Joint Report on GEH BWRX-300 Safety Strategy White Paper

A Collaborative Review by the U.S. Nuclear Regulatory Commission and the Canadian Nuclear Safety Commission

July 2023

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Preface

On August 15, 2019, the Canadian Nuclear Safety Commission (CNSC) and the United States (US) Nuclear Regulatory Commission (NRC) signed a joint memorandum of cooperation (MOC) [1] aimed at enhancing technical reviews of advanced reactor and small modular reactor technologies. This MOC is intended to supplement and strengthen the existing memorandum of understanding between the two parties signed in August 2017 [2]. Additional information on international agreements and the CNSC can be found at https://nuclearsafety.gc.ca/eng/resources/international-cooperation/international-agreements.cfm.

Cooperation between the CNSC and the USNRC provides opportunities for both agencies to share scientific information about technical matters that could support more efficient reviews of small modular reactor and advanced reactor technologies. Cooperative activities can be conducted, while acknowledging differences between the Canadian and U.S. regulatory frameworks and licensing processes, by leveraging fundamental scientific and engineering findings from other reviews to the extent practicable.

Activities under the MOC are coordinated by a subcommittee of the CNSC-USNRC Steering Committee, called the Advanced Reactor Technologies and Small Modular Reactors subcommittee. The subcommittee approves and prioritizes work plans to accomplish specific cooperative activities under the MOC.

Cooperative activities between both organizations are established and governed under Terms of Reference (see https://nuclearsafety.gc.ca/eng/resources/international-cooperation/international-agreements/cnsc-usnrc-smr-advanced-reactor-moc-tor.cfm) and are designed to do the following:

- Contribute to better use of the regulators' resources by leveraging the technical knowledge and capabilities between the USNRC and the CNSC.
- Enhance the depth and breadth of the respective CNSC and USNRC staffs' understanding of the counterpart nation's regulatory review activities and requirements.
- Enhance the joint opportunities for learning about and understanding the advanced reactor and small modular reactor technologies being reviewed.

The decision of the CNSC and the USNRC to cooperate in activities that concern specific reactors, and their associated vendors depends on the state of the design. It is based on the following factors that the vendor or applicant must address in a proposed work plan that both regulators accept:

- The extent the vendor or applicant is engaging in meaningful licensing or prelicensing activity with each regulator.
- The similarities between the vendor's engagement activities in each country in order to achieve a useful cooperation outcome. For example, the objectives of the CNSC's vendor design review process differ from those of the U.S. certification and engagement processes, yet opportunities exist for leveraging information between the two regulators.

- The timelines for engaging with each regulator.
- The way the vendor is sharing information about its design with both regulators to enable cooperation.

These joint products are envisioned to enhance advanced reactor design reviews and support regulatory reviews by each regulator, as appropriate.

Executive Summary

This report documents the results of collaborative activities between the Canadian Nuclear Safety Commission (CNSC) and the United States (U.S.) Nuclear Regulatory Commission (NRC) concerning a request by GE-Hitachi Nuclear Energy Americas LLC, to obtain feedback on its Safety Strategy white paper for the BWRX-300 submitted to the U.S. NRC and CNSC on December 6, 2022 (Agencywide Documents Access and Management System Accession No. ML22341A058). The results of this report may be used by the vendor or a potential licensee in future discussions with either regulator, but they are not legally binding on the CNSC or the USNRC.

In general, the proposed strategy in the white paper appears to be consistent with CNSC's regulations and processes but will require further development to demonstrate adherence to CNSC requirements. With respect to the NRC, the proposed safety strategy in the white paper may benefit from better clarity on how it demonstrates compliance with the NRC regulations and guidance regarding event categorization, mitigation, and safety analyses acceptance criteria, including identification of planned exemption requests from specific requirements that are otherwise met through GEH's alternative approach[1].

[1] After submittal of the white paper, the NRC continued to engage with GEH on the safety strategy, including having two public meetings on the topic (ML23087A095).

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List of Acronyms

ADAMS	Agencywide Documents Access and Management System
BWR	boiling-water reactor
CFR	*Code of Federal Regulations*
CNSC	Canadian Nuclear Safety Commission
DBA	design-basis accident
DEC	design extension condition
D-in-D	defense-in-depth
DL	defense line
ESBWR	Economic Simplified Boiling-Water Reactor
FA	focus area
GDC	design criterion/criteria
GEH	General Electric Hitachi
IAEA	International Atomic Energy Agency
MOC	memorandum of cooperation
MOU	memorandum of understanding
NRC	Nuclear Regulatory Commission
NEI	Nuclear Energy Institute
OPG	Ontario Power Generation
PDC	principal design criterion/criteria
PIE	postulated initiating event
REGDOC	regulatory document
RG	regulatory guide
RISC	risk-informed safety class
SAMDAs	Severe Accident Mitigation Design Alternatives
SSC	structure, system, and component
TVA	Tennessee Valley Authority
US	United States
VDR	vendor design review

1. Introduction

This report documents the results of collaborative activities between the Canadian Nuclear Safety Commission (CNSC) and the U.S. Nuclear Regulatory Commission (USNRC) concerning a request by GE Hitachi Nuclear Energy Americas LLC (GEH), to obtain feedback on its Safety Strategy white paper for the BWRX-300 submitted to the NRC and CNSC on December 6, 2022 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML22341A058).

In April 2022, the Tennessee Valley Authority (TVA) and Ontario Power Generation (OPG) announced plans to jointly work to help develop and deploy small modular reactors (SMRs) in both Canada and the U.S. They have signed a Memorandum of Understanding (MOU) that allows the companies to coordinate efforts on the design, licensing, construction, and operation of SMRs. CNSC and USNRC are currently engaged in licensing and pre-application activities with OPG and TVA, respectively. In September of 2022, CNSC and USNRC signed a Charter [13] establishing a collaborative relationship on the BWRX-300 SMR design project. Under this charter, OPG, TVA and GEH have identified several licensing and lifecycle topics, including safety strategy, that this report addresses, where they are seeking additional guidance and clarity of CNSC and USNRC regulatory expectations for cross-border deployment. The CNSC and the USNRC will determine which topics are appropriate to consider jointly.

Nothing in this report fetters the powers, duties or discretion of CNSC or NRC designated officers, CNSC or NRC inspectors or the respective Commissions regarding making regulatory decisions or taking regulatory action. Nothing in this report is to be construed or interpreted as affecting the jurisdiction and discretion of the CNSC in any assessment of any application for licensing purposes under the Nuclear Safety and Control Act of January 2017, its associated regulations or the CNSC Rules of Procedure. Likewise, nothing in this report is to be construed or interpreted as affecting the jurisdiction and discretion of the NRC in any evaluation of any application for licensing purposes under the Atomic Energy Act of 1954, as amended, its associated regulations and the NRC Management Directives. This report does not involve the issuance of a license under section 24 of the Nuclear Safety and Control Act or under section 103 of the Atomic Energy Act of 1954. The conclusions in this collaborative report are of the CNSC and NRC staff.

1.1. GEH Engagement with the USNRC

In September 2019, GEH initiated pre-application activities with the NRC on its BWRX-300 reactor design to support a future license application. The BWRX-300 is a ~300 MWe light-water-cooled, natural circulation SMR with passive safety systems. The design of the BWRX-300 is based in part on the U.S. NRC-certified 1,520 MWe Economic Simplified Boling-Water Reactor (ESBWR). GEH has submitted five licensing topical reports (LTRs) on key licensing issues since 2020 that have been reviewed and approved by the NRC staff. LTRs describe the BWRX-300 design approaches and analyses methodologies for the BWRX-300 SMR in advance of a future 10 CFR Part 50 or Part 52 license application. GEH has also submitted two white papers in 2022 as part of a pre-LTR submittal engagement, including one on safety strategy, which is the subject of this report.

After submittal of the white paper, the NRC continued to engage with GEH on the safety strategy, including having two public meetings on the topic, which are documented in a public meeting summary (ML23087A095). During those public meetings, GEH provided additional clarity on the safety strategy and the NRC staff provided perspectives from its review. The NRC staff perspectives in this paper reflect feedback on the white paper and do not include the content of discussions in those meetings.

1.2. GEH Engagement with the CNSC

GEH and the CNSC entered a combined optional pre-licensing Phase 1 and 2 Vendor Design Review (VDR) in December 2019 through a service agreement. The VDR determined whether GEH understands CNSC regulatory requirements and to what extent the reactor design meets those requirements. The VDR took place during the design process while the design was still evolving to provide early feedback. This allows for early identification and resolution of potential regulatory or technical issues in the safety analysis and design process, particularly those that could result in significant changes to the design.

The BWRX-300 VDR concluded that GEH understands and correctly interpreted the intent of Canadian regulatory requirements for the design of nuclear power plants. However, the review did reveal some technical areas for development to better demonstrate adherence to CNSC requirements.

2. Scope and Objectives for the Cooperative Activity

The work plan [3] issued in September 2022, describes the scope of work and objectives as follows:

> *"To share regulatory experiences and insights for the BWRX-300 SMR design. Specifically, the scope of work is to perform a collaborative review of a white paper on BWRX-300 Safety Strategy. An exchange of information between the CNSC and USNRC will cover regulatory approaches and the application of the IAEA defense-in-depth methodology."*

The main objective of this report is to document the USNRC and the CNSC staff's joint assessment of the BWRX-300 Safety Strategy white paper [4].

3. Regulatory Criteria and Observations

3.1. CNSC

3.1.1. Regulatory Framework

GEH states that the safety strategy is the overall safety philosophy of the BWRX-300 reactor design, aimed to achieve a high-level of safety through the application of defense-in-depth (D-in-D) concepts. Therefore, it was deemed that the high-level regulatory expectations were appropriate to assess the adequacy of GEH safety philosophy, with the focus on the requirements pertinent to safety principles and concepts, D-in-D and safety analysis. The criteria used by CNSC for the review of the safety strategy proposed by GEH in [4], are listed below:

- REGDOC-2.5.2, “Design of Reactor Facilities: Nuclear Power Plants,” [5].
- REGDOC-2.4.1, “Deterministic Safety Analysis,” [6].
- REGDOC-2.4.2, “Probabilistic Safety Assessment (PSA) for Reactor Facilities, V.2” [7].
- Specific Safety Requirements No. SSR-2/1 (Rev.1) [8].

It should be noted that this joint review focused on the GEH White Paper [4] only. The GEH engagement with the CNSC included other instances were a BWRX-300 safety strategy or safety analysis has been reviewed (e.g., during the VDR), however due to the development and evolution of the design, each review has been documented individually.

3.1.2. Observations

3.1.2.1 General Observation

a. In general, the proposed strategy appears to be consistent with CNSC’s regulations and processes. The GEH Safety Strategy [4] is consistent with the safety objectives and D-in-D principles in REGDOC-2.5.2. The safety analysis scope and approach, including the associated PIEs selection and event sequencies and acceptance criteria, also largely complies with those specified by REGDOC-2.5.2, REGDOC-2.4.1, and REGDOC-2.4.2. Nevertheless, CNSC has observations and clarifications that are summarized in the following sections. They are expected to be followed-up during the on-going review of the License to Construct (LTC) application for the Darlington New Nuclear Project (DNNP).

b. In section 1.1 of [4] GEH acknowledges that “*the BWRX-300 Safety Strategy incorporates selected guidance from the International Atomic Energy Agency (IAEA) Safety Standards Specific Safety Requirements No. SSR-2/1, Revision 1, “Safety of Nuclear Power Plants: Design*.”” However, it is not clear what selection criteria from SSR-2/1 have been applied, as well as the reason(s) that some principal design requirements from the SSR -2/1 were not adopted by the GEH Safety Strategy (e.g., Interfaces of safety with security and safeguards or proven engineering practices). A more precise definition and scope of BWRX-300 Safety Strategy would help to better convey the intent and usage of this document.

c. In section 1.1 Purpose, GEH states that “The BWRX-300 Safety Strategy includes the use of a risk-informed performance-based (RIPB) approach…” However, subsequent description of the methodology and additional details presented suggests a more or less traditional International Atomic Energy Agency (IAEA) approach. Although this approach takes risk into consideration, it typically cannot be claimed as a risk-informed performance-based approach. Based on the CNSC framework, risk-informed performance-based approach should systematically consider and integrate multiple factors, such as DID, safety analysis methodology, risk significance, operating experience, engineering judgment, proven engineering practices and measurable performance goals. It is noted that the BWRX-300 Safety Strategy touches some of these factors, but it is unclear how it can be considered as a risk-informed performance-based approach.

d. In section 3.6 GEH explains their principles of the achievement of D-in-D lines independence. Previous engagements between CNSC and GEH under the VDR, identified concerns stemming from sharing of certain SSCs between defense lines (DLs). As such, sharing of DL2 and DL4a sensors required more justification and clarification. CNSC staff requested that GEH assess that when DL3 is called upon to mitigate the failures of a single DL2 component that is also shared with DL4a, the required DL4a safety functions are available when DL3 functions fail due to common cause failures. This is being followed up as part of the review of License To Construct application that is currently underway.

e. Some terms used by GEH require further clarity. For example, the word "graded" used by GEH in various circumstances ("graded QA approach," "graded approach," "graded acceptance criteria") may have different meaning depending on the circumstances it was being used, as well as the specific terminology and definitions of each organization. "Graded" in these contexts should be clearly defined and elaborated to allow CNSC staff to provide meaningful assessment to confirm their uses meets CNSC regulatory requirements.

f. White paper [4] section 4.2.7, "Analysis of Design Extension Conditions with Core Damage (Severe Accidents)" describes the safety strategy to meet CNSC requirement on practical elimination of plant states that could lead to significant radioactive releases. The white paper claims that "Fault Sequences that are either physically impossible or extremely unlikely (<1E-09 per reactor-year) to occur are considered for Practical Elimination." However, REGDOC-2.5.2 clearly states that practical elimination of an accident should not be claimed solely based on the compliance with a probabilistic cut-off value. REGDOC-2.5.2 describes a systematic approach for the demonstration of the practical elimination as extremely unlikely with a high degree of confidence. The white paper [4] lacks the description of a systematic strategy/approach for meeting this requirement.

3.1.2.2 Specific Observations

a. Application of Defense-In-Depth (D-in-D)

In section 2.3.4 of white paper [4] GEH described their approach for D-in-D however they did not demonstrate how the strategy will ensure that the concept of D-in-D is maintained, and how the design is able to prevent: *"(a) Challenges to the integrity of physical barriers; (b) Failure of one or more barriers; (c) Failure of a barrier as a consequence of the failure of another barrier; (d) The possibility of harmful consequences of errors in operation and maintenance*" as required is section 4.1.1 of REGDOC-2.5.2. These requirements are important for a robust and well balanced DiD strategy and should be appropriately considered.

b. Implementation of safety strategy

It is noted that the safety strategy outlines high-level nuclear safety principles and objectives; it's implementation (in pre-licensing or licensing engagements) requires the development of additional documents, specifications, and analysis, that shall meet relevant regulatory expectations. This is yet to be demonstrated by GEH. The information included in the safety strategy white paper [4] is general and addresses the regulatory requirements and guidance at a high-level. The following sections (i to v) summarize potential areas of future work, should the safety strategy be implemented and the supporting deterministic, probabilistic and hazard analysis developed further. Such aspects include, but are not limited to: derivation of PIEs, application of single failure criterion, trip effectiveness, acceptance criteria, the treatment of uncertainties.

i. Analysis and acceptance criteria for DSA

In section 2.1.2 of the white paper [4] GEH state that "The BWRX-300 design includes measures consistent with acceptance criteria and safety objective." GEH also stated in section 2.3.5 that the "Consideration of PIEs and development of Fault Sequences, including determination of the DL functions (DL2, DL3, DL4a, and DL4b) credited for mitigating the consequences of the Fault Sequences to meet applicable Safety Analysis acceptance criteria…" However, the safety strategy may benefit from better clarity on what GEH understands as "applicable Safety Analysis acceptance criteria" (e.g., dose acceptance criteria, derived acceptance criteria) how acceptance criteria are developed for different class of events (NO, AOOs, DBAs and DECs/BDBAs) and what measures are undertaken that allows GEH to meet the safety objectives. REGDOC-2.4.1 requires that "Acceptance criteria are established to serve as thresholds of safe operation in normal operation, AOOs, DBAs and, to the extent practicable, for BDBAs. The limits and conditions used by plant designers and operators should be supported by adequate experimental evidence, and be consistent with the safety analysis acceptance criteria…"

Moreover, REGDOC-2.4.1, clause 4.3.1 requires that: "Analysis for normal operation of the NPP, performed during the design phase, shall demonstrate that radiological doses to workers and members of the public are within the limits acceptable to the CNSC and releases of radioactive material into the environment fall within the allowable limits for normal operation." GEH should provide further clarity for their approach toward safety analysis acceptance criteria (both regulatory and derived) for normal operation. Also, GEH should provide further clarifications of the "graded acceptance criteria" mentioned under section 3.2 of white paper [4].

ii. Accounting for uncertainties

GEH approach to account for uncertainties was not presented in the safety strategy [4]. REGDOC-2.4.1 clause 4.4.3 states that: "Significant uncertainties in analysis data, including those associated with NPP performance, operational measurements, and modelling parameters, shall be identified." SSR2/1 states: "The safety analysis shall provide assurance that uncertainties have been given adequate consideration in the design of the plant and in particular that adequate margins are available to avoid cliff edge effects and early radioactive releases or large radioactive releases." The safety strategy should include a discussion about how the uncertainties are being addressed in the BWRX-300 design and safety analysis.

iii. Trip effectiveness

GEH should provide deterministic safety analysis demonstrating the effectiveness of the means of shutdown with appropriate derived acceptance criteria, as requested by section 8.4.1 of REGDOC-2.5.2 which requires that: “The design authority shall specify derived acceptance criteria for reactor trip parameter effectiveness for all AOOs and DBAs and shall perform a safety analysis to demonstrate the effectiveness of the means of shutdown.”

iv. Single failure criterion

Section 7.6.2 of REGDOC-2.5.2 requires that: “All safety groups shall function in the presence of a single failure.” GEH was silent about this aspect in the proposed safety strategy for the safety analysis. The safety strategy should include a high-level description on how single failure is addressed by the safety analysis.

v. Identification, Categorization and Grouping of PIEs and Accident Scenarios

Under section 4.3, GEH presented their approach for the identification and determination of accident Scenarios. GEH mentions four types of hazards, including functional failures, external and internal hazards, as well as human operation hazard. GEH is expected to demonstrate the safety strategy alignment with relevant regulatory requirements such as REGDOC-2.5.2, section 5.4 and REGDOC-2.4.1, section 4.2 that states "The licensee shall use a systematic process to identify events, event sequences, and event combinations (“events” hereafter in this document) that can potentially challenge the safety or control functions of the NPP. The licensee shall also identify events that may lead to fission product releases, including those related to spent fuel pools (also called irradiated fuel bays) and fuel-handling systems. This process shall be based on regulatory requirements and guidance, past licensing precedents, operational experience, engineering judgment, results of deterministic and probabilistic assessments, and any other systematic reviews of the design”.
The safety strategy should clearly describe how the four hazard categories identified are used to derive the potential PIEs for the BWRX-300, the Fault Sequences, their grouping and the screening criteria applied, consistent with the regulatory expectations mentioned above.

3.2. USNRC

3.2.1. Regulatory Framework

New reactor designs in the U.S. are assessed against the criteria outlined in Title 10 of the *Code of Federal Regulations* (CFR) Part 50 [9] *“Domestic Licensing of Production and Utilization Facilities,”* or 10 CFR Part 52 [10] *“Licenses, Certifications, and Approvals for Nuclear Power Plants,”* although the substantive regulations are largely equivalent. Additionally, the NRC is currently developing another licensing pathway for new reactor designs: 10 CFR Part 53 *“Risk-Informed, Technology-Inclusive Regulatory Framework for Commercial Nuclear Plants.”*

GEH has entered an agreement with the TVA to develop a construction permit application under 10 CFR Part 50 to potentially deploy a BWRX-300 at the Clinch River site. As such, the NRC has focused on the regulatory requirements in Part 50 to assess the design.

The NRC has developed a Standard Review Plan (SRP), NUREG-0800 [11], to assist staff in performing its reviews. SRP Chapter 15, “Transient and Accident Analysis,” is one of the chapters used by the staff to evaluate the white paper. The SRP describes the review process and acceptance criteria used to analyze accident and transient behavior.

Additionally, the NRC has developed guidance for industry, such as Regulatory Guide (RG) 1.26 [12], “Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants,” that describes the quality standards for SSCs acceptable to the NRC staff for satisfying the requirements of General Design Criteria (GDC) 1.

The following is a partial list of NRC regulations that the NRC staff uses to review the proposed GEH Safety Strategy:

- 10 CFR 50.2, “Definitions” “Safety-related,”
- 10 CFR 50.34, “Contents of applications; technical information,”
- 10 CFR 50.36, “Technical specifications,”
- 10 CFR 50.46, “Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors,”
- 10 CFR 50.55a, “Codes and Standards,”
- 10 CFR 50.65, “Requirements for monitoring the effectiveness of maintenance at nuclear power plants,”
- 10 CFR 50.155, “Mitigation of beyond-design-basis events,”
- 10 CFR Part 50, Appendix A, “General Design Criteria for Nuclear Power Plants,”
- 10 CFR Part 50, Appendix B, “Quality Assurance Criteria for Nuclear Power Plants and Fuel,” and
- 10 CFR Part 50, Appendix S, “Earthquake Engineering Criteria for Nuclear Power Plants.”

These regulations help ensure maintenance of safety margin, defense-in-depth, and the reliability and availability of SSCs relied upon in the safety analysis. NRC regulations also provide for exemptions from specific requirements under certain conditions, and Commission policy supports the use of risk informed approaches to support reduction of unnecessary conservatism in deterministic approaches.

3.2.2. Observations

3.2.2.1 General Observations

The BWRX-300 Safety Strategy, as described in the white paper, does not clearly address all elements of the NRC's regulatory framework, which is guided by reasonable assurance of compliance with regulations and adequate protection of the public health and safety. While this novel approach by GEH could be successful, NRC approval of the safety strategy will be based on an applicant showing conformance to NRC regulations, including acceptable justification of applicable exemptions.

In proposing a risk-informed, performance-based approach, GEH states in the white paper that it will use line of defense concepts supported by probabilistic risk assessment (PRA) fault sequence frequency to identify different categories of events. This approach may need further clarification to demonstrate clear compliance with the deterministic requirements for structures, systems, and components (SSCs) under 10 CFR Part 50 or 52. While a risk-informed approach may be acceptable, GEH would need to provide additional information to inform the staff's safety conclusion. Application of a risk informed, performance-based approach should be consistent with Commission policy in SECY-98-144 which states, in part, that a risk-informed approach provides for the identification and quantification of uncertainties and a means to test the sensitivity of results to key assumptions. The treatment of uncertainties and the means to test assumptions are not well described in the white paper. Finally, the BWRX-300 Safety Strategy should demonstrate consistency with the Commission's policy statements on the use of PRA in regulatory activities (60 FR 42622; August 16, 1995), severe accidents regarding future designs and existing plants (50 FR 32138; August 8, 1985), and staff requirements memoranda for advanced light-water designs.

In its white paper, GEH identified the fundamental safety functions for DL 3 with a fault sequence frequency between 1.E-2/year and 1.E-5/year. Numerical cutoff frequencies delineating event categories may conflict with consideration of some hypothetical design-basis events required by 10 CFR Part 50. For example, if the final design is determined to have a loss-of-coolant from the reactor coolant pressure boundary with a frequency less than 1.E-5/year, the proposed strategy could result in a loss-of-coolant accident (LOCA) being defined as a beyond-design-basis accident which would not appear to comply with 10 CFR 50.46 and may necessitate an exemption. In addition, postulated reactivity accidents in GDC 28 include steam-line rupture and rod drop accidents, which are additional examples of non-mechanistic events that are required to be considered in the design of the reactivity control systems. As such, the proposed safety strategy concept of applying fault sequence frequencies to determine event categories needs to be consistent with NRC risk-informed principles and comply with the NRC regulations, including justified exemptions.

The proposed BWRX-300 Safety Strategy may benefit from better clarity on how it demonstrates compliance with the NRC regulations and guidance on the characterization of the safety-related SSCs needed for the mitigation of AOOs. Specifically, in Section 3.2, "Defense Line 2," on page 18, of the white paper, GEH states that, "there is no regulatory basis for asserting that AOOs must be mitigated by safety related SSCs." The NRC staff could not identify how GEH's proposal satisfied 10 CFR 50.2 requirements that safety-related SSCs are those that are relied on during or following a design-basis event (DBE) to assure, in part: (1) the integrity of the reactor coolant pressure boundary, and (2) the capability to shut down the reactor and maintain it in a safe shutdown condition. For AOOs, the NRC's regulations prescribe a safe shutdown condition to be one where heat is being sufficiently removed and the fuel integrity barrier is maintained by demonstration of appropriate margin to the specified acceptable fuel design limits.

The proposed approach to classifying SSCs for the BWRX-300 should clearly address the NRC regulations and the Commission policy regarding regulatory treatment of non-safety systems designated for specific functions in advanced passive light-water reactors. 10 CFR Part 50, Appendix A, GDC 1, "Quality Standards and Records," require SSCs important to safety be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed. Further, 10 CFR 50.55a, "Codes and Standards," provides the specific requirements for design, fabrication, erection, and testing standards for certain systems and components of boiling- and pressurized-water reactors. NRC Regulatory Guide 1.26, "Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants," describes the quality standards for pressure-retaining components acceptable to the NRC staff for satisfying the requirements of GDC 1. The white paper does not appear to define the various safety classes, quality classes, and seismic categories included in the strategy, nor describe the corresponding regulatory treatment of SSCs other than by specifying a safety class designation and associated reliability target for DLs 2, 3, and 4 safety functions.

IAEA SSR-2/1, which provides the foundation for GEH's Safety Strategy for BWRX-300, focuses both on safety and the environment. The white paper did not discuss how GEH's Safety Strategy addresses the environmental aspects to conform with NRC requirements, including the evaluation of Severe Accident Mitigation Design Alternatives (SAMDAs). The NRC's licensing process requires an applicant to evaluate SAMDAs to examine the residual risk and if incorporation of additional mitigation is practicable to implement.

3.2.2.2 Specific Observations

a. The detailed technical basis for the numerical threshold demarcating the event sequence frequency boundary between DBEs (DL3) and DECs (DL4) as described under white paper section 3.3, "Defense Line 3," is not provided.

b. The technical basis for how design-basis hurricanes, hurricane missiles, and tornadoes (which are assessed at 1E-7 annual exceedance frequency) should be better aligned with what is considered acceptable for satisfying NRC regulations in addition to how GEH evaluated them using the numerical thresholds demarcating the Safety Strategy DLs.

c. The safety strategy did not seem to include provisions for or references to meeting the mitigating strategies rule under 10 CFR 50.155, "Mitigation of beyond-design-basis events." This includes the provisions related to the Spent Fuel Pool level monitoring and cooling makeup capabilities.

d. GEH's use of numerical screening thresholds for DL 5 and the concept of "practical elimination of large releases" should be clarified as to how it is connected to NRC licensing. If it is not connected to NRC licensing, that should be clarified. If it is intended to address NRC requirements, such role should be explained.

e. A detailed roadmap explaining which NRC regulations the proposed safety strategy is intended to address and how each regulation is satisfied would be valuable.

4. CNSC-USNRC Joint Conclusion

In general, the proposed strategy in the white paper appears to be consistent with CNSC's regulations and processes. However, as described in section 3.1 above, the CNSC staff review identified areas which require further development to demonstrate adherence to the CNSC regulatory requirements. With respect to the NRC, the proposed safety strategy in the white paper may benefit from better clarity on how it demonstrates compliance with the NRC regulations and guidance regarding event categorization, mitigation, and safety analyses acceptance criteria, including identification of planned exemption requests from specific requirements that are otherwise met through GEH's alternative approach.

For future review requests, the CNSC and the USNRC would find it valuable for the submission to include a roadmap outlining how the submission meets the regulatory requirements of each jurisdiction. The roadmap can also identify any potential gaps/differences and areas that would need exemptions from the current regulatory requirements. Furthermore, the staff will benefit from examples of implementation of various aspects of the safety strategy and a summary of how the proposed BWRX-300 Safety Strategy is similar to or different as compared to the strategies implemented by GEH for the NRC approved designs such as ESBWR. Areas that both regulators agree need additional clarity include:

- How uncertainties are treated
- How environmental aspects are addressed
- What acceptance criteria are used for each event category
- How single failure is incorporated
- How the safety strategy meets all aspects of a risk-informed performance-based approach

5. References

1. “Memorandum of Cooperation on Advanced Reactor and Small Modular Reactor Technologies between the United States Nuclear Regulatory Commission and the Canadian Nuclear Safety Commission,” August 15, 2019 (ADAMS Accession No. ML19275D578)

2. “Memorandum of Understanding between the United States Nuclear Regulatory Commission and the Canadian Nuclear Safety Commission for the Exchange of Technical Information and Cooperation in Nuclear Safety Matters,” August 2017 (ML196168A017)

3. Work Plan between CNSC and US NRC “Cooperation in Pre-application Review Activities Pertinent to Small Modular Reactor (SMR) – GE-Hitachi’s Boiling-Water Reactor X-300 (BWRX-300) – Safety Strategy,” Revision 0, dated September 2022, MLA, e-doc 68756261

4. GEH letter to USNRC and CNSC “NEDO-33989, Revision 0, BWRX-300 Safety Strategy white paper,” M220163, December 6, 2022, and its Enclosure 1, NEDO-33989, Revision 0, BWRX-300 Safety Strategy white paper – Non-Proprietary Information

5. CNSC, REGDOC-2.5.2, “Design of Reactor Facilities: Nuclear Power Plants,” May 2014

6. CNSC, REGDOC-2.4.1, “Deterministic Safety Analysis,” May 2014

7. CNSC, REGDOC-2.4.2, “Probabilistic Safety Assessment (PSA) for Reactor Facilities V.2,” May 2022

8. Specific Safety Requirements No. SSR-2/1 (Rev.1), IAEA, Vienna, 2016

9. 10 CFR Part 50, “Domestic licensing of production and utilization facilities”

10. 10 CFR Part 52, “Licenses, certifications, and approvals for nuclear power plants”

11. NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition”

12. Regulatory Guide 1.26, “Quality Group Classifications and Standards for Water-, Steam-, and Radioactive-Waste-Containing Components of Nuclear Power Plants”

13. Charter - NRC/CNSC Collaboration on GE Hitachi's BWRX-300 Design (ML22284A024)