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | Undiscounted | 3% NPV | 7% NPV |
| 2017 | Initial Breakaway Test (Watts Bar, Vogtle 2 & 3, Summer 2) | 4 | 0.04 | $200,000 | $32,000 | $32,000 | $32,000 |
| 2019 | Initial Breakaway Test (Summer 3) | 1 | 0.04 | $200,000 | $8,000 | $8,000 | $7,000 |
| 2020 | Initial Breakaway Test (Bellefonte) | 1 | 0.04 | $200,000 | $8,000 | $7,000 | $7,000 |
| | | | | **Total:** | **$48,000** | **$47,000** | **$46,000** |

**Industry Implementation Costs: Future Operating Reactors**

| Year | Activity (Includes PQD, Breakaway, LTC) | Number of AOR | Per AOR | | Cost per year | | |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | Undiscounted | 3% NPV | 7% NPV |
| 2020 | Track #1 (Watts Bar) | 1 | 0.25 | $200,000 | $50,000 | $50,000 | $41,000 |
| 2021 | | | 0.25 | | $50,000 | $44,000 | $38,000 |
| 2024 | Track #1 (Vogtle and Summer Units) | 4 | 0.25 | $200,000 | $200,000 | $160,000 | $120,000 |
| 2025 | | | 0.25 | | $200,000 | $160,000 | $120,000 |
| 2026 | Track #1 (Bellefonte) | 1 | 0.25 | $200,000 | $50,000 | $38,000 | $27,000 |
| 2027 | | | 0.25 | | $50,000 | $37,000 | $25,000 |
| | | | | **Total:** | **$600,000** | **$490,000** | **$370,000** |

**Industry Implementation Option Costs: LTC Tests: Future Operating Reactors**

| Year | Activity | Number of Reactor | Per Reactor | | Undiscounted | 3% NPV | 7% NPV |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | | | |
| 2020 | LTC Test (Watts Bar, Vogtle 2 & 3, Summer 2) | 4 | 0.04 | $200,000 | $32,000 | $32,000 | $32,000 |
| 2022 | LTC Tests (Summer 3) | 1 | 0.04 | $200,000 | $8,000 | $7,000 | $6,000 |
| 2023 | LTC Tests (Bellefonte) | 1 | 0.04 | $200,000 | $8,000 | $7,000 | $5,000 |
| | | | | **Total:** | **$48,000** | **$46,000** | **$43,000** |

| | Undiscounted | 3% NPV | 7% NPV |
|---|---|---|---|
| **Total Industry Future Operating Reactor Implementation Cost (Indirect):** | **$48,000** | **$47,000** | **$46,000** |
| **Total Industry Future Operating Reactor Implementation Cost (Direct):** | **$648,000** | **$540,000** | **$410,000** |
| **Total Industry Future Operating Reactor Implementation Cost:** | **$700,000** | **$580,000** | **$460,000** |

## Table 5 - Industry Operation Costs for Operating Reactors

**Industry Operation Costs (Risk-Informed Alternative)**

| Year | Activity (Update to PRA) | Number of AOR | Per AOR | | Cost per year | | |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | Total | 3% NPV | 7% NPV |
| 2021 | Track #1 | 10 | 0.050 | $200,000 | $100,000 | $89,000 | $76,000 |
| 2021 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $8,900 | $7,600 |
| 2022 | Track #2 | 1 | 0.050 | $200,000 | $10,000 | $8,600 | $7,100 |
| 2022 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $8,600 | $7,100 |
| 2023 | Track #3 | 1 | 0.050 | $200,000 | $10,000 | $8,400 | $6,700 |
| 2023 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $8,400 | $6,700 |
| 2024 | Track # 2 | 0 | 0.050 | $200,000 | $0 | $0 | $0 |
| 2024 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $8,100 | $6,200 |
| 2025 | Track #1 | 10 | 0.050 | $200,000 | $100,000 | $79,000 | $58,000 |
| 2025 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $7,900 | $5,800 |
| 2026 | Track # 2 | 1 | 0.050 | $200,000 | $10,000 | $7,700 | $5,400 |
| 2026 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $7,700 | $5,400 |
| 2027 | Track #3 | 1 | 0.050 | $200,000 | $10,000 | $7,400 | $5,100 |
| 2027 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $7,400 | $5,100 |
| 2028 | Track # 2 | 0 | 0.050 | $200,000 | $0 | $0 | $0 |
| 2028 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $7,200 | $4,800 |
| 2029 | Track #1 | 10 | 0.050 | $200,000 | $100,000 | $70,000 | $44,000 |
| 2029 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $7,000 | $4,400 |
| 2030 | Track # 2 | 1 | 0.050 | $200,000 | $10,000 | $6,800 | $4,100 |
| 2030 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $6,800 | $4,100 |
| 2031 | Track #3 | 1 | 0.050 | $200,000 | $10,000 | $6,600 | $3,900 |
| 2031 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $6,600 | $3,900 |
| 2032 | Track # 2 | 0 | 0.050 | $200,000 | $0 | $0 | $0 |
| 2032 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $6,400 | $3,600 |
| 2033 | Track #1 | 10 | 0.050 | $200,000 | $100,000 | $62,000 | $34,000 |
| 2033 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $6,200 | $3,400 |
| 2034 | Track # 2 | 1 | 0.050 | $200,000 | $10,000 | $6,100 | $3,200 |
| 2034 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $6,100 | $3,200 |
| 2035 | Track #3 | 1 | 0.050 | $200,000 | $10,000 | $5,900 | $3,000 |
| 2035 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $5,900 | $3,000 |
| 2036 | Track # 2 | 0 | 0.050 | $200,000 | $0 | $0 | $0 |
| 2036 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $5,700 | $2,800 |
| 2037 | Track #1 | 10 | 0.050 | $200,000 | $100,000 | $55,000 | $26,000 |
| 2037 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $5,500 | $2,600 |
| 2038 | Track # 2 | 1 | 0.050 | $200,000 | $10,000 | $5,400 | $2,400 |
| 2038 | Error Found and Change Made | 1 | 0.050 | $200,000 | $10,000 | $5,400 | $2,400 |
| 2039 | Track #3 | 1 | 0.050 | $200,000 | $10,000 | $5,200 | $2,300 |
| 2039 | Error Found and Change Made | 1 | 0.050 | $200,001 | $10,000 | $5,200 | $2,300 |
| | | | | **Total:** | **$790,000** | **$550,000** | **$370,000** |

**Industry Operation Costs (Indirect - Vendor Operation Costs)**

| Year | Activity | Per Year | | | Indirect Operation Cost | | |
|---|---|---|---|---|---|---|---|
| | | Number of Reloads | Per Reload | | Total | 3% NPV | 7% NPV |
| | | | FTE Required | Yearly Rate | | | |
| 2019 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $570,000 | $520,000 |
| 2020 | Periodic Breakaway Tests | 0 | 0.05 | $200,000 | $0 | $0 | $0 |
| 2021 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $530,000 | $460,000 |
| 2022 | Periodic Breakaway Tests | 44 | 0.05 | $200,000 | $440,000 | $380,000 | $310,000 |
| 2023 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $500,000 | $400,000 |
| 2024 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $490,000 | $370,000 |
| 2025 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $470,000 | $350,000 |
| 2026 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $460,000 | $330,000 |
| 2027 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $450,000 | $310,000 |
| 2028 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $430,000 | $290,000 |
| 2029 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $420,000 | $270,000 |
| 2030 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $410,000 | $250,000 |
| 2031 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $400,000 | $230,000 |
| 2032 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $390,000 | $220,000 |
| 2033 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $370,000 | $200,000 |
| 2034 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $360,000 | $190,000 |
| 2035 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $350,000 | $180,000 |
| 2036 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $340,000 | $170,000 |
| 2037 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $330,000 | $160,000 |
| 2038 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $320,000 | $140,000 |
| 2039 | Periodic Breakaway Tests | 60 | 0.05 | $200,000 | $600,000 | $310,000 | $140,000 |
| | | | | **Total:** | **$9,400,000** | **$7,000,000** | **$4,900,000** |

| | | | |
|---|---|---|---|
| **Total Industry Operating Reactor Operation Cost (Direct):** | **$790,000** | **$550,000** | **$370,000** |
| **Total Industry Operating Reactor Operation Cost (Indirect):** | **$9,400,000** | **$7,000,000** | **$4,900,000** |
| **Total Industry Operating Reactor Operation Cost:** | **$10,000,000** | **$7,600,000** | **$5,300,000** |
| **Total Industry Operating Reactor Cost:** | **$31,000,000** | **$29,000,000** | **$25,000,000** |

# Table 6 - Industry Operation Costs for Future Operating Reactors

**Industry Operation Costs (Indirect - Vendor Operation Costs): Future Operating Reactors**

| Year | Activity | Per Year | | | Indirect Operation Cost | | |
|---|---|---|---|---|---|---|---|
| | | Number of Reloads | Per Reload | | Total | 3% NPV | 7% NPV |
| | | | FTE Required | Yearly Rate | | | |
| 2019 | Periodic Breakaway Tests | 4 | 0.05 | $200,000 | $40,000 | $38,000 | $35,000 |
| 2020 | Periodic Breakaway Tests | 0 | 0.05 | $200,000 | $0 | $0 | $0 |
| 2021 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $44,000 | $38,000 |
| 2022 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $8,600 | $7,100 |
| 2023 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $42,000 | $33,000 |
| 2024 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $8,100 | $6,200 |
| 2025 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $39,000 | $29,000 |
| 2026 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $7,700 | $5,400 |
| 2027 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $37,000 | $25,000 |
| 2028 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $7,200 | $4,800 |
| 2029 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $35,000 | $22,000 |
| 2030 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $6,800 | $4,100 |
| 2031 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $33,000 | $19,000 |
| 2032 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $6,400 | $3,600 |
| 2033 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $31,000 | $17,000 |
| 2034 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $6,100 | $3,200 |
| 2035 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $29,000 | $15,000 |
| 2036 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $5,700 | $2,800 |
| 2037 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $28,000 | $13,000 |
| 2038 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $5,400 | $2,400 |
| 2039 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $26,000 | $11,000 |
| 2040 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $5,100 | $2,100 |
| 2041 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $25,000 | $9,900 |
| 2042 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $4,800 | $1,800 |
| 2043 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $23,000 | $8,600 |
| 2044 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $4,500 | $1,600 |
| 2045 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $22,000 | $7,500 |
| 2046 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $4,200 | $1,400 |
| 2047 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $21,000 | $6,600 |
| 2048 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $4,000 | $1,200 |
| 2049 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $19,000 | $5,700 |
| 2050 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $3,800 | $1,100 |
| 2051 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $18,000 | $5,000 |
| 2052 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $3,600 | $940 |
| 2053 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $17,000 | $4,400 |
| 2054 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $3,300 | $820 |
| 2055 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $16,000 | $3,800 |
| 2056 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $3,200 | $710 |
| 2057 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $15,000 | $3,300 |
| 2058 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $3,000 | $620 |
| 2059 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $14,000 | $2,900 |
| 2060 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $2,800 | $550 |
| 2061 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $14,000 | $2,500 |
| 2062 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $2,600 | $480 |
| 2063 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $13,000 | $2,200 |
| 2064 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $2,500 | $420 |
| 2065 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $12,000 | $1,900 |
| 2066 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $2,300 | $360 |
| 2067 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $11,000 | $1,700 |
| 2068 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $2,200 | $320 |
| 2069 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $11,000 | $1,500 |
| 2070 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $2,100 | $280 |
| 2071 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $10,000 | $1,300 |
| 2072 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $2,000 | $240 |
| 2073 | Periodic Breakaway Tests | 5 | 0.05 | $200,000 | $50,000 | $9,600 | $1,100 |
| 2074 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $1,900 | $210 |
| 2075 | Periodic Breakaway Tests | 4 | 0.05 | $200,000 | $40,000 | $7,200 | $790 |
| 2076 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $1,700 | $180 |
| 2077 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $1,700 | $170 |
| 2078 | Periodic Breakaway Tests | 1 | 0.05 | $200,000 | $10,000 | $1,600 | $160 |
| 2079 | Periodic Breakaway Tests | 0 | 0.05 | $200,000 | $0 | $0 | $0 |
| 2080 | Periodic Breakaway Tests | 0 | 0.05 | $200,000 | $0 | $0 | $0 |
| | | | | **Total:** | **$1,700,000** | **$780,000** | **$380,000** |

| | | | |
|---|---|---|---|
| **Total Industry Future Operating Reactor Operation Cost (Indirect):** | **$1,700,000** | **$780,000** | **$380,000** |

## Table 7 - Total Industry Costs

| | Industry Costs | | |
|---|---|---|---|
| | Total: | 3% NPV | 7% NPV |
| **Total Industry Cost (Indirect):** | **$18,000,000** | **$14,000,000** | **$11,000,000** |
| **Total Industry Cost (Direct):** | **$17,000,000** | **$17,000,000** | **$15,000,000** |
| **Total Industry Implementation Cost:** | **$22,000,000** | **$22,000,000** | **$21,000,000** |
| **Total Industry Operation Cost:** | **$11,000,000** | **$7,800,000** | **$5,300,000** |
| **Total Industry Cost:** | **$35,000,000** | **$31,000,000** | **$26,000,000** |

## Table 8 - Industry Average Implementation Cost per Designated Unit

**Industry Implementation Costs (Indirect - Vendor Implementation Costs): Operating Reactors**

| Year | Activity | Total Cost | 3% NPV | 7% NPV | Average Cost Per AOR (77 AORs) | |
|---|---|---|---|---|---|---|
| | | | | | 3% NPV | 7% NPV |
| 2019 | Cladding Hydrogen Update Models (Including Topic Rpts) | $1,400,000 | $1,400,000 | $1,400,000 | $18,000 | $18,000 |
| 2016 | LOCA Models (PQD, Breakaway) | $900,000 | $900,000 | $900,000 | $12,000 | $12,000 |
| 2017 | | $900,000 | $900,000 | $900,000 | $12,000 | $12,000 |
| 2016 | LOCA Models (LTC) | $600,000 | $600,000 | $600,000 | $8,000 | $8,000 |
| 2017 | | $600,000 | $600,000 | $600,000 | $8,000 | $8,000 |
| 2017 | Initial Breakaway Test | $600,000 | $600,000 | $600,000 | $8,000 | $8,000 |
| | **Total:** | **$5,000,000** | **$5,000,000** | **$5,000,000** | **$66,000** | **$66,000** |

**Industry Implementation Costs: Risk-Informed Alternative**

| Year | Activity (Alternative Approach) | Total Cost | 3% NPV | 7% NPV | Average Cost Per AOR (77 AORs) | |
|---|---|---|---|---|---|---|
| | | | | | 3% NPV | 7% NPV |
| 2018 | Track #1 | $5,000,000 | $4,900,000 | $4,700,000 | $64,000 | $61,000 |
| 2018 | Exemption Request (ER) Preperation and Submission | ($2,000,000) | ($1,900,000) | ($1,900,000) | ($25,000) | ($25,000) |
| 2019 | Track #2 | $500,000 | $470,000 | $440,000 | $6,100 | $5,700 |
| 2019 | Exemption Request (ER) Preperation and Submission | ($140,000) | ($130,000) | ($120,000) | ($1,700) | ($1,600) |
| 2020 | Track #3 | $500,000 | $460,000 | $410,000 | $6,000 | $5,300 |
| 2020 | Exemption Request (ER) Preperation and Submission | ($140,000) | ($130,000) | ($110,000) | ($1,700) | ($1,400) |
| | **Total:** | **$3,700,000** | **$3,700,000** | **$3,400,000** | **$48,000** | **$44,000** |

**Industry Implementation Costs: Operating Reactors**

| Year | Activity (Includes PQD, Breakaway, LTC) | Total Cost | 3% NPV | 7% NPV | Average Cost Per AOR (77 AORs) | |
|---|---|---|---|---|---|---|
| | | | | | 3% NPV | 7% NPV |
| 2017 | Track #1 (50 AORs) | $2,500,000 | $2,500,000 | $2,500,000 | $32,000 | $32,000 |
| 2018 | | $2,500,000 | $2,400,000 | $2,300,000 | $31,000 | $30,000 |
| 2018 | Track # 2 (13 AORs) | $1,200,000 | $1,200,000 | $1,100,000 | $16,000 | $14,000 |
| 2019 | | $1,200,000 | $1,100,000 | $1,000,000 | $14,000 | $13,000 |
| 2020 | | $1,200,000 | $1,100,000 | $980,000 | $14,000 | $13,000 |
| 2019 | Track # 3 (14 AORs) | $1,950,000 | $1,800,000 | $1,700,000 | $23,000 | $22,000 |
| 2020 | | $1,950,000 | $1,800,000 | $1,600,000 | $23,000 | $21,000 |
| 2021 | | $1,950,000 | $1,700,000 | $1,500,000 | $22,000 | $19,000 |
| | **Total:** | **$14,000,000** | **$14,000,000** | **$13,000,000** | **$180,000** | **$160,000** |

**Industry Implementation Costs: Exemption Request Savings: Operating Reactors**

| Year | Activity | Total Cost | 3% NPV | 7% NPV | Average Cost Per AOR (77 AORs) | |
|---|---|---|---|---|---|---|
| | | | | | 3% NPV | 7% NPV |
| 2017 | Exemption Request | ($200,000) | ($200,000) | ($200,000) | ($3,000) | ($3,000) |
| 2018 | Exemption Request | ($200,000) | ($190,000) | ($190,000) | ($2,000) | ($2,000) |
| 2019 | Exemption Request | ($200,000) | ($190,000) | ($170,000) | ($2,000) | ($2,000) |
| 2020 | Exemption Request | ($200,000) | ($180,000) | ($160,000) | ($2,000) | ($2,000) |
| 2021 | Exemption Request | ($200,000) | ($180,000) | ($150,000) | ($2,000) | ($2,000) |
| 2022 | Exemption Request | ($200,000) | ($170,000) | ($140,000) | ($2,000) | ($2,000) |
| 2023 | Exemption Request | ($200,000) | ($170,000) | ($130,000) | ($2,000) | ($2,000) |
| 2024 | Exemption Request | ($200,000) | ($160,000) | ($120,000) | ($2,000) | ($2,000) |
| 2025 | Exemption Request | ($200,000) | ($160,000) | ($120,000) | ($2,000) | ($2,000) |
| 2026 | Exemption Request | ($200,000) | ($150,000) | ($110,000) | ($2,000) | ($1,000) |
| | **Total:** | **($2,000,000)** | **($1,800,000)** | **($1,500,000)** | **($21,000)** | **($20,000)** |

**Industry Implementation Option Costs: PQD Tests: Operating Reactors**

| Year | Activity | Total Cost | 3% NPV | 7% NPV | Average Cost Per AOR (77 AORs) | |
|---|---|---|---|---|---|---|
| | | | | | 3% NPV | 7% NPV |
| 2017 | PQD Test - Accepted NRC Reg Guide | $0 | $0 | $0 | $0 | $0 |
| 2017 | PQD Test - Redone NRC Version | $100,000 | $100,000 | $100,000 | $1,000 | $1,000 |
| 2017 | PQD Test - Industry Version | $0 | $0 | $0 | $0 | $0 |
| | **Total:** | **$100,000** | **$100,000** | **$100,000** | **$1,000** | **$1,000** |

**Industry Implementation Option Costs: LTC Tests: Operating Reactors**

| Year | Activity | Total Cost | 3% NPV | 7% NPV | Average Cost Per AOR (77 AORs) | |
|---|---|---|---|---|---|---|
| | | | | | 3% NPV | 7% NPV |
| 2017 | LTC Tests | $270,000 | $270,000 | $270,000 | $4,000 | $4,000 |
| | **Total:** | **$270,000** | **$270,000** | **$270,000** | **$4,000** | **$4,000** |

| | | | | | |
|---|---|---|---|---|---|
| **Total Industry Operating Reactor Implementation Cost:** | **$21,000,000** | **$21,000,000** | **$20,000,000** | **$280,000** | **$260,000** |

**Industry Implementation Costs (Indirect - Vendor Implementation Costs): Design Certification**

| Year | Activity | Undiscounted | 3% NPV | 7% NPV | Average Cost Per Design Certification (2 DCs) | |
|---|---|---|---|---|---|---|
| | | | | | 3% NPV | 7% NPV |
| 2020 | Initial Breakaway Test | $600,000 | $550,000 | $490,000 | $280,000 | $250,000 |
| | **Total:** | **$600,000** | **$550,000** | **$490,000** | **$280,000** | **$250,000** |

| | | | | | |
|---|---|---|---|---|---|
| **Total Industry Design Certification Implementation Cost:** | **$600,000** | **$550,000** | **$490,000** | **$280,000** | **$250,000** |

**Industry Implementation Costs (Indirect - Vendor Implementation Costs): Future Operating Reactors**

| Year | Activity | Undiscounted | 3% NPV | 7% NPV | Average Cost Per Reactor/AOR | |
|---|---|---|---|---|---|---|
| | | | | | 3% NPV | 7% NPV |
| 2017 | Initial Breakaway Test (Watts Bar, Vogtle 2 & 3, Summer 2) | $32,000 | $32,000 | $32,000 | $8,000 | $8,000 |
| 2019 | Initial Breakaway Test (Summer 3) | $8,000 | $7,000 | $6,000 | $7,000 | $6,000 |
| 2020 | Initial Breakaway Test (Bellefonte) | $8,000 | $7,000 | $5,000 | $7,000 | $5,000 |
| | **Total:** | **$48,000** | **$46,000** | **$43,000** | **$22,000** | **$19,000** |

**Industry Implementation Costs: Future Operating Reactors**

| Year | Activity (Includes PQD, Breakaway, LTC) | Undiscounted | 3% NPV | 7% NPV | Average Cost Per Reactor/AOR | |
|---|---|---|---|---|---|---|
| | | | | | 3% NPV | 7% NPV |
| 2020 | Track #1 (Watts Bar) | $50,000 | $50,000 | $33,000 | $50,000 | $33,000 |
| 2021 | | $50,000 | $41,000 | $31,000 | $41,000 | $31,000 |
| 2024 | Track #1 (Vogtle and Summer Units) | $200,000 | $149,000 | $102,000 | $37,000 | $26,000 |
| 2025 | | $200,000 | $144,000 | $95,000 | $36,000 | $24,000 |
| 2026 | Track #1 (Bellefonte) | $50,000 | $35,000 | $22,000 | $35,000 | $22,000 |
| 2027 | | $50,000 | $34,000 | $21,000 | $34,000 | $21,000 |
| | **Total:** | **$600,000** | **$453,000** | **$304,000** | **$233,000** | **$157,000** |

**Industry Implementation Option Costs: LTC Tests: Future Operating Reactors**

| Year | Activity | Undiscounted | 3% NPV | 7% NPV | Average Cost Per Reactor/AOR | |
|---|---|---|---|---|---|---|
| | | | | | 3% NPV | 7% NPV |
| 2020 | LTC Test (Watts Bar, Vogtle 2 & 3, Summer 2) | $32,000 | $32,000 | $32,000 | $8,000 | $8,000 |
| 2022 | LTC Tests (Summer 3) | $8,000 | $6,000 | $5,000 | $6,000 | $5,000 |
| 2023 | LTC Tests (Bellefonte) | $8,000 | $6,000 | $4,000 | $6,000 | $4,000 |
| | **Total:** | **$48,000** | **$44,000** | **$41,000** | **$20,000** | **$17,000** |

| | | | | | |
|---|---|---|---|---|---|
| **Total Industry Future Operating Reactor Implementation Cost:** | **$700,000** | **$540,000** | **$390,000** | **$280,000** | **$190,000** |

## Table 9 - NRC Implementation Costs Affecting Operating Reactors, Design Certifications, and Future Operating Reactors

**NRC Implementation Costs**

| Year | Activity | FTE Required | Yearly Rate | Cost per year | | |
|---|---|---|---|---|---|---|
| | | | | Undiscounted | 3% NPV | 7% NPV |
| 2014 | Draft Regulatory Guide - Development & Issuance | 2 | $173,000 | $350,000 | $350,000 | $350,000 |
| 2014 | Draft Regulatory Guide - Risk-Informed Alternative | 2 | $173,000 | $350,000 | $350,000 | $350,000 |
| 2014 | Revise Regulatory Guides after Comment Period | 2 | $173,000 | $350,000 | $350,000 | $350,000 |
| 2014 | Revise Risk-Informed Alternative Regulatory Guide after Comment Period | 2 | $173,000 | $350,000 | $350,000 | $350,000 |
| 2015 | Issue Final Regulatory Guides | 1 | $173,000 | $170,000 | $170,000 | $170,000 |
| 2015 | Issue Final Regulatory Guide for Risk-Informed Alternative | 1 | $173,000 | $170,000 | $170,000 | $170,000 |
| 2015 | Revise SRP | 1 | $173,000 | $170,000 | $170,000 | $170,000 |
| 2014 | Development of Final Rule | 2 | $173,000 | $350,000 | $350,000 | $350,000 |
| 2015 | | 2 | $173,000 | $350,000 | $350,000 | $350,000 |
| 2016 | | 2 | $173,000 | $350,000 | $350,000 | $350,000 |
| 2018 | NRC Review of Cladding Hydrogen Uptake Models | 2 | $173,000 | $350,000 | $340,000 | $330,000 |
| 2018 | NRC Review of LOCA Models (PQD, Breakaway) | 2 | $173,000 | $350,000 | $340,000 | $330,000 |
| 2019 | | 2 | $173,000 | $350,000 | $330,000 | $310,000 |
| 2018 | NRC Review of LOCA Models (LTC) | 1 | $173,000 | $170,000 | $170,000 | $160,000 |
| 2019 | | 1 | $173,000 | $170,000 | $160,000 | $150,000 |
| | | | **Total:** | **$4,400,000** | **$4,300,000** | **$4,200,000** |

## Table 10 - NRC Implementation Costs for Operating Reactors

**NRC Implementation Costs: Operating Reactors**

| | | | | | | |
|---|---|---|---|---|---|---|
| 2018 | Breakaway Test Review | 1 | $173,000 | $170,000 | $170,000 | $160,000 |
| | | | **Total:** | **$170,000** | **$170,000** | **$160,000** |

**NRC Implementation Costs: Risk-Informed Alternative: Operating Reactors**

| Year | Activity | FTE Required | Yearly Rate | Cost Per year | | |
|---|---|---|---|---|---|---|
| | | | | Undiscounted | 3% NPV | 7% NPV |
| 2019 | Track #1 | 5.6 | $173,000 | $960,000 | $830,000 | $680,000 |
| 2019 | Exemption Request Review | 1.61 | $173,000 | ($280,000) | ($240,000) | ($200,000) |
| 2020 | Track #2 | 0.56 | $173,000 | $96,000 | $80,000 | $64,000 |
| 2020 | Exemption Request Review | 0.11 | $173,000 | ($20,000) | ($17,000) | ($13,000) |
| 2021 | Track #3 | 0.56 | $173,000 | $96,000 | $78,000 | $60,000 |
| 2021 | Exemption Request Review | 0.11 | $173,000 | ($20,000) | ($16,000) | ($12,000) |
| | | | **Total:** | **$830,000** | **$720,000** | **$580,000** |

**NRC Implementation Costs: License Amendment Reviews: Operating Reactors**

| Year | Activity | FTE Required | Yearly Rate | Cost Per year | | |
|---|---|---|---|---|---|---|
| | | | | Undiscounted | 3% NPV | 7% NPV |
| 2019 | Track #1 | 0 | $173,000 | $0 | $0 | $0 |
| 2020 | | 0 | $173,000 | $0 | $0 | $0 |
| 2021 | Track #2 | 2 | $173,000 | $350,000 | $310,000 | $270,000 |
| 2022 | | 2 | $173,000 | $350,000 | $300,000 | $250,000 |
| 2022 | Track #3 | 2 | $173,000 | $350,000 | $300,000 | $250,000 |
| 2023 | | 2 | $173,000 | $350,000 | $290,000 | $230,000 |
| | | | **Total:** | **$1,400,000** | **$1,200,000** | **$1,000,000** |

**NRC Implementation Costs: Exemption Request Savings: Operating Reactors**

| Year | Activity | Number of Exemption Requests | Per Exemption Request | | Cost per year | | |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | Undiscounted | 3% NPV | 7% NPV |
| 2017 | Exemption Request Review | 5 | 0.1 | $173,000 | ($87,000) | ($87,000) | ($87,000) |
| 2018 | Exemption Request Review | 5 | 0.1 | $173,000 | ($87,000) | ($84,000) | ($81,000) |
| 2019 | Exemption Request Review | 5 | 0.1 | $173,000 | ($87,000) | ($82,000) | ($76,000) |
| 2020 | Exemption Request Review | 5 | 0.1 | $173,000 | ($87,000) | ($80,000) | ($71,000) |
| 2021 | Exemption Request Review | 5 | 0.1 | $173,000 | ($87,000) | ($77,000) | ($66,000) |
| 2022 | Exemption Request Review | 5 | 0.1 | $173,000 | ($87,000) | ($75,000) | ($62,000) |
| 2023 | Exemption Request Review | 5 | 0.1 | $173,000 | ($87,000) | ($73,000) | ($58,000) |
| 2024 | Exemption Request Review | 5 | 0.1 | $173,000 | ($87,000) | ($71,000) | ($54,000) |
| 2025 | Exemption Request Review | 5 | 0.1 | $173,000 | ($87,000) | ($69,000) | ($51,000) |
| 2026 | Exemption Request Review | 5 | 0.1 | $173,000 | ($87,000) | ($67,000) | ($47,000) |
| | | | | **Total:** | **($870,000)** | **($770,000)** | **($650,000)** |

**NRC Implementation Costs: PQD Tests: Operating Reactors**

| Year | Activity | Number of Cladding Alloys | Per Cladding Alloy | | Cost per year | | |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | Undiscounted | 3% NPV | 7% NPV |
| 2018 | PQD Test - Accepted NRC Reg Guide | 7 | 0 | $173,000 | $0 | $0 | $0 |
| 2018 | PQD Test - Redone NRC Version | 2 | 0.25 | $173,000 | $87,000 | $84,000 | $81,000 |
| 2018 | PQD Test - Licensee Version | 0 | 0.5 - 2.5 | $173,000 | $0 | $0 | $0 |
| | | | | **Total:** | **$87,000** | **$84,000** | **$81,000** |

**NRC Implementation Costs: LTC Test Reviews: Operating Reactors**

| Year | Activity | Number of Cladding Alloys | Per Cladding Alloy | | Cost per year | | |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | Undiscounted | 3% NPV | 7% NPV |
| 2018 | LTC Test Reviews | 9 | 0.15 | $173,000 | $230,000 | $220,000 | $210,000 |
| | | | | **Total:** | **$230,000** | **$220,000** | **$210,000** |

| | | | |
|---|---|---|---|
| **Total NRC Operating Reactor Implementation Cost:** | **$6,200,000** | **$5,900,000** | **$5,600,000** |

## Table 11 - NRC Implementation Costs for Design Certifications

**NRC Implementation Costs: Certification Amendment Reviews: Design Certification**

| Year | Activity | Number of Design Certifications | Per Design Certification | | Undiscounted | 3% NPV | 7% NPV |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | | | |
| 2021 | Track #2 | 2 | 0.27 | $173,000 | $92,000 | $82,000 | $70,000 |
| | | | | **Total:** | **$92,000** | **$82,000** | **$70,000** |

| | | | |
|---|---|---|---|
| **Total NRC Design Certification Implementation Cost:** | **$92,000** | **$82,000** | **$70,000** |

## Table 12 - NRC Implementation Costs for Future Operating Reactors

**NRC Implementation Costs: Future Operating Reactors**

| Year | Activity | FTE Required | Yearly Rate | Cost per year | | |
|---|---|---|---|---|---|---|
| | | | | Undiscounted | 3% NPV | 7% NPV |
| 2018 | Breakaway Test Review (Watts Bar, Vogtle 2 & 3, Summer 2) | 0.05 | $173,000 | $8,000 | $8,000 | $7,000 |
| 2020 | Breakaway Test Review (Summer 3) | 0.01 | $173,000 | $2,000 | $2,000 | $2,000 |
| 2021 | Breakaway Test Review (Bellefonte) | 0.01 | $173,000 | $2,000 | $2,000 | $2,000 |
| | | | **Total:** | **$12,000** | **$12,000** | **$11,000** |

**NRC Implementation Costs: License Amendment Reviews: Future Operating Reactors**

| Year | Activity (Includes PQD, Breakaway, LTC) | FTE Required | Yearly Rate | Cost per year | | |
|---|---|---|---|---|---|---|
| | | | | Undiscounted | 3% NPV | 7% NPV |
| 2019 | Track #1 (Watts Bar) | 0 | $173,000 | $0 | $0 | $0 |
| 2020 | | 0 | | $0 | $0 | $0 |
| 2023 | Track #1 (Vogtle and Summer Units) | 0 | $173,000 | $0 | $0 | $0 |
| 2024 | | 0 | | $0 | $0 | $0 |
| 2025 | Track #1 (Bellefonte) | 0 | $173,000 | $0 | $0 | $0 |
| 2026 | | 0 | | $0 | $0 | $0 |
| | | | **Total:** | **$0** | **$0** | **$0** |

**NRC Implementation Costs: LTC Test Reviews: Future Operating Reactors**

| Year | Activity | Number of Reactor | Per Reactor | | Undiscounted | 3% NPV | 7% NPV |
|---|---|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | | | |
| 2018 | LTC Test Review (Watts Bar, Vogtle 2 & 3, Summer 2) | 4 | 0.04 | $173,000 | $28,000 | $27,000 | $26,000 |
| 2023 | LTC Test Review (Summer 3) | 1 | 0.04 | $173,000 | $7,000 | $6,000 | $5,000 |
| 2024 | LTC Test Review (Bellefonte) | 1 | 0.04 | $173,000 | $7,000 | $6,000 | $4,000 |
| | | | | **Total:** | **$42,000** | **$39,000** | **$35,000** |
| | **Total NRC Future Operating Reactor Implementation Cost:** | | | | **$54,000** | **$51,000** | **$46,000** |

## Table 13 - NRC Operation Costs for Operating Reactors

**NRC Operation Costs: Operating Reactors**

| Start Year | Activity | Per year | | Indirect Operation Cost | | |
|---|---|---|---|---|---|---|
| | | FTE Required | Yearly Rate | Total | 3% NPV | 7% NPV |
| 2020 | Periodic Breakaway Test Reviews | 0.15 | $173,000 | $26,000 | $24,000 | $21,000 |
| 2021 | Periodic Breakaway Test Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2022 | Periodic Breakaway Test Reviews | 0.15 | $173,000 | $26,000 | $22,000 | $19,000 |
| 2022 | Update to PRA Reviews | 5.6 | $173,000 | $960,000 | $830,000 | $680,000 |
| 2022 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $4,300 | $3,600 |
| 2023 | Periodic Breakaway Test Reviews | 0.15 | $173,000 | $26,000 | $22,000 | $17,000 |
| 2023 | Update to PRA Reviews | 0.56 | $173,000 | $96,000 | $80,000 | $64,000 |
| 2023 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $4,200 | $3,300 |
| 2024 | Periodic Breakaway Test Reviews | 0.15 | $173,000 | $26,000 | $21,000 | $16,000 |
| 2024 | Update to PRA Reviews | 0.56 | $173,000 | $96,000 | $78,000 | $60,000 |
| 2024 | Periodic Breakaway Test Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2024 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $4,100 | $3,100 |
| 2025 | Update to PRA Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2025 | Periodic Breakaway Test Reviews | 0.15 | $173,000 | $26,000 | $21,000 | $15,000 |
| 2025 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $3,900 | $2,900 |
| 2026 | Update to PRA Reviews | 5.6 | $173,000 | $960,000 | $740,000 | $520,000 |
| 2026 | Periodic Breakaway Test Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2026 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $3,800 | $2,700 |
| 2027 | Update to PRA Reviews | 0.56 | $173,000 | $96,000 | $71,000 | $49,000 |
| 2027 | Periodic Breakaway Test Reviews | 0.15 | $173,000 | $26,000 | $19,000 | $13,000 |
| 2027 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $3,700 | $2,500 |
| 2028 | Update to PRA Reviews | 0.56 | $173,000 | $96,000 | $69,000 | $46,000 |
| 2028 | Periodic Breakaway Test Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2028 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $3,600 | $2,400 |
| 2029 | Update to PRA Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2029 | Periodic Breakaway Test Reviews | 0.15 | $173,000 | $26,000 | $18,000 | $12,000 |
| 2029 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $3,500 | $2,200 |
| 2030 | Update to PRA Reviews | 5.6 | $173,000 | $960,000 | $650,000 | $400,000 |
| 2030 | Periodic Breakaway Test Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2030 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $3,400 | $2,100 |
| 2031 | Update to PRA Reviews | 0.56 | $173,000 | $96,000 | $63,000 | $37,000 |
| 2031 | Periodic Breakaway Test Reviews | 0.15 | $173,000 | $26,000 | $17,000 | $10,000 |
| 2031 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $3,300 | $1,900 |
| 2032 | Update to PRA Reviews | 0.56 | $173,000 | $96,000 | $62,000 | $35,000 |
| 2032 | Periodic Breakaway Test Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2032 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $3,200 | $1,800 |
| 2033 | Update to PRA Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2033 | Periodic Breakaway Test Reviews | 0.15 | $173,000 | $26,000 | $16,000 | $8,800 |
| 2033 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $3,100 | $1,700 |
| 2034 | Update to PRA Reviews | 5.6 | $173,000 | $960,000 | $580,000 | $300,000 |
| 2034 | Periodic Breakaway Test Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2034 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $3,000 | $1,600 |
| 2035 | Update to PRA Reviews | 0.56 | $173,000 | $96,000 | $56,000 | $28,000 |
| 2035 | Periodic Breakaway Test Reviews | 0.15 | $173,000 | $26,000 | $15,000 | $7,700 |
| 2035 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $2,900 | $1,500 |
| 2036 | Update to PRA Reviews | 0.56 | $173,000 | $96,000 | $55,000 | $27,000 |
| 2036 | Periodic Breakaway Test Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2036 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $2,900 | $1,400 |
| 2037 | Update to PRA Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2037 | Periodic Breakaway Test Reviews | 0.15 | $173,000 | $26,000 | $14,000 | $6,700 |
| 2037 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $2,800 | $1,300 |
| 2038 | Update to PRA Reviews | 5.6 | $173,000 | $960,000 | $520,000 | $230,000 |
| 2038 | Periodic Breakaway Test Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2038 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $2,700 | $1,200 |
| 2039 | Update to PRA Reviews | 0.56 | $173,000 | $96,000 | $50,000 | $22,000 |
| 2039 | Periodic Breakaway Test Reviews | 0.15 | $173,000 | $26,000 | $14,000 | $5,900 |
| 2039 | Review of Error and Change | 0.029 | $173,000 | $5,000 | $2,600 | $1,100 |
| | | | **Total:** | **$6,100,000** | **$4,200,000** | **$2,700,000** |

| | | | |
|---|---|---|---|
| **Total NRC Operating Reactor Operation Cost:** | **$6,100,000** | **$4,200,000** | **$2,700,000** |

## Table 14 - NRC Operating Costs for Future Operating Reactors

**NRC Operation Costs: Future Operating Reactors**

| Year | Activity | Per Year | | Indirect Operation Cost | | |
|---|---|---|---|---|---|---|
| | | FTE Required | Yearly Rate | Total | 3% NPV | 7% NPV |
| 2020 | Periodic Breakaway Test Reviews | 0.04 | $173,000 | $6,920 | $6,300 | $5,600 |
| 2021 | Periodic Breakaway Test Reviews | 0 | $173,000 | $0 | $0 | $0 |
| 2022 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $7,500 | $6,200 |
| 2023 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $1,400 | $1,200 |
| 2024 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $7,000 | $5,400 |
| 2025 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $1,400 | $1,000 |
| 2026 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $6,600 | $4,700 |
| 2027 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $1,300 | $880 |
| 2028 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $6,200 | $4,100 |
| 2029 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $1,200 | $770 |
| 2030 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $5,900 | $3,600 |
| 2031 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $1,100 | $670 |
| 2032 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $5,600 | $3,100 |
| 2033 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $1,100 | $590 |
| 2034 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $5,200 | $2,700 |
| 2035 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $1,000 | $510 |
| 2036 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $4,900 | $2,400 |
| 2037 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $960 | $450 |
| 2038 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $4,600 | $2,100 |
| 2039 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $900 | $390 |
| 2040 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $4,400 | $1,800 |
| 2041 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $850 | $340 |
| 2042 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $4,100 | $1,600 |
| 2043 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $800 | $300 |
| 2044 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $3,900 | $1,400 |
| 2045 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $760 | $260 |
| 2046 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $3,700 | $1,200 |
| 2047 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $710 | $230 |
| 2048 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $3,500 | $1,100 |
| 2049 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $670 | $200 |
| 2050 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $3,300 | $930 |
| 2051 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $630 | $170 |
| 2052 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $3,100 | $810 |
| 2053 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $600 | $150 |
| 2054 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $2,900 | $710 |
| 2055 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $560 | $130 |
| 2056 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $2,700 | $620 |
| 2057 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $530 | $120 |
| 2058 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $2,600 | $540 |
| 2059 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $500 | $100 |
| 2060 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $2,400 | $470 |
| 2061 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $470 | $88 |
| 2062 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $2,300 | $410 |
| 2063 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $440 | $77 |
| 2064 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $2,200 | $360 |
| 2065 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $420 | $67 |
| 2066 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $2,000 | $310 |
| 2067 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $390 | $59 |
| 2068 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $1,900 | $270 |
| 2069 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $370 | $51 |
| 2070 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $1,800 | $240 |
| 2071 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $350 | $45 |
| 2072 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $1,700 | $210 |
| 2073 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $330 | $39 |
| 2074 | Periodic Breakaway Test Reviews | 0.05 | $173,000 | $8,650 | $1,600 | $180 |
| 2075 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $310 | $34 |
| 2076 | Periodic Breakaway Test Reviews | 0.04 | $173,000 | $6,920 | $1,200 | $130 |
| 2077 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $290 | $30 |
| 2078 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $290 | $28 |
| 2079 | Periodic Breakaway Test Reviews | 0.01 | $173,000 | $1,730 | $280 | $26 |
| 2080 | Periodic Breakaway Test Reviews | 0 | $173,000 | $0 | $0 | $0 |
| | | | **Total:** | **$300,000** | **$130,000** | **$62,000** |

| | | | |
|---|---|---|---|
| **Total NRC Future Operating Reactor Operation Cost:** | **$300,000** | **$130,000** | **$62,000** |

## Table 15 - Total NRC Costs

| | NRC Costs | | |
|---|---|---|---|
| | Total: | 3% NPV | 7% NPV |
| **Total NRC Operation Cost:** | **$6,000,000** | **$4,300,000** | **$2,800,000** |
| **Total NRC Implementation Cost:** | **$6,300,000** | **$6,000,000** | **$5,700,000** |
| **Total NRC Cost:** | **$12,000,000** | **$10,000,000** | **$8,500,000** |

## Table 16 - Total Costs

**Total Rule Costs**

| **Implementation Costs** | Undiscounted | 3% NPV | 7% NPV |
|---|---|---|---|
| Total NRC Costs | $6,300,000 | $6,000,000 | $5,700,000 |
| Total Industry Costs (Direct) | $17,000,000 | $17,000,000 | $15,000,000 |
| Total Industry Costs (Indirect) | $7,300,000 | $6,400,000 | $5,900,000 |
| **Total:** | **$31,000,000** | **$29,000,000** | **$27,000,000** |

| **Operation Costs** | Undiscounted | 3% NPV | 7% NPV |
|---|---|---|---|
| Total NRC Costs | $6,400,000 | $4,330,000 | $2,800,000 |
| Total Industry Costs (Indirect) | $11,000,000 | $7,800,000 | $5,300,000 |
| **Total:** | **$17,000,000** | **$12,000,000** | **$8,100,000** |

| **Grand Total 50.46c** | Undiscounted | 3% NPV | 7% NPV |
|---|---|---|---|
| Total NRC Costs | $13,000,000 | $10,000,000 | $8,500,000 |
| Total Industry Costs | $35,000,000 | $31,000,000 | $26,000,000 |
| **Total:** | **$48,000,000** | **$41,000,000** | **$35,000,000** |

| **Average Implementation Costs per AOR** | 3% NPV | 7% NPV |
|---|---|---|
| Industry Costs (Direct) | $91,000 | $76,000 |
| Industry Costs (Indirect) | $100,000 | $74,000 |
| **Total:** | **$190,000** | **$150,000** |

## Table 17 - Industry Costs for Future Design Certifications

**Industry Implementation Costs (Indirect - Vendor Implementation Costs): Future Design Certification**

| Year | Activity | Number of Design Certifications | Per Design Certification | | Undiscounted |
|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | |
| X | Initial Breakaway Test | 1 | 0.04 | $200,000 | $8,000 |
| | | | | **Total:** | **$8,000** |

**Industry Implementation Option Costs: PQD Tests: Future Design Certificaion**

| Year | Activity | Number of Design Certifications | Per Design Certification | | Undiscounted |
|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | |
| X | PQD Test - Accepted NRC Reg Guide | 0 | 0 | $200,000 | $0 |
| X | PQD Test - Redone NRC Version | 1 | 0.01 | $200,000 | $2,000 |
| X | PQD Test - Industry Version | 0 | 0.5 - 2.5 | $200,000 | $0 |
| | | | | **Total:** | **$2,000** |

| | |
|---|---|
| **Total Industry Future Design Certification Cost (Indirect):** | **$8,000** |
| **Total Industry Future Design Certification Cost (Direct):** | **$2,000** |
| **Total Industry Future Design Certification Cost:** | **$10,000** |

## Table 18 - NRC Costs for Future Design Certifications

**NRC Implementation Costs: Future Design Certification**

| Year | Activity | FTE Required | Yearly Rate | Undiscounted |
|---|---|---|---|---|
| X+1 | Breakaway Test Review | 0.01 | $173,000 | $2,000 |
| | | | **Total:** | **$2,000** |

**NRC Implementation Costs: PQD Tests: Future Design Certification**

| Year | Activity | Number of Design Certifications | Per Design Certification | | Undiscounted |
|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | |
| X+1 | PQD Test - Accepted NRC Reg Guide | 0 | 0 | $173,000 | $0 |
| X+1 | PQD Test - Redone NRC Version | 1 | 0.005 | $173,000 | $1,000 |
| X+1 | PQD Test - Licensee Version | 0 | 0.5 - 2.5 | $173,000 | $0 |
| | | | | **Total:** | **$1,000** |

| | |
|---|---|
| **Total NRC Future Design Certification Implementation Cost:** | **$3,000** |

# Table 19 - Industry Costs for Hypothetical Future Operating Reactor

**Industry Implementation Costs (Indirect - Vendor Implementation Costs): Hypothetical Future Operating Reactor**

| Year | Activity | Number of Reactor | Per Reactor | | Undiscounted |
|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | |
| X | Initial Breakaway Test | 1 | 0.04 | $200,000 | $8,000 |
| | | | | **Total:** | **$8,000** |

**Industry Implementation Costs: Hypothetical Future Operating Reactor**

| Year | Activity (Includes PQD, Breakaway, LTC) | Number of AOR | Per AOR | | Undiscounted |
|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | |
| X | Track #1 | 1 | 0.25 | $200,000 | $50,000 |
| X+1 | | | 0.25 | | $50,000 |
| | | | | **Total:** | **$100,000** |

**Industry Implementation Option Costs: LTC Tests: Hypothetical Future Operating Reactor**

| Year | Activity | Number of Reactor | Per Reactor | | Undiscounted |
|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | |
| X | LTC Test | 1 | 0.04 | $200,000 | $8,000 |
| | | | | **Total:** | **$8,000** |

**Industry Operation Costs (Indirect - Vendor Operation Costs): Hypothetical Future Operating Reactor**

| Start Year | Activity | Per Year | | | | Number of Years | Undiscounted Total |
|---|---|---|---|---|---|---|---|
| | | Average Number of Reloads | Per Reload | | Total Cost | | |
| | | | FTE Required | Yearly Rate | | | |
| X+1.5 | Periodic Breakaway Tests | 0.67 | 0.05 | $200,000 | $6,667 | 58.5 | $390,000 |
| | | | | | | **Total:** | **$390,000** |

| | |
|---|---|
| **Total Industry Hypothetical Future Operating Reactor Implementation Cost:** | **$116,000** |
| **Total Industry Hypothetical Future Operating Reactor Operation Cost:** | **$390,000** |
| **Total Industry Hypothetical Future Operating Reactor Cost (Indirect):** | **$398,000** |

## Table 20 - NRC Costs for Hypothetical Future Operating Reactor

**NRC Implementation Costs: Hypothetical Future Operating Reactor**

| Year | Activity | FTE Required | Yearly Rate | Undiscounted |
|---|---|---|---|---|
| X+1 | Breakaway Test Review | 0.08 | $173,000 | $14,000 |
| | | | **Total:** | **$14,000** |

**NRC Implementation Costs: License Amendment Reviews: Hypothetical Future Operating Reactor**

| Year | Activity (Includes PQD, Breakaway, LTC) | Per AOR | | Undiscounted |
|---|---|---|---|---|
| | | FTE Required | Yearly Rate | |
| X+1 | Track #1 | 0 | $173,000 | $0 |
| X+2 | | 0 | | $0 |
| | | | **Total:** | **$0** |

**NRC Implementation Option Costs: LTC Test Reviews: Hypothetical Future Operating Reactor**

| Year | Activity | Number of Units | Per Unit | | Undiscounted |
|---|---|---|---|---|---|
| | | | FTE Required | Yearly Rate | |
| X+1 | LTC Test Review | 1 | 0.04 | $173,000 | $7,000 |
| | | | | **Total:** | **$7,000** |

**NRC Operation Costs: Hypothetical Future Operating Reactor**

| Start Year | Activity | Per Year | | | Number of Years | Undiscounted Total |
|---|---|---|---|---|---|---|
| | | FTE Required | Yearly Rate | Total Cost | | |
| X+2.5 | Periodic Breakaway Test Reviews | 0.002 | $173,000 | $346 | 57.5 | $20,000 |
| | | | | | **Total:** | **$20,000** |

| | |
|---|---|
| **Total NRC Hypothetical Future Operating Reactor Implementation Cost:** | **$21,000** |
| **Total NRC Hypothetical Future Operating Reactor Operating Cost:** | **$20,000** |
| **Total NRC Hypothetical Future Operating Reactor Cost:** | **$41,000** |