**X Energy, LLC**
801 Thompson Avenue
Rockville, MD 20852
+1 301.358.5600

04-Nov-2022 2022-XE-NRC-029

Project No. 99902071

U.S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

**Submission of X Energy, LLC (X-energy) Xe-100 Licensing Topical Report, "Risk-informed, Performance-Based Licensing Basis Development," Accepted Version**

**REFERENCES:**

1) Letter from M. van Staden to U.S. Nuclear Regulatory Commission (NRC) dated 7 July 2021, "Submission of X Energy, LLC (X-energy) Xe-100 Licensing Topical Report: Risk-informed Performance-Based Licensing Basis Development" (ML21196A070)
2) Email from NRC to X-energy dated 5 November 2021, "U.S. NRC Preliminary Questions regarding X Energy LLC Topical Report: "Xe-100 Risk-Informed Performance-Based Licensing Basis Development" (XE00-R-R1ZZ-RDZZ-L-001522)" (ML21312A166)

3) Letter from T. Chapman to NRC dated 15 March 2022, "Submission of X Energy, LLC (X-energy) Xe-100 Licensing Topical Report: Risk-informed Performance-Based Licensing Basis Development Revision 2" (ML22074A288)

4) Letter from NRC to T. Chapman dated 4 August 2022, "X Energy, LLC. – Safety Evaluation for X Energy, LLC - Xe-100 Licensing Topical Report XE00-R-R1ZZ-RDZZ-L, "Risk-Informed Performance-Based Licensing Basis Development, Revision 2" (EPID L-2021-TOP-0019)" (ML22187A267)

In Reference 1 listed above, X Energy, LLC (X-energy), submitted Revision 1 of Licensing Topical Report, "Risk-Informed Performance-Based Licensing Basis Development" for NRC review. In Reference 2, NRC transmitted preliminary questions regarding Reference 1, and a public meeting was held to discuss the preliminary questions. In Reference 3, X-energy submitted Revision 2 of the topical report which addressed the preliminary questions. In Reference 4, NRC transmitted the Safety Evaluation Report for Reference 2. This letter transmits the accepted version of the Licensing Topical Report.

If you have any questions or require additional information, please contact Stephen Vaughn at svaughn@x-energy.com or Ingrid Nordby at inordby@x-energy.com.

Sincerely,

DocuSigned by:
F053E736949E4C3...

Travis A. Chapman
Manager, U.S. Licensing, Xe-100 Program
X Energy, LLC

**X Energy, LLC**
801 Thompson Avenue
Rockville, MD 20852
+1 301.358.5600

cc:
X-energy, LLC
George Vanderheyden
Steve Miller
Martin van Staden

Nuclear Regulatory Commission
William Jessup
Lucieann Vechioli-Feliciano
Michael Orenak

U.S. Department of Energy
Jeff Ciocco
Carl Friesen

Enclosures:

1) X Energy, LLC. – Safety Evaluation for X Energy, LLC - Xe-100 Licensing Topical Report XE00-R-R1ZZ-RDZZ-L, "Risk-Informed Performance-Based Licensing Basis Development, Revision 2" (EPID L-2021-TOP-0019)

2) U.S. NRC Preliminary Questions regarding X Energy LLC Topical Report: "Xe-100 Risk-Informed Performance-Based Licensing Basis Development

3) X Energy, LLC Xe-100 Licensing Topical Report, "Risk-Informed Performance-Based Licensing Basis Development, Revision 2"

**X Energy, LLC**
801 Thompson Avenue
Rockville, MD 20852
+1 301.358.5600

**Enclosure 1**

**X Energy, LLC. – Safety Evaluation for X Energy, LLC - Xe-100 Licensing Topical Report XE00-R-R1ZZ-RDZZ-L, "Risk-Informed Performance-Based Licensing Basis Development, Revision 2" (EPID L-2021-TOP-0019)**

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

August 4, 2022

Travis Chapman
Lead Licensing Engineer
X-Energy, LLC.
801 Thompson Avenue
Rockville, MD 20852

SUBJECT: X ENERGY, LLC. - SAFETY EVALUATION FOR X ENERGY, LLC - XE-100 LICENSING TOPICAL REPORT XE00-R-R1ZZ-RDZZ-L, "RISK-INFORMED PERFORMANCE-BASED LICENSING BASIS DEVELOPMENT, REVISION 2" (EPID L-2021-TOP-0019)

Dear Mr. Chapman:

By letter dated July 7, 2021, (Agencywide Documents Access and Management System (ADAMS) Accession No. ML21196A069), X Energy, LLC (X-energy) submitted its Xe-100 Licensing Topical Report (TR) XE00-R-R1ZZ-RDZZ-L, "Risk-Informed Performance-Based Licensing Basis Development," Revision 1 dated June 25, 2021, for the U.S. Nuclear Regulatory Commission (NRC) staff's review. This TR provides a description of the approach taken by X-energy to develop a technology-inclusive, risk-informed, and performance-based process for the selection of licensing basis events, safety classification of structures, systems, and components to include associated risk-informed special treatments, and a determination of defense-in-depth adequacy that will form a portion of the Xe-100 licensing basis. As part of its review, the NRC staff developed a set of preliminary questions and sent them to X-energy on November 5, 2021 (ML21312A166). On November 17, 2021, the NRC staff held a public meeting with X-energy representatives to discuss these questions. The meeting summary can be found at ML21347A947. Subsequently, on March 15, 2022, X-energy submitted Revision 2 of its TR to the NRC staff, addressing the set of preliminary questions (ML22074A288).

On June 17, 2022, the NRC staff provided X-energy a draft of the safety evaluation (SE) for the purpose of identifying proprietary information (ML22131A068). On June 27, 2022, X-energy confirmed that the SE did not include proprietary information (ML22181B117). The final NRC staff's SE for "Risk-Informed Performance-Based Licensing Basis Development, Revision 2" is enclosed.

In accordance with the NRC's published information for Topical Reports available at https://www.nrc.gov/about-nrc/regulatory/licensing/topical-reports.html, the NRC staff requests that X-energy publish an accepted version of this topical report within 3 months of receipt of this letter. The accepted version should incorporate this letter and the enclosed SE. Also, the accepted version must contain historical review information, including requests for additional information (RAIs) and/or preliminary questions and respective responses. The accepted version should include a "-A" (designated accepted) following the topical report identification number.

As an alternative to including the RAI and RAI responses (or preliminary questions), if changes to the topical report were provided to the NRC staff to support the resolution of RAI responses,

and the NRC staff reviewed and approved those changes, there are two ways that the accepted version can capture the RAIs:

1. The RAIs and RAI responses (or preliminary questions) can be included as an Appendix to the accepted version.

2. The RAIs and RAI responses (or preliminary questions) can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the accepted version of the topical report. The table should reference the specific RAI and RAI responses (or preliminary questions) which resulted in any changes, as shown in the accepted version of the topical report.

If you have any questions or comments concerning this matter, please contact Lucieann Vechioli Feliciano at (301) 415-6035 or via e-mail at or Lucieann.VechioliFeliciano@nrc.gov.

Sincerely,

Signed by Jessup, William
on 08/04/22

William Jessup, Chief
Advanced Reactor Licensing Branch 1
Division of Advanced Reactors and Non-power
Production and Utilization Facilities
Office of Nuclear Reactor Regulation

Project No.: 99902071

Enclosure:
As stated

cc: inordby@x-energy.com
tchapman@x-energy.com

SUBJECT: X ENERGY, LLC. - SAFETY EVALUATION FOR X ENERGY, LLC - XE-100 LICENSING TOPICAL REPORT XE00-R-R1ZZ-RDZZ-L, "RISK-INFORMED PERFORMANCE-BASED LICENSING BASIS DEVELOPMENT, REVISION 2" (EPID L-2021-TOP-0019) DATED: AUGUST 4, 2022

**DISTRIBUTION**:
PUBLIC
LVechioli, NRR
WJessup, NRR
DGreene, NRR
CSmith, NRR
JBowen, NRR
MShams, NRR
RidsNrrLACSmith Resource
RidsNrrOd Resource
RidsOgcMailCenter Resource
RidsNrrDanu Resource
RidsNrrDanuUal1 Resource

**ADAMS Accession Nos.:**
**Package: ML22187A279**
**Letter: ML22187A267**
**Enclosure: ML22187A271** **NRR-106**

| | | | |
|---|---|---|---|
| **OFFICE** | NRR/DANU/UAL1/PM | NRR/DANU/UAL1/LA | OGC |
| **NAME** | LVechioli | DGreene | JEzell |
| **DATE** | 7/8/2022 | 7/13/2022 | 7/26/2022 |
| **OFFICE** | NRR/DANU/UAT1/BC | NRR/DANU/UAL1/BC | |
| **NAME** | MHayes | WJessup | |
| **DATE** | 8/1/2022 | 8/4/2022 | |

**OFFICIAL RECORD COPY**

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

**X ENERGY, LLC – SAFETY EVALUATION OF XE-100 LICENSING TOPICAL REPORT: RISK-INFORMED PERFORMANCE-BASED LICENSING BASIS DEVELOPMENT, REVISION NO. 2 (EPID L-2021-TOP-0019)**

| | |
|---|---|
| **Sponsor:** | X Energy, LLC (X-energy) |
| **Sponsor Address:** | X Energy, LLC<br>801 Thompson Ave<br>Rockville, MD 20852 |
| **Project No.:** | 99902071 |
| **Submittal Date:** | June 25, 2021 (Topical Report (TR) Revision 1)<br>March 15, 2022 (TR, Revision 2) |

**Submittals Agencywide Documents Access and Management System (ADAMS) Accession Nos.:** ML21196A069 (TR Revision 1); ML22074A288 (TR Revision 2)

**Brief Description of the Topical Report:** This topical report (TR) describes how the risk-informed performance-based methodology, contained in the Licensing Modernization Project (LMP), is being implemented by X-energy for design, analysis, and licensing of its Xe-100 reactor. The guidance regarding the LMP is contained in Nuclear Energy Institute (NEI) 18-04, Revision 1, "Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development" (Reference 1), and the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certification, and Approvals for Non-Light-Water Reactors" (Reference 2). RG 1.233 endorses, with clarifications, NEI 18-04, Revision 1. X-energy requested that the NRC staff review the approach described in this TR to determine its acceptability in implementing the NEI 18-04 guidance for the selection of licensing basis events (LBEs); classification of structures, systems, and components (SSCs) and associated special treatments; determination of defense-in-depth (DID) adequacy for non-LWRs; and addressing the clarifications provided in RG 1.233. X-energy intends to use the TR to inform the content for future safety analysis reports to fulfill the regulatory requirements for prospective Xe-100 licensing applications under Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic licensing of production and utilization facilities;" 10 CFR Part 52, "Licenses, certifications, and approvals for nuclear power plants"; and/or future 10 CFR Part 53.

For additional details regarding the submittals, please refer to the documents located under the ADAMS Accession Numbers identified above.

## REGULATORY EVALUATION

**Regulatory Basis:** The regulations under 10 CFR 50.34, “Contents of applications; technical information;” 10 CFR 52.47, “Contents of applications; technical information;” 10 CFR 52.79, “Contents of applications; technical information in final safety analysis report;” 10 CFR 52.137, “Contents of applications; technical information;” and 10 CFR 52.157, “Contents of applications; technical information in final safety analysis report” contain the technical requirements for applications for a construction permit, operating license, standard design certification, combined license, standard design approval, and manufacturing license for nuclear power facilities.

RG 1.233 provides the NRC staff’s guidance regarding using a technology-inclusive, risk-informed, and performance-based methodology to inform the licensing basis and content of applications for non-light-water reactors (non-LWRs). It endorses, with clarifications, NEI 18-04, Revision 1, as one acceptable method for informing the licensing basis and determining the appropriate scope and level of detail for parts of applications for licenses, certifications, and approvals for non-LWRs.

NEI 18-04, Revision 1, presents a technology-inclusive, risk-informed, and performance-based process for selection of LBEs, classification of SSCs and associated special treatments, and determination of DID adequacy for non-LWRs. It provides applicants one acceptable method for informing the licensing basis and content of applications regarding the forementioned topics above.

## TECHNICAL EVALUATION

Consistent with X-energy’s request, the NRC staff evaluated the approach described in this TR to determine its acceptability in implementing the NEI 18-04 guidance for selection of LBEs, classification of SSCs and associated special treatments, and determination of the DID adequacy, and in addressing the clarifications provided in RG 1.233. The NRC staff’s evaluation is based on TR, Revision 2, which has been updated from TR, Revision 1, to address the NRC staff’s preliminary questions (Reference 3). The meeting summary for the virtual public meeting held between the NRC staff and X-energy regarding the set of preliminary questions developed by the NRC staff to improve its understanding of the information provided in the TR can be located at ML21347A947. In its evaluation, the NRC staff primarily used the guidance in RG 1.233, Revision 0 and NEI 18-04, Revision 1.

Section 1 of the TR summarizes the purpose, scope, interfacing references, and applicable regulations of this document.

Section 2 outlines the applicability of the LMP approach outlined by RG 1.233 to licensing of the Xe-100 design.

Sections 3 through 5 of the TR, which correspond to Sections 3 through 5 of NEI 18-04, cover selection of LBEs, classification of SSCs and associated special treatments, and determination of the DID adequacy, respectively. Each section presents a discussion of how the Xe-100 approach (called the Xe-100 Program) adopts, or provides additional implementation descriptions to, the guidance in NEI 18-04. For example, Section 3 of the TR specifies that the current LBE frequency estimates are based on insights from previous high-temperature gas-cooled reactor technologies and will be refined further to incorporate new information from the Xe-100 design, safety analyses, and probabilistic risk assessment. These three TR sections also address the following eight clarifications identified in RG 1.233:

- Subsection 3.4, Clarification C.1.a through C.1.e (Selection of LBEs)
- Subsection 4.5, Clarification C.2.a, and C.2.b (Classification of SSCs)
- Subsection 5.10, Clarification C.3.a (Determination of the DID Adequacy)

The NRC staff confirmed that Sections 3 through 5 of the TR follow the guidelines provided by the corresponding sections of NEI 18-04 with no deviations, but it adds implementation descriptions for clarity. The NRC staff found that the added descriptions in the TR are minor and remain consistent with the principles and methodology in NEI 18-04. The TR also follows the NRC staff's clarifications (i.e., NRC Staff Positions) described in RG 1.233 but contains additional implementation descriptions to the clarifications. The NRC staff finds that the added descriptions to the RG 1.233 clarifications in the TR are minor and acceptable as they are within the guidelines provided by RG 1.233. For example, RG 1.233, Section C.1.c provides, in part, that if an applicant proposes a method for identifying a design-basis external hazard level (DBEHL) that the NRC staff has not previously reviewed and approved, the NRC staff will review such methodologies on a case-by-case basis. X-energy's additional implementation descriptions for this clarification states that while NEI 18-04, as endorsed by RG 1.233, uses the term DBEHL, X-energy instead uses the term DBHL to clarify that both external and internal hazards are considered. X-energy states that it expects to "use NRC reviewed and approved methods to identify DBHLs." However, it acknowledges that if it chooses to propose methods that have not been previously reviewed and approved, such methods would be reviewed by the NRC staff on a case-by-case basis. In all, the NRC staff determined that the approach, as described in the TR in implementing the NEI 18-04 guidance, is acceptable because the proposed approach meets the principles and methodology in NEI 18-04, and the clarifications provided in RG 1.233.

Since the TR is based on NEI 18-04 and guidance included in RG 1.233, statements from RG 1.233 regarding exemptions from NRC regulations apply. For example, the applicant's methodology, consistent with NEI 18-04, defines and uses some terms in a manner that differs from NRC regulations. Thus, consistent with RG 1.233, an applicant referencing this TR is expected to "identify exceptions to and exemptions needed from NRC regulations," as needed. Also, as stated in RG 1.233, "…system designs and safety evaluations may also demonstrate compliance with or justify exemptions from specific NRC regulations." The TR does not request approval of any exemptions and the NRC staff is not approving any exemptions in this safety evaluation (SE). Thus, the NRC staff is adding Item 1 of this SE, "Limitations and Conditions," to clarify that this SE is not approving any exemptions and that an applicant using this TR will need to address compliance with pertinent regulations and request exemptions, as needed.

Section 6 of the TR describes the X-energy's plan for implementing the risk-informed, performance-based licensing basis framework. The NRC does not reach any conclusions on the acceptability of this information.

## LIMITATIONS AND CONDITIONS

The NRC staff imposes the following limitation and condition with regard to the subject TR:

- This SE does not approve any exemptions from NRC regulations, and an applicant using this TR will need to address compliance with pertinent regulations and request exemptions as needed.

## CONCLUSION

Based on consistency with RG 1.233 and NEI 18-04, the NRC staff finds that X-energy TR, "Xe-100 Licensing Topical Report: Risk-Informed Performance-Based Licensing Basis Development, Revision 2," subject to the limitations and conditions discussed above, provides an approach acceptable to the NRC staff for the selection of LBEs, classification of SSCs and associated special treatments, and determination of the DID adequacy based on a risk-informed and performance-based process.

Accordingly, subject to the limitation and condition identified above, the NRC staff concludes that the X-energy TR can be used to inform the licensing basis of the Xe-100 reactor design that supports the compliance with the relevant regulatory requirements for prospective Xe-100 reactor licensing applications under 10 CFR Parts 50 and 52.

## REFERENCES

1. Nuclear Energy Institute, NEI 18-04, Revision 1, "Risk-Informed Performance-Based Guidance for Non-Light Water Reactor Licensing Basis Development," issued August 2019 (ML19241A472).

2. Regulatory Guide, RG 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors," Revision 0, issued June 2020 (ML20091L698).

3. NRC, "U.S. Nuclear Regulatory Commission Preliminary Questions regarding X Energy LLC Topical Report: Xe-100 Risk-Informed Performance-Based Licensing Basis Development," Revision 2, issued November 2021 (ML21312A478).

Principal Contributor(s): Ian Jung
Hosung Ahn

Date: August 4, 2022

**X Energy, LLC**
801 Thompson Avenue
Rockville, MD 20852
+1 301.358.5600

**Enclosure 2**

**U.S. NRC Preliminary Questions regarding X Energy LLC Topical Report: "Xe-100 Risk-Informed Performance-Based Licensing Basis Development"**

**U.S. Nuclear Regulatory Commission Preliminary Questions regarding X Energy LLC Topical Report: Xe-100 Risk-Informed Performance-Based Licensing Basis Development" (XE00-R-R1ZZ-RDZZ-L-001522)**

X Energy LLC (X-energy) submitted a licensing topical report XE00-R-R1ZZ-RDZZ-L, "Xe-100 Risk-Informed Performance-Based Licensing Basis Development," (Agencywide Documents Access and Management System (ADAMS) Accession No. ML21196A071) in June 2021. The U.S. Nuclear Regulatory Commission (NRC) staff performed an acceptance review of the subject topical report and found in August 2021, that the material presented was sufficient to begin the detailed review (ADAMS Accession No. ML21210A311).

During the detailed review of the topical report, the NRC staff identified a set of preliminary questions and observations to improve its understanding of the information presented in the subject report. The questions are intended to:

- Obtain clarification regarding the material in the topical report.
- Promptly identify areas where additional information may be needed.
- Facilitate discussions and continue an effective communication between the NRC staff and X-energy.

The NRC staff request that X-energy propose a date to discuss the enclosed preliminary questions in a public meeting. Based on the outcome of its discussions with X-energy, the NRC staff may develop formal requests for additional information or continue with the development of the safety evaluation report.

Preliminary Questions:

1. The topical report appears to use the terms 'departure' and 'deviation' interchangeably. The NRC staff recommends consistent use of 'deviation' because 'departure' is typically associated with the changes from the certified information in Title 10 of the *Code of Federal Regulations* (10 CFR) Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants."

2. Regarding Section 3.4.3., "Clarification C.1.c and Xe-100 Position," of the topical report, Nuclear Energy Institute (NEI) 21-07, Revision 0, "Technology Inclusive Guidance for Non-Light Water Reactors: Safety Analysis Report Content for Applicants Using the NEI 18-04 Methodology," was submitted to the NRC for review and approval in August 2021. It states the following:

   > *These considerations are reflected in the selection of the Design Basis Hazard Levels (DBHLs) for the standard plant design (referred to as Design Basis External Hazard Levels or DBEHLs in NEI 18-04).*
   >
   > *Note that this guidance document uses the nomenclature of DBHL instead of the DBEHL term from NEI 18-04. While not discussed comprehensively in NEI 18-04, there is a need to consider not only hazards external to the plant (traditional external events) but also hazards external to the SSCs performing PRA* [Probabilistic Risk Assessment] *Safety Functions – i.e., internal plant hazards such as internal fires, floods, turbine missiles, and high energy line breaks. To clarify the original intent of NEI 18-04 to address both categories of hazards, this guidance document uses the DBHL term instead of DBEHL.*

   NEI 21-07, Revision 0 indicates that DBEHLs in NEI 18-04, Revision 1, "Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development," are meant to include both internal and external hazards.

**Please state if X-energy plans to capture this distinction in this topical report or address it separately, outside of this topical report, after the NRC staff's position on NEI 21-07, Revision 0, is formally established as part of the Technology-Inclusive Content of Application Project (TICAP) and Advanced Reactor Content of Application Project (ARCAP) efforts.**

3. Section 3.4.5., "Clarification C.1.e and Xe-100 Position," of the topical report recites a portion of the NRC staff clarification regarding NEI 18-04:

> *The methodology in NEI 18-04 includes an expanded role for PRA beyond that currently required by 10 CFR Part 52 and policies related to new applications under 10 CFR Part 50. The staff's review of the PRA prepared by a reactor designer could be facilitated by the designer's use of NRC-endorsed consensus codes and standards (e.g., potential NRC endorsement of the American Society of Mechanical Engineers/American Nuclear Society RA-S-1.4, "Probabilistic Risk Assessment Standard for Advanced Non-LWR Nuclear Power Plants"). However, the NRC has not yet endorsed a consensus code or standard for non-LWR PRAs. In the absence of such an endorsed standard, the NRC staff will develop review strategies to address the performance and use of PRAs for specific applications.*

Regarding the last sentence, note that the NRC staff developed a draft white paper titled "Non-Light Water Review Strategy" (ADAMS Accession No. ML19275F299), in 2019 and discussed it with stakeholders. Although it is not a formal guidance document, it provides useful information on PRAs.

Regarding the NRC staff clarification above, the topical report states:

> *The Xe-100 Program PRA will be developed to meet the requirements of the American Society of Mechanical Engineers/American Nuclear Society RA-S-1.4, "Probabilistic Risk Assessment Standard for Advanced Non-LWR Nuclear Power Plants." [3] It is anticipated that the NRC will issue a draft Regulatory Guide in late 2021 endorsing this PRA Standard. X-energy is proceeding with PRA development and monitoring the endorsement activities as they progress at this time.*

The NRC staff notes that the agency released preliminary Draft Regulatory Guide (RG) 1.247, "Acceptability of Probabilistic Risk Assessment Results for Advanced Non-Light Water Reactor Risk-Informed Activities" (ADAMS Accession No. ML21246A216), for interactions with stakeholders. This document is expected to be issued for public comments later this year. Also note that preliminary Draft RG 1.247 proposes endorsement of NEI 20-09, "Performance of PRA Peer Reviews Using the ASME/ANS Advanced Non-LWR PRA Standard." The NRC staff's endorsement may include clarifications that should be addressed by applicants when using ASME/ANS RA-S-1.4 and NEI 20-09.

**Please state if X-energy intends to follow NEI 20-09.** If not, the NRC staff request X-energy to clarify what guidance it plans to use to perform a peer review of its PRA.

4. Section 4.1., "SSC Safety Classification Approach for the Xe-100," of the topical report states:

> *NEI 18-04 is not explicitly clear on the level of decomposition (e.g., functional level, system or component level, event sequence level) the reliability and capability targets should be derived from to support licensing documentation. The Xe-100 Program does not require any departures from NEI 18-04 guidance but will clarify an approach that identifies reliability and capability targets at an appropriate level of decomposition for documentation in the licensing bases and plant records and programs.*

Section 4.4., "Development of SSC Design and Performance Requirements," of the topical report states:

> *At the end of [NEI 18-04] section 4.4.5, "Special Treatment Requirements for SSCs" paragraph entitled "Reliability Assurance for SSCs" notes that all safety-significant SSCs should be included in a Reliability Assurance Program (RAP) similar to that described in the Standard Review Plan (SRP), Chapter 17.4. Similar to the discussion at the end of Section 4.1 of this report, the Xe-100 program will clarify an approach that identifies reliability targets for safety-significant SSCs at an appropriate level of decomposition for documentation in the licensing bases and plant records and programs.*

The topical report states that X-energy "will clarify an approach that identifies reliability and capability targets at an appropriate level." **Please discuss how X-energy will document the approach in the future.**

The NRC staff notes that the topic of reliability and capability targets is one of the key topics surrounding NEI 21-07, Revision 0 and the NRC staff review of the document as part of the TICAP/ARCAP efforts.

Section 5.6., "Establishing the Adequacy of Plant Capability DID [Defense in Depth]," of the topical report states that, "The Xe-100 Program follows the guidance in section 5.6.1 through 5.6.3 and does not require any departures from or clarifications of NEI 18-04 guidance."

It appears that NEI 18-04 contains guidance for applicants under the Section 5.6 heading outside of the lower-level Sections 5.6.1 - 5.6.3. For example, NEI 18-04 Section 5.6 states, "This decision should be clearly recorded, including the bases for this decision, in a configuration-controlled document."

**Please discuss if X-energy intends to follow the entirety of the guidance under NEI 18-04 Section 5.6. If X-energy intends to just follow Sections 5.6.1-5.6.3, please provide a justification for not following all of Section 5.6.**

Section 5.7., "Evaluation of Licensing Basis Events against Layers of Defense," of the topical report states that, "The Xe-100 Program follows the guidance in section 5.7.1 through 5.7.2 and does not require any departures from or clarifications of NEI 18-04 guidance."

**Please discuss if X-energy intends to follow the entirety of the guidance under NEI 18-04 Section 5.7. If X-energy intends to just follow Sections 5.7.1 and 5.7.2, please provide a justification for not following all of Section 5.7.**

Section 6., "X-energy Implementation of the NEI 18-04 RIPB Licensing Basis Framework," of the topical report states that, "The Xe-100 Program follows a Systems Engineering Management Plan (SEMP) approach to design that implements a phased process of the system life cycle (e.g., conceptual design, preliminary design, final and detailed design, etc.)."

Typically, a systems engineering plan (SEP) is used to implement a design through a system lifecycle. According to available literature, a SEMP appears to be a document that addresses a contractor's overall systems engineering management approach (e.g., the application of a contractor's standards, capability models, configuration management, and toolsets to their organization).

**Due to the differences between the generally accepted definitions/uses of SEPs and SEMPs, please provide more details on the X-energy SEMP if they are available. If the X-energy SEMP is already in place, state if it could be made available for NRC staff audit as part of the topical report review.**

**X Energy, LLC**
801 Thompson Avenue
Rockville, MD 20852
+1 301.358.5600

**Enclosure 3**

**X Energy, LLC Xe-100 Licensing Topical Report,**

**"Risk-Informed Performance-Based Licensing Basis Development, Revision 2"**

# Xe-100 Licensing Topical Report

# Risk-Informed Performance-Based Licensing Basis Development

| | | |
|---|---|---|
| **Configuration Classification** | : | **XE00-R-R1ZZ-RDZZ-L** |
| **Revision** | : | **2** |
| **Status** | : | **Approved** |
| **Issue Date** | : | **07-Dec-2021** |
| **Project** | : | **Xe-100** |

## E-SIGNATURE: DOCUMENT APPROVAL

Preparer:
Electronically signed by Stephen Vaughn
14-Feb-2022 15:02

Reviewer:
Electronically signed by Travis Chapman
16-Feb-2022 21:46

Reviewer:
Electronically signed by Kyle Metzroth
16-Feb-2022 21:46

Approver:
Electronically signed by Martin Van Staden
21-Feb-2022 12:44

## Copyright Notice



## 10 CFR 810 Export-Controlled Information Disclaimer

This document was reviewed by X-energy and determined not to contain information designated as export-controlled per Title 10 of the Code of Federal Regulations (CFR) Part 810 or 10 CFR 110.

## Department of Energy Acknowledgement and Disclaimer

This material is based upon work supported by the Department of Energy under Award Number DE-NE0008745.

## EXECUTIVE SUMMARY

This report describes how the risk-informed performance-based methodology developed in the US Licensing Modernization Project is being implemented by X Energy, LLC (X-energy) for design, analysis, and licensing of the Xe-100 reactor. It provides a reproduction of the section headers of the guidance, with identification of conformance or interpretation where necessary, contained in Nuclear Energy Institute (NEI) 18-04, “Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development” [1] with clarifications identified in the U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.233 “Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certification, and Approvals for Non-Light-Water Reactors”[2]. It also provides implementation guidance used by X-energy for the safety design approach and analyses of the Xe-100 reactor.

The Xe-100 is a 200 MWt (80 MWe) pebble bed high temperature gas-cooled reactor design. X-energy uses a comprehensive and iterative systems engineering approach to discretize the Xe-100 development into design phases based on defined milestones, establishing new design baselines at the conclusion of each phase. This approach lends itself to implementing NEI 18-04 in an iterative manner as the design matures through progressive phases.

NEI 18-04 describes a risk-informed, performance-based (RIPB) methodology for:

1. Selection of licensing basis events and categorization based on frequency of occurrence;
2. Safety classification of structures, systems and components including identification of design criteria and performance requirements; and
3. Evaluation and confirmation of the adequacy of defense in depth in the design.

Each of these processes is further addressed in their respective sections, with X-energy-specific identification of conformance to NEI 18-04 and the RG 1.233 clarifications. X-energy requests the NRC staff review the approach described in this topical report to determine its acceptability in implementing the NEI 18-04 guidance for licensing basis event selection, classification of SSCs, ensuring the adequacy of defense-in-depth, and addressing clarifications provided in RG 1.233. This information will be used as content for future safety analysis reports to fulfill the regulatory requirements for prospective Xe-100 licensing applications under 10 CFR 50, 10 CFR 52, and/or a future 10 CFR 53.

# CONFIGURATION CONTROL

## Document Change History

| Rev. | Date | Preparer | Changes |
|---|---|---|---|
| A | 26-Oct-2020 | T. Chapman | Initial draft |
| 1 | 25-Jun-2021 | S. Vaughn | For approval |
| 1A | 08-Dec-2021 | S. Vaughn | Revised based on clarification questions from the NRC [14] |
| 2 | 14-Feb-2022 | S. Vaughn | For approval |

## Document Approval

| Action | Designation | Name | Signature | Date |
|---|---|---|---|---|
| Preparer | Licensing Engineer | S Vaughn | | |
| Reviewer | Safety Analysis Lead | K Metzroth | | |
| Reviewer | Licensing Manager | T Chapman | | |
| Approver | Xe-100 Program Manager | M van Staden | | |

## CONTENTS

## ABBREVIATIONS

This list contains the abbreviations and acronyms used in this document.

| Abbreviation or Acronym | Definition |
|---|---|
| AOO | Anticipated Operational Occurrence |
| BDBE | Beyond Design Basis Event |
| DBA | Design Basis Accident |
| DBE | Design Basis Event |
| DID | Defense in Depth |
| DOE | Department of Energy |
| EAB | Exclusion Area Boundary |
| EI&C | Event identification and classification |
| F-C Target | Frequency-Consequence Target |
| FMEA | Failure Modes and Effects Analysis |
| HAZOP | Hazard and Operability |
| IAEA | International Atomic Energy Agency |
| LBE | Licensing Basis Event |
| LMP | Licensing Modernization Project |
| LWR | Light Water Reactor |
| NEA | Nuclear Energy Agency |
| NRC | Nuclear Regulatory Commission |
| NSCA | Nuclear Safety and Control Act |
| NSRST | Non-Safety-Related with Special Treatment |
| NST | Non-Safety-Related with No Special Treatment |
| IE | Initiating Event |
| PRA | Probabilistic Risk Assessment |
| PSF | PRA Safety Function |
| QHO | Quantitative Health Objective |
| RG | Regulatory Guide |
| RIPB | Risk-informed performance-based |
| RFDC | Required Functional Design Criteria |
| RSF | Required Safety Function |
| SR | Safety Related |

| Abbreviation or Acronym | Definition |
|---|---|
| SSC | Structures, systems and components |
| ST | Special Treatment |
| TI-RIPB | Technology-inclusive Risk-informed Performance-based |
| US | United States (of America) |

# 1. INTRODUCTION

## 1.1. PURPOSE

The purpose of this licensing topical report is to describe how X-energy, LLC (X-energy) has approached implementation of the "Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development" [1] (referred to as NEI 18-04) to support licensing X-energy's Xe-100 reactor design in the United States (US). The Xe-100 is a 200 MWt (80 MWe) pebble bed high temperature gas reactor (HTGR) that can be configured as a single unit or a multi-unit plant, though typically in a 4-unit plant [4].

NEI 18-04 presents:

> "…a technology-inclusive, risk-informed, and performance-based (TI-RIPB) process for selection of Licensing Basis Events (LBEs); safety classification of structures, systems, and components (SSCs) and associated risk-informed special treatments; and determination of defense-in-depth (DID) adequacy for non-light water reactors (non-LWRs) including, but not limited to, molten salt reactors, high-temperature gas cooled reactors, and a variety of fast reactors at all thermal power capacities."

As part of the Licensing Modernization Project (LMP) funded by the US Department of Energy (DOE), the LMP process was applied to a pre-conceptual design version of the Xe-100 to demonstrate the process and to improve US regulatory certainty for the Xe-100 design. The results are documented in Reference [5], which is referred to in this document as the LMP report. The overall technology-inclusive, risk-informed, and performance-based methodology is referred to as the RIPB methodology or process.

This document summarizes how the Xe-100 approach adopts and, where necessary for effective implementation, interprets the NEI 18-04 guidance and addresses the Xe-100 approach to the NEI 18-04 clarifications noted in RG 1.233. X-energy requests the NRC staff review the approach described in this topical report to determine its acceptability in implementing the NEI 18-04 guidance for licensing basis event selection, classification of SSCs, ensuring the adequacy of defense-in-depth, and addressing clarifications provided in RG 1.233.

Using the LMP methodology does not directly exempt X-energy from existing regulations, nor does the process address all regulations applicable to nuclear power plants and does not specify any regulatory exemptions. Rather, the process describes the methodology to inform the safety analysis report for the Xe-100 design, which will in part demonstrate compliance with the regulations.

## 1.2. SCOPE

The scope of this report covers the elements of the RIPB process described in NEI 18-04 [1]. These elements are:

1. Selection of LBEs and categorization based on frequency of occurrence;
2. Safety classification and performance criteria of SSCs; and
3. Evaluation of Defense-in-Depth (DID) adequacy.

### 1.3. INTERFACING REFERENCES

The RIPB licensing basis development process is described in Reference [1] and its application to a pre-conceptual version of the Xe-100 is described in Reference [5]. This LTR incorporates insights from several sources as described in the Reference section and throughout the report. Reviewers are advised to reference the Xe-100 Technical Report "Technology Description" (XE00-P-G1ZZ-RDZZ-D-01118 Revision 1) for details on the Xe-100 reactor design and plant operations [4]. NRC staff review and/or approval of that report is not requested at this time. Detailed reports developed as part of X-energy's implementation of the NEI 18-04 methodology will be provided as references in future licensing applications.

### 1.4. DOCUMENT LAYOUT

Section 2 outlines the regulatory applicability of the LMP approach to licensing of the Xe-100 design.

Sections 3-5 provide a reproduction of the NEI 18-04 section numbers and titles followed by a discussion of how the Xe-100 approach adopts, or provides clarification to, the written guidance. The last subsection of Sections 3-5 explicitly addresses the clarifications identified in RG 1.233 for each of the corresponding subjects and outlines how the Xe-100 approach implements these clarifications.

While NEI 18-04 encompasses non-LWR technology in general, this report specifically concerns the Xe-100. It supports several purposes:

1) to describe X-energy's approach to implement NEI 18-04 (either acceptance or clarification to the guidance) to develop portions of the licensing basis in a risk-informed, performance-based, systematic manner that follows each design phase iteration,

2) to provide this approach to the NRC for review, and

3) to provide a comprehensive resource for X-energy's engineering team to reference through training and implementation.

### 1.5. OVERVIEW OF REGULATORY REQUIREMENTS AND GUIDANCE

Regulatory Guide (RG) 1.233 provides the NRC's guidance on using a technology-inclusive, risk-informed, and performance-based methodology to inform the licensing basis and content of applications for non-light-water reactors (non-LWRs). This RG may be used by non-LWR applicants applying for permits, licenses, certifications, and approvals under Title 10 of the Code of Federal Regulations (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities", and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants". It is anticipated to apply to the future advanced reactor regulatory framework being developed as Part 53.

NEI 18-04 was developed and piloted by several advanced reactor developers, including X-energy, through the LMP effort. As part of the LMP, the NRC developed a draft RG, DG-1353 "Guidance for the Technology-inclusive, Risk-Informed, Performance-Based Approach to Inform the Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors" to engage the public in endorsement of the NEI 18-04 guidance. RG 1.233, which was formally issued by the NRC in June 2020, provides the guidance to select LBEs, classify SSCs, and evaluate the adequacy of DID for non-LWR designs by endorsing the NEI 18-04 methodology with clarifications.

Sections 3-5 of this report provide an assessment of the NEI 18-04 content and processes used to support development of the Xe-100 licensing basis, including clarifications to the endorsed guidance. Given that the NEI 18-04 process is iterative in nature, as the Xe-100 design progresses and associated safety analyses and PRA model updates are refined accordingly, the Xe-100 risk-informed performance-based licensing bases will continue to mature. Section 6 of this report briefly describes the X-energy design process and X-energy's ongoing participation in industry working groups that support NEI 18-04 implementation.

### 1.6. NRC REVIEW OUTCOME OBJECTIVES

X-energy requests the NRC staff review the approach described in this topical report to determine its acceptability in implementing the NEI 18-04 guidance for licensing basis event selection, classification of SSCs, ensuring the adequacy of defense-in-depth, and addressing clarifications provided in RG 1.233. The information developed through this implementation will be used as content for future safety analysis reports to fulfill the regulatory requirements for prospective Xe-100 licensing applications under 10 CFR 50, 10 CFR 52, and/or a future 10 CFR 53.

## 2. LICENSING BASIS DEVELOPMENT PROCESS

The overall objective of this report is to document X-energy's implementation of a systematic and reproducible process for selection of LBEs, classification of SSCs, and determination of DID adequacy such that different knowledgeable parties would arrive at similar conclusions. These outcomes are important to the development of applications for licenses, certifications, or approvals because they provide necessary insights into the scope and level of detail for the description of plant SSCs and programmatic controls in the application. This process facilitates a systematic iterative process for completion of tasks as the design progresses, providing immediate feedback to the designer to make better informed decisions.

Sections 3-5 describe the Xe-100 implementation of the NEI 18-04 processes for licensing basis development:

- Systematic definition, categorization, and evaluation of event sequences for selection of LBEs, which include Anticipated Operational Occurrences (AOOs), Design Basis Events (DBEs), Design Basis Accidents (DBAs), and Beyond Design Basis Events (BDBEs)
- Systematic safety classification of SSCs, development of performance requirements, and application of special treatments
- Guidelines for evaluation of DID adequacy

These processes are:

- Risk-informed to fully utilize the insights from a systematic risk assessment in combination with structured prescriptive rules to address the uncertainties which are not addressed in the risk assessment. This approach can provide reasonable assurance that adequate protection is provided for public radiological protection.
- Performance-based to evaluate effectiveness relative to realizing desired outcomes that are achieved by using quantifiable performance metrics for LBE frequencies and consequences and performance requirements for SSC capabilities to prevent and mitigate events. This is an alternative to a prescriptive approach specifying particular features, actions, or programmatic elements to be included in the design or process as the means for achieving desired objectives.

The NEI 18-04 methodology can be used to:

- Develop logical, coherent, and complete bases for the development of the safety design; and, evaluation of the safety design based on the specific technology.
- Apply a sound PRA, including appropriate probabilistic models based on available standards, to develop and evaluate safety design outcomes.
- Answer the following broad questions:
  - What are the plant initiating events and event sequences that are associated with the design?
  - How does the proposed design and its SSCs respond to initiating events?
  - What are the margins provided by the facility's response as it relates to prevention and mitigation of radiological releases within prescribed limits to protect public health and safety?
  - Is the philosophy of DID adequately reflected in the design and operation of the facility?

In summary, the outcomes from executing the processes in this guidance support developing a risk-informed and performance-based safety design approach and a safety-focused application for NRC and other regulators' review by systematically demonstrating that:

- The selected LBEs adequately cover the range of hazards that a specific design is exposed to and reflect the impacts of SSC failure modes that are appropriate for the design.
- The LBEs are defined in terms of successes and failures of SSCs that perform safety functions modeled in the PRA, hereafter referred to as PRA Safety Functions (PSFs). PSFs are defined as those functions responsible for the prevention and mitigation of an unplanned radiological release from any source within the plant.
- Collectively, the SSCs that perform the PSFs are adequately capable, reliable, diverse, and/or redundant across the layers of defense in the design.
- The philosophy of DID is apparent in the design and programmatic features included in the licensing application and outcomes of systematic evaluations of DID adequacy. The DID evaluation focus is to assure adequate layers of plant capability and programmatic defense.
- Sufficient and integrated design decisions are made, reconciling plant capabilities and programmatic controls based on risk-informed insights with respect to providing reasonable assurance of adequate protection.
- The scope and level of detail for plant SSCs and programmatic controls included in applications are commensurate with their safety and risk significance.

The processes covered in this report provide a broad, integrated, and systematic framework to develop the Xe-100 licensing basis.

The following Sections 3-5 provide a reproduction of the NEI 18-04 section numbers and titles followed by a discussion of how the Xe-100 Program's approach adopts, or provides clarification to, the written guidance. The Xe-100 Program includes the development and commercialization of the Xe-100 and its design and licensing bases. Through this assessment X-energy has not identified any sections of the guidance that appear to require explicit deviation, however, the clarifications provided are intended to describe how X-energy is implementing NEI 18-04 in practice. The last subsection of Sections 3-5 explicitly addresses the clarifications identified in RG 1.233 for each of the corresponding subjects and outlines how the Xe-100 approach implements these clarifications.

# 3. SELECTION OF LICENSING BASIS EVENTS

## 3.1. LICENSING BASIS EVENT DEFINITIONS

The Xe-100 Program uses the LBE definitions in Table 3-1, “Definitions of Licensing Basis Events” of NEI 18-04. The Xe-100 Program does not require any deviations from or clarifications of NEI 18-04 guidance.

## 3.2. XE-100 LBE SELECTION APPROACH

### 3.2.1. Frequency-Consequence Evaluation Criteria

The Xe-100 Program follows the F-C Target process described in Figure 3-1, “Frequency-Consequence Target” and steps 7a-7c of Figure 3-2, “Process for Selecting and Evaluating Licensing Basis Events” in NEI 18-04. The current LBE frequency estimates are based on insights from previous HTGR technologies [5] and will be refined further to incorporate new information from the Xe-100 design, safety analyses, and PRA. Furthermore, as described in Task 7a of Figure 3-2 of NEI 18-04, the Xe-100 Program does not consider the F-C targets as specific acceptance criteria, rather as a tool to inform iterations in the design process and demonstrate margin. The Xe-100 Program does not require any deviations from or clarifications of NEI 18-04 guidance.

### 3.2.2. LBE Selection Process

The initial set of LBEs for the Xe-100 Program is based on extensive experience with HTGR PRAs, in particular the modular high temperature gas-cooled reactor (MHTGR), the pebble-bed module reactor (PBMR), the next generation nuclear plant (NGNP), and previously constructed and operated German pebble-bed reactors [5] [10]. Given that the NEI 18-04 methodology is an iterative process, the current set of LBEs incorporates insights from design, safety analyses, and the PRA, which follow the process described in Tasks 1-4 of Figure 3-2 in NEI 18-04. Tasks 5-10 of Figure 3-2 in NEI 18-04 are addressed in subsequent sections of this report given the overlap of content between sections 3, 4, and 5 of NEI 18-04. The Xe-100 Program does not require any deviations from or clarifications of NEI 18-04 guidance.

### 3.2.3. Evolution of LBEs Through Design and Licensing Stages

As the Xe-100 design matures and associated safety analyses and PRA model updates are refined, the list of LBEs will evolve. The Xe-100 Program does not require any deviations from or clarifications of NEI 18-04 guidance.

## 3.3. ROLE OF THE PRA IN LBE SELECTION

### 3.3.1. Use of PRA in LBE Selection Process

The continued development of the Xe-100 PRA generally follows Figure 3-3 “Flow Chart for Initial PRA Development” in NEI 18-04 and plays an important role in risk-informing the Xe-100 design and associated safety analyses. X-energy implements the published 2021 edition of the ASME/ANS Advanced Non-Light-Water PRA Standard [3]. Regarding sections 3.3.1 through 3.3.6 of NEI 18-04, the Xe-100 Program does not require any deviations from or clarifications of NEI 18-04 guidance.

## 3.4. REGULATORY GUIDE 1.233 CLARIFICATIONS TO NEI 18-04: SELECTION OF LICENSING BASIS EVENTS

This RG endorses the methods described in NEI 18-04 for informing the licensing basis and content of applications for permits, licenses, certifications, and approvals for non-LWRs. NRC staff takes no exceptions to the guidance in NEI 18-04, however the staff does provide clarifications and points of emphasis as detailed in this RG. Section C.1 expresses the Staff Position that NEI 18-04 provides an acceptable method for identifying and categorizing events, with the following clarifications listed in this section.

### 3.4.1. Clarification C.1.a and Xe-100 Position

RG 1.233 Section C.1 expresses the Staff Position that NEI 18-04 provides an acceptable method for identifying and categorizing events, with the following clarification:

*The staff emphasizes the cautions in NEI 18-04 that the F-C target figure does not depict acceptance criteria or actual regulatory limits. The anchor points used for the F-C target figure are expressed in different units, timescales, and distances than those used in NRC regulations to provide common measures for the evaluations included in the methodology. The F-C target provides a reasonable approach for use within a broader, integrated approach to determine risk significance, support SSC classification, and confirm the adequacy of DID.*

The Xe-100 Program will adhere to the broad, integrated approach to determine risk significance, support SSC classification, and confirm the adequacy of DID as described in NEI 18-04.

### 3.4.2. Clarification C.1.b and Xe-100 Position

RG 1.233 Section C.1 expresses the Staff Position that NEI 18-04 provides an acceptable method for identifying and categorizing events, with the following clarification:

*The F-C target and related discussions in NEI 18-04 include an upper bound event sequence frequency (i.e., 95th percentile) of $5\times10^{-7}$/plant-year to define the lower range of BDBEs. Applicants should not consider this demarcation of lowest-event frequencies on the F-C target and category definitions a hard-and-fast cutoff but instead should consider it in the context of other parts of the methodology described in NEI 18-04. These other considerations include the role of the integrated decision making panel described in Section*

*5 of NEI 18-04, DID assessments, accounting for uncertainties, and assessing for potential "cliff-edge effects," which involve a dramatic change in plant behavior caused by a small change in a plant parameter.*

The Xe-100 program does not rely on a hard-and-fast cut-off for consideration of low-frequency events, rather, it treats low-frequency events and their associated uncertainties in the context of the broad, integrated approach described in NEI 18-04. Cliff-edge effects and uncertainties are addressed through the PRA and DID adequacy evaluation for the Xe-100.

### 3.4.3. Clarification C.1.c and Xe-100 Position

RG 1.233 Section C.1 expresses the Staff Position that NEI 18-04 provides an acceptable method for identifying and categorizing events, with the following clarification:

*NEI 18-04 describes a set of DBEHLs that will determine the design-basis seismic events and other external events that the SR SSCs will be required to withstand. When the DBEHLs are determined using NRC-approved methodologies, this approach is generally consistent with current practices and provides acceptable protection of SR SSCs. When supported by available methods, the PRA model is expected to address the full spectrum of internal events and external hazards that pose challenges to the capabilities of the plant, including external hazard levels exceeding the DBEHLs. The inclusion of external events within the BDBE category supports the overall risk-informed approach in NEI 18-04 and the DID assessments described in subsequent sections. The PRA results, including consideration of external hazards, will also validate a designer's initial selections of DBAs and SR SSCs protected against DBEHLs, and ensure no new DBAs are introduced by external hazards.*

*NEI 18-04 states the following:*

> *When supported by available methods, data, design, and site information, and supporting guides and standards, these DBEHLs will be informed by a probabilistic external hazards analysis and included in the PRA after the design features that are included to withstand these hazards are defined.*

*If applicants propose methods to identify DBEHLs that the NRC staff has not previously reviewed and approved, the staff would review the proposed methodologies on a case-by-case basis. An applicant may need to reconcile a probabilistic approach to assessing external hazards with the use of applicable consensus standards for the design and construction of safety significant SSCs.*

NEI 18-04, as endorsed by RG 1.233, uses the term DBEHLs. However, with the development of NEI 21-07, "Safety Analysis Report Content for Applicants Using the NEI 18-04 Methodology" the term DBHL replaces the term DBEHL to clarify that both external and internal hazards. As such, the Xe-100 Program expects to use NRC reviewed and approved methods to identify DBHLs. If the Xe-100 Program proposes methods to identify DBHLs that the NRC has not previously reviewed and approved, X-energy understands that the Staff would review the proposed methodologies on a case-by-case basis.

### 3.4.4. Clarification C.1.d and Xe-100 Position

RG 1.233 Section C.1 expresses the Staff Position that NEI 18-04 provides an acceptable method for identifying and categorizing events, with the following clarification:

*NEI 18-04 describes how the application of a single-failure criterion is not deemed necessary for the designs using the methodology because advanced non-LWRs will employ a diverse combination of inherent, passive, and active design features to perform the required safety functions across layers of defense and will be subjected to an evaluation of DID adequacy. The process described in NEI 18-04 includes assessing event sequences (including reliability and availability of SSCs and combinations of SSCs) over a wide range of frequencies and establishing risk and safety function reliability measures. The approach described in NEI 18-04 is consistent with the Commission's SRM approving the recommendation in SECY-03-0047 to replace the single-failure criterion with a probabilistic (reliability) criterion. The staff finds that the NEI 18-04 methodology, including assessments of event sequences and DID, obviates the need to use the single-failure criterion as it is applied to the deterministic evaluations of AOOs and DBAs for LWRs. The staff notes that the NEI 18-04 methodology is similar to Alternative 3 in SECY-05-0138, "Risk-Informed and Performance-Based Alternatives to the Single-Failure Criterion," dated August 2, 2005. The staff's finding is based primarily on the integrated methodology described in NEI 18-04 and to a lesser degree on the design attributes of non-LWRs.*

*Non-LWR developers that construct a licensing basis for a design using an alternative to the NEI 18-04 methodology would need to maintain or justify not applying the single-failure criterion to those LBEs analyzed in a deterministic or stylized approach, such as DBAs. RG 1.232 describes an approach that maintains the single-failure criterion, but acknowledges the potential future benefits of risk informing the non-LWR design criteria. The NRC provided guidance related to assumptions on passive failures and the application of the single-failure criterion in SECY-94-0084, "Policy and Technical Issues Associated with the Regulatory Treatment of Non-Safety Systems in Passive Plant Designs," dated March 28, 1994, and the related SRM dated June 30, 1994.*

The Xe-100 Program licensing basis does not use an alternative to the NEI 18-04 methodology.

### 3.4.5. Clarification C.1.e and Xe-100 Position

RG 1.233 Section C.1 expresses the Staff Position that NEI 18-04 provides an acceptable method for identifying and categorizing events, with the following clarification:

*The methodology in NEI 18-04 includes an expanded role for PRA beyond that currently required by 10 CFR Part 52 and policies related to new applications under 10 CFR Part 50. The staff's review of the PRA prepared by a reactor designer could be facilitated by the designer's use of NRC-endorsed consensus codes and standards (e.g., potential NRC endorsement of the American Society of Mechanical Engineers/American Nuclear Society RA-S-1.4, "Probabilistic Risk Assessment Standard for Advanced Non-LWR Nuclear Power Plants"). However, the NRC has not yet endorsed a consensus code or standard for non-LWR PRAs. In the absence of such an endorsed standard, the NRC staff will develop review strategies to address the performance and use of PRAs for specific applications.*

The Xe-100 Program PRA will be developed to meet the requirements of the American Society of Mechanical Engineers/American Nuclear Society RA-S-1.4, "Probabilistic Risk Assessment Standard for Advanced Non-LWR Nuclear Power Plants." [3] X-energy has reviewed, and provided comments on, the Trial Use Regulatory Guide 1.247, "Acceptability of Probabilistic Risk Assessment Results for Advanced Non-Light Water Reactor Risk-Informed Activities" and intendeds to follow NEI 20-09, "Performance of

PRA Peer Reviews Using the ASME/ANS Advanced Non-LWR PRA Standard." X-energy is proceeding with PRA development and monitoring the endorsement activities as they progress at this time.

# 4. SAFETY CLASSIFICATION AND PERFORMANCE CRITERIA FOR STRUCTURES, SYSTEMS, AND COMPONENTS

## 4.1. SSC SAFETY CLASSIFICATION APPROACH FOR THE XE-100

The Xe-100 Program leverages an integrated decision-making process (IDP) to identify PRA safety functions (PSFs), determine required safety functions (RSFs), identify required functional design criteria (RFDC), and develop the plant SSC classification list. The process consists of meetings with a multidisciplinary team to identify PSFs, RSFs, and develop a list of SR and NSRST SSCs by incorporating insights from past HTGR designs, current Xe-100 PRA documentation, and associated LMP-derived working procedures. The main objectives of the process to date is to support ongoing design and analysis activities and document an initial set of Xe-100-specific PSFs, RSFs, RFDC, and SSC classifications to support NEI 18-04 implementation. As the Xe-100 design, safety analyses, and PRA model continue to develop, the SSC safety classifications, as described in Figure 4-1, “SSC Function Safety Classification” of NEI 18-04, will be refined as appropriate.

Task 6, “SSC Reliability and Capability Targets” in Figure 4-1 notes that reliability and capability targets for SSCs modeled in the PRA should be identified and used to develop specific design criteria and special treatments as described in Task 7, “Determine SSC Specific Design Criteria and Special Treatment Requirements.” NEI 18-04 is not explicitly clear on the level of decomposition (e.g., functional level, system or component level, event sequence level) the reliability and capability targets should be derived from to support licensing documentation. The Xe-100 Program does not require any deviations from NEI 18-04 guidance and will identify reliability and capability targets at an appropriate level of decomposition for documentation in the licensing bases and plant records and programs.

## 4.2. DEFINITION OF SAFETY-SIGNIFICANT AND RISK-SIGNIFICANT SSCS

The Xe-100 Program uses the NEI 18-04 definitions for safety-significant and risk-significant SSCs and therefore does not require any deviations from or clarifications of NEI 18-04 guidance.

## 4.3. SSCS REQUIRED FOR DEFENSE-IN-DEPTH ADEQUACY

Task 2, “Identify and Evaluate SSC Capabilities and Programs to Support Defense-in-Depth” in Figure 4-1 of NEI 18-04 provides a feedback loop from the evaluation of DID adequacy, which is described in more detail in Section 5 of this report. The Xe-100 Program does not require any deviations from or clarifications of NEI 18-04 guidance.

## 4.4. DEVELOPMENT OF SSC DESIGN AND PERFORMANCE REQUIREMENTS

Regarding sections 4.4.1 through 4.4.4, the Xe-100 Program does not require any deviations from or clarifications of NEI 18-04 guidance. At the end of section 4.4.5, “Special Treatment Requirements for SSCs” paragraph entitled “Reliability Assurance for SSCs” notes that all safety-significant SSCs should be included in a Reliability Assurance Program (RAP) similar to that described in the Standard Review Plan (SRP), Chapter 17.4. Furthermore, Table 4-1, “Summary of Special Treatments for SR and NSRST SSCs”

notes that there is additional available guidance in SRP Chapter 19.3 and ASME Section XI, Division 2 "Reliability Integrity and Management (RIM) Programs for Nuclear Power Plants." Similar to the discussion at the end of Section 4.1 of this report, the Xe-100 program will identify reliability targets for safety-significant SSCs at an appropriate level of decomposition for documentation in the licensing bases and plant records and programs.

## 4.5. REGULATORY GUIDE 1.233 CLARIFICATIONS TO NEI 18-04 SAFETY CLASSIFICATION AND PERFORMANCE CRITERIA FOR SSCS

This RG endorses the methods described in NEI 18-04 for informing the licensing basis and content of applications for permits, licenses, certifications, and approvals for non-LWRs. NRC staff takes no exceptions to the guidance in NEI 18-04, however the staff does provide clarifications and points of emphasis as detailed in this RG. Section C.2 expresses the Staff Position that NEI 18-04 provides an acceptable method for assessing and classifying non-LWR SSCs as SR, NSRST, or non-SR with no special treatment. The staff offers the following clarifications in RG 1.233 Section C.2, which are repeated in this section along with the Xe-100 position.

### 4.5.1. Clarification C.2.a and Xe-100 Position

RG 1.233 Section C.2 expresses the Staff Position that NEI 18-04 provides an acceptable method for assessing and classifying non-LWR SSCs as SR, NSRST, or non-SR with no special treatment. The staff offers the following clarification:

*The SSC classifications and logic outlined in NEI 18-04 are part of an integrated methodology, which includes a defined relationship among LBEs, equipment classification, and assessments of DID for non-LWRs. The classifications and related outcomes may not apply for alternative approaches that do not follow the other parts of the NEI 18-04 methodology. The staff expects that SSCs that provide essential support (including required human actions) for SR or NSRST SSCs will be classified in a manner consistent with the higher-level function, even if the supporting SSC is not explicitly modeled in the PRA.*

The Xe-100 Program will classify SSCs that provide essential support (including required human actions) for SR or NSRST SSCs in a manner consistent with the higher-level function, even if the supporting SSC is not explicitly modeled in the PRA.

### 4.5.2. Clarification C.2.b and Xe-100 Position

RG 1.233 Section C.2 expresses the Staff Position that NEI 18-04 provides an acceptable method for assessing and classifying non-LWR SSCs as SR, NSRST, or non-SR with no special treatment. The staff offers the following clarification:

*The SSC classifications outlined in NEI 18-04 include the term "safety-related," which is defined in NRC regulations in 10 CFR 50.2. Use of the term "safety-related" in NEI 18-04 for non-LWRs is not the same as the definition in 10 CFR 50.2, and the SSCs included in the "safety-related" classification for non-LWRs may not be the same as those considered safety-related for LWRs. Additionally, "nonsafety-related" is used in NEI 18-04 but is not a defined term in NRC regulations and has different meaning depending on the context*

*in which it has been used in guidance documents and specific applications. As used in this RG and NEI 18-04, the term "nonsafety-related" means SSCs or an SSC that is not safety-related. NEI 18-04 includes a glossary to help alleviate some of the issues that will arise because of differences in terminology. Applicants referencing this RG are expected to use the terminology in NEI 18-04 and, as needed, identify exceptions to and exemptions needed from NRC regulations.*

The Xe-100 Program will use the terminology in NEI 18-04 and provide clarifications as necessary in future licensing applications as necessary.

# 5. EVALUATION OF DEFENSE-IN-DEPTH ADEQUACY

## 5.1. DEFENSE-IN-DEPTH PHILOSOPHY

The Xe-100 Program agrees with the defense-in-depth (DID) philosophy described in this section and does not require any deviations from or clarifications of NEI 18-04 guidance.

## 5.2. FRAMEWORK FOR ESTABLISHING DID ADEQUACY

The Xe-100 Program evaluates DID from both a plant capability and programmatic perspective and leverages the IDP in developing a risk-informed evaluation of DID. As such, the Xe-100 Program does not require any deviations from or clarifications of NEI 18-04 guidance.

## 5.3. INTEGRATED FRAMEWORK FOR INCORPORATION AND EVALUATION OF DID

The Xe-100 Program follows the iterative process described in Figure 5-4, “Integrated Process for Incorporation and Evaluation of Defense-in-Depth” and does not require any deviations from or clarifications of NEI 18-04 guidance.

## 5.4. HOW MAJOR ELEMENTS OF THE TI-RIPB FRAMEWORK ARE EMPLOYED TO ESTABLISH DID ADEQUACY

The Xe-100 IDP uses the guidance described in Table 5-1, “Role of Major Elements of TI-RIPB Framework in Establishing DID Adequacy” to ensure each risk-informed performance-based element is appropriately considered in establishing DID adequacy. As such, the Xe-100 Program does not require any deviations from or clarifications of NEI 18-04 guidance.

## 5.5. RIPB COMPENSATORY ACTION SELECTION AND SUFFICIENCY

Because the Xe-100 design, safety analyses, and PRA are developed in an iterative fashion, the DID adequacy evaluation and baseline are updated as the Xe-100 design matures. The Xe-100 Program follows Figure 5-2, “Guidelines for Establishing the Adequacy of Overall Plant Capability Defense-in-Depth” and does not require any deviations from or clarifications of NEI 18-04 guidance.

## 5.6. ESTABLISHING THE ADEQUACY OF PLANT CAPABILITY DID

The Xe-100 IDP is responsible for making the deliberate, affirmative decision that DID adequacy is achieved and the bases for the decision are clearly recorded in accordance with Xe-100 processes and procedures. The Xe-100 Program follows the guidance in sections 5.6, 5.6.1, 5.6.2, and 5.6.3 and does not require any deviations from or clarifications of NEI 18-04 guidance.

## 5.7. EVALUATION OF LICENSING BASIS EVENTS AGAINST LAYERS OF DEFENSE

The Xe-100 IDP is responsible for performing a systematic review of the LBEs against the layers of defense, which is necessary to evaluate the plant capabilities for DID and to identify any programmatic DID

measures that may be necessary for establishing DID adequacy. The Xe-100 Program follows the guidance in sections 5.7, 5.7.1, and 5.7.2 and does not require any deviations from or clarifications of NEI 18-04 guidance.

### 5.8. ESTABLISHING THE ADEQUACY OF PROGRAMMATIC DID

The Xe-100 Program follows the guidelines, strategies, and evaluation considerations provided in sections 5.8, 5.8.1 and 5.8.2 and does not require any deviations from or clarifications of NEI 18-04 guidance.

### 5.9. RISK-INFORMED AND PERFORMANCE-BASED EVALUATION OF DID ADEQUACY

The Xe-100 IDP uses a risk-informed performance-based integrated decision-making (RIPB-DM) process in developing DID capability and programmatic adequacy. Furthermore, the Xe-100 IDP follows the actions, considerations, and guidance described in sections 5.9 through 5.9.7 in developing a baseline evaluation of DID and does not require any deviations from or clarifications of NEI 18-04 guidance.

### 5.10. REGULATORY GUIDE 1.233 CLARIFICATIONS TO NEI 18-04 EVALUATION OF DID ADEQUACY

This RG endorses the methods described in NEI 18-04 for informing the licensing basis and content of applications for permits, licenses, certifications, and approvals for non-LWRs. NRC staff takes no exceptions to the guidance in NEI 18-04, however the staff does provide clarifications and points of emphasis as detailed in this RG. Section C.3 expresses the Staff Position that NEI 18-04 provides an acceptable method for assessing the adequacy of DID to be provided by plant capabilities and programmatic controls, with the following clarification. The staff offers the following clarifications in RG 1.233 Section C.3, which are repeated in this section along with the Xe-100 position.

#### 5.10.1. Clarification C.3.a and Xe-100 Position

RG 1.233 Section C.3 expresses the Staff Position that NEI 18-04 provides an acceptable method for assessing the adequacy of DID to be provided by plant capabilities and programmatic controls, with the following clarification:

*Section 5.9.6 in NEI 18-04 discusses change control processes following the issuance of a license, certification, or approval. The staff makes no findings on this topic. The staff may address such change control processes, as well as other aspects of how design assumptions carry into plant operations, in future regulatory actions, including possible rulemakings, licenses conditions, and development of guidance documents.*

The Xe-100 Program change control processes will be developed in accordance with available NRC guidance and regulatory requirements for future licensing application submissions.

## 6. X-ENERGY IMPLEMENTATION OF THE NEI 18-04 RIPB LICENSING BASIS FRAMEWORK

The Xe-100 Program follows a systems engineering approach to design that implements a phased process of the system life cycle (e.g., conceptual design, preliminary design, final and detailed design, etc.) As the Xe-100 design matures, additional safety analyses are performed and the PRA model is refined, the implementation of NEI 18-04 to support a risk-informed performance-based licensing basis begins to take shape. Overall, the Xe-100 Program is well suited to parallel its design approach with the iterative nature of the NEI 18-04 methodology and is committed to implementing the LMP process in accordance with appropriate Xe-100 quality and configuration controls.

The Xe-100 Program is an active participant in ongoing advanced reactor regulatory activities, specifically the industry-led Technology Inclusive Content of Application Project (TICAP) and the NRC staff-led Advanced Reactor Content of Application Project (ARCAP) efforts. As those two efforts begin to provide helpful products for prospective non-LWR applicants, the Xe-100 Program plans to leverage that guidance while continuing to implement the NEI 18-04 process.

## 7. CONCLUSION

This report presents the Xe-100 implementation of the risk-informed, performance-based methodology to develop portions of the licensing basis in compliance with NEI 18-04 and RG 1.233. In addition, this report explicitly addresses the RG 1.233 clarifications to NEI 18-04. As the Xe-100 design matures, additional iterations of the IDP process will occur and LBE identification and categorizations, SSC safety classifications, and DID adequacy evaluations will be revised through the phased design approach.

As described in Section 1.6, X-energy requests the NRC staff review the approach described in this topical report to determine its acceptability in implementing the NEI 18-04 guidance for licensing basis event selection, classification of SSCs, ensuring the adequacy of defense-in-depth, and addressing clarifications provided in RG 1.233. This information will be used as content for future technical and regulatory reports to fulfill the regulatory requirements for prospective Xe-100 licensing applications under 10 CFR 50, 10 CFR 52, and/or a future 10 CFR 53.

## 8. REFERENCES

[1] Nuclear Engineering Institute, “Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development”, NEI 18-04, Rev. 1, August 2019.

[2] US NRC, “Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors”, Regulatory Guide 1.233, June 2020.

[3] American Society of Mechanical Engineers / American Nuclear Society. “Probabilistic Risk Assessment Standard for Advanced Non-Light Water Reactor Nuclear Power Plants.” ASME/ANS RA-S-1.4-2021.

[4] X-energy, “Xe-100 Technical Report Technology Description”, XE00-P-G1ZZ-RDZZ-D, Revision 1, April 2021.

[5] Southern Company, “Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors – High Temperature, Gas-Cooled Pebble Bed Reactor Licensing Modernization Project Demonstration”, SC-29980-200 Rev. 0, August 2018.

[6] IAEA, “Proposal for Technology-Neutral Safety Approach for New Reactor Designs”, TECDOC-1570, September 2007.

[7] IAEA, “Safety of Nuclear Power Plants: Design”, NS-R-1, 2000.

[8] IAEA, “Assessment of Defense in Depth for Nuclear Power Plants”, SSR 46, 2005.

[9] GEN IV International Forum, “An Integrated Safety Assessment Methodology (ISAM) for Generation IV Nuclear Systems”, Version 1.1, June 2011.

[10] Southern Company, “Modernization of Technical Requirements for Licensing of Advanced Non-Light Water Reactors – Probabilistic Risk Assessment Approach”, SC-29980-101 Rev 1, March 2020.

[11] US NRC, “Next Generation Nuclear Plant Phenomena Identification and Ranking Tables (PIRTs) Volume 1: Main Report”, NUREG-CR-6944 Vol. 1, March 2008.

[12] US Atomic Energy Commission, “Application of the Single-Failure Criterion to Nuclear Power Plant Protection Systems”, Regulatory Guide 1.54, June 1973.

[13] Nuclear Energy Agency, “Probabilistic Risk Criteria and Safety Goals”, NEA/CSNI/R(2009)16, 17-Dec-2009.

[14] U.S. Nuclear Regulatory Commission Preliminary Questions Regarding X-Energy, LLC Topical Report: Xe-100 Risk-Informed Performance-Based Licensing Basis Development (XE00-R-R1ZZ-RDZZ-L-001522)