UNITED STATES
NUCLEAR REGULATORY COMMISSION
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X ENERGY, LLC – FINAL SAFETY EVALUATION OF TOPICAL REPORT XE-100 LICENSING TOPICAL REPORT: CONTROL ROOM STAFFING ANALYSIS METHODOLOGY, REVISION 2 AND ASSOCIATED IMPLEMENTATION PLANS (EPID L-2021-TOP-0028)

SPONSOR AND SUBMITTAL INFORMATION

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Brief Description of the Topical Report:

By letter dated January 4, 2022 (ML22004A333), as supplemented by letters dated August 24, 2022 (ML22236A665), and October 19, 2022 (ML22293B806), X Energy, LLC (X-energy) requests the U.S. Nuclear Regulatory Commission (NRC, the Commission) staff's review and approval of, "Xe-100 Licensing Topical Report: Control Room Staffing Analysis Methodology," Revision 2 (the topical report (TR)), which addresses the proposed control room staffing analysis methodology for the Xe-100 reactor facility design. The letter dated January 4, 2022, submitting the TR also included (as enclosures) copies of the Human Factors Engineering (HFE) Program Management Plan and implementation plans for individual elements of the HFE program for the Xe-100. The TR and these enclosures are referred to collectively as the TR submittal.

In Section 1, "Introduction," of the TR, X-energy provides that the purpose of the TR is to: (1) describe the approach for the control room staffing analysis of the Xe-100 reactor facility, (2) describe the planned X-energy methodologies for the operator task analysis (TA) and validation testing of the staffing plan, and (3) initiate the NRC staff's review of the control room staffing plan analysis approach and methodologies and to obtain the NRC's approval of the X-energy control room staffing approach. A control room staffing analysis, completed using the methodologies proposed in the TR submittal, would be intended to provide the technical basis necessary to support a requested exemption from the established control room staffing regulatory requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.54, "Conditions of licenses," paragraph (m) (discussed below in Section 2.0 of this safety evaluation (SE)).

In the executive summary of the TR, X-energy states, in part, the following:

> The base case for the Xe-100 is to deploy four units at a site, managed by a 3-person control room staff in one central control room. Additional expansion capability, either by adding single units to an existing deployment or additional four-unit plants, requires consideration of options such as additional control rooms, expanding the footprint of a single control room, and changes to shift operations, as well as the associated HFE impacts. The approach described [in the TR submittal] is intended to be flexible enough to provide credible HFE activities to validate that control room operations will be safely managed and the number of control room operators, their tasking, their span of unit control (4 units), and the associated control room design all support a robust defense-in-depth capability.

Furthermore, Section 4.9, "Staffing Plan Validation," of the TR states the following with regards to staffing plan validation (SPV) activities: "The assessment should demonstrate that the proposed Xe-100 plant shift crew, three operators in one control room operating multiple reactor units, can satisfy the plant and human performance requirements…."

Based on these provisions, the NRC staff determined that any regulatory conclusions drawn regarding the proposed control room staffing analysis methodologies discussed in the TR submittal should be considered applicable to the base case discussed (i.e., four units operated by a three-person control room staff). The TR submittal also includes consideration of the potential for expansion beyond this base case, along with the potential associated HFE impacts. The NRC staff's consideration of a potential expansion beyond the base case in future submittals is addressed in the Conclusion section of this SE.

In accordance with the requirements of 10 CFR 50.34, "Contents of applications; technical information," paragraph (b)(6)(i) and 10 CFR 52.79, "Contents of applications; technical information in final safety analysis report," paragraph (a)(26), details regarding an applicant's operations organization, including the structure, allocations or responsibilities and authorities, and personnel qualifications requirements must be provided as part of a final safety analysis report to support the facility's operating license or combined operating license application. Under these requirements, the NRC staff would typically expect any novel operator staffing considerations to be addressed within such a report and any necessary staffing-related exemption requests to be submitted for consideration in conjunction with the licensing application. To date however, X-energy has not provided a completed control room staffing analysis for the Xe-100 design. Therefore, the NRC staff determined that the review of the TR submittal would be limited to a consideration of only the methodology described within the submittal, with no conclusions drawn (or approval granted) at this time regarding specific staffing levels for a given number of units. Additional details regarding how a future submittal, including a completed control room staffing analysis, may be considered, are included in the Conclusion section of this SE.

Section 7, "NRC Topical Report Review Objectives," of the TR states, in part, the following:

> This report has been prepared to provide the proposed methodology for the Xe-100 HFE Program, which will be used as the basis for developing the technical basis for control room staffing in accordance with the guidance in NUREG-1791, or in support of a future 10 CFR [Part] 52 Design Certification

application. X-energy is requesting NRC review and acceptance of this approach as a means to conduct the HFE program methodologies to support approval of the Xe-100 control room staffing and develop a valid basis for licensees requesting exemptions from 10 CFR 50.54(m) or X-energy to use in support of a future Design Certification application.

The NRC staff also notes that X-energy has not formally submitted the "Human Factors Engineering Program Management Plan" or the HFE program implementation plans for comprehensive NRC review in accordance with the guidance of NUREG-0711, Revision 3, "Human Factors Engineering Program Review Model" (ML12324A013), dated November 2012. Therefore, the NRC staff did not review the submitted materials against the criteria in NUREG-0711. If a future submittal were to request the NRC staff's review of the full HFE program in accordance with the guidance of NUREG-0711 (e.g., as part of the review of a separate topical report or an application for licensing or design certification), the NRC staff would consider conducting a full HFE program review against the NUREG-0711 criteria at that time.

The NRC staff considered the following versions of the "Human Factors Engineering Program Management Plan" and HFE program implementation plans throughout its review of the TR submittal:

- Human Factors Engineering Program Management Plan, Revision 2;
- Xe-100 Operating Experience Review Implementation Plan, Revision 1;
- Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan, Revision 1;
- Xe-100 Task Analysis Implementation Plan, Revision 1;
- Xe-100 Staffing and Qualifications Implementation Plan, Revision 1;
- Xe-100 Treatment of Important Human Actions Implementation Plan, Revision 1;
- Xe-100 Human-System Interface Design Implementation Plan, Revision 1;
- Xe-100 Human Factors Verification and Validation Implementation Plan, Revision 1; and
- Xe-100 Design Implementation Plan, Revision 1.

The NRC staff considered the possibility that these plans may be revised in the future and included as part of a future licensing submittal. Further discussion of this consideration is included in the Conclusion section of this SE.

The NRC staff reviewed the information in the TR submittal, as supplemented, to determine whether the methodology proposed for conducting control room staffing analyses for the Xe-100 reactor facility design is acceptable. The results of this review are summarized in the Technical Evaluation section of this SE.

REGULATORY EVALUATION

The regulatory requirements, Commission policy, and guidance that the NRC staff considered in its review of the TR submittal, as supplemented, are as follows:

- 10 CFR 50.12, "Specific exemptions," and 10 CFR 52.7, "Specific exemptions," which state, in part, that the Commission may grant exemptions from the requirements of 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," and 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants," respectively, in instances where such exemptions are authorized by law, will not present an undue risk to the public health and safety, and are consistent with the common defense and security and where special circumstances are present.

- 10 CFR 50.54(m)(1), which requires, in part, that a licensed senior operator be present at the facility or readily available on call at all times during its operation and be present at the facility during refueling.

- 10 CFR 50.54(m)(2)(i), which requires that licensees meet certain minimum licensed operator staffing requirements based on the number of operating nuclear power units, number of control rooms, and total number of units onsite.

- 10 CFR 50.54(m)(2)(ii), which requires, in part, that each licensee have at its site a person holding a senior operator license for all fueled units at the site who is assigned responsibility for overall plant operation at all times there is fuel in any unit.

- 10 CFR 50.54(m)(2)(iii), which requires that when a nuclear power unit is in an operational mode other than cold shutdown or refueling, each licensee have a person holding a senior operator license for the nuclear power unit in the control room at all times. In addition to this senior operator, for each fueled nuclear power unit, a licensed operator or senior operator shall be present at the controls at all times.

- 10 CFR 50.54(m)(2)(iv), which requires that each licensee have present, during alteration of the core of a nuclear power unit (including fuel loading or transfer), a person holding a senior operator license limited to fuel handling to directly supervise the activity and, during this time, the licensee may not assign other duties to this person.

- 10 CFR 50.120, "Training and qualification of nuclear power plant personnel," paragraph (b)(2), which requires, in part, that nuclear power plant licensees, in their established training program, provide for the training and qualification of specified categories of nuclear power plant personnel including, among others, shift supervisor and shift technical advisor (STA).

- The Commission's, "Policy Statement on Engineering Expertise on Shift," published in Volume 50 of the *Federal Register*, page 43621 (50 *FR* 43621; October 28, 1985), which provides facility licensees with two options for providing engineering expertise on shift at nuclear power plants operating under an NRC license—either: (1) a dedicated STA or (2) a combined senior reactor operator (SRO)/STA.

- NUREG-1791, "Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m)," dated

July 2005 (ML052080125), which provides guidance for the review of exemption requests associated with proposed control room staffing plans that deviate from those specified by the minimum control room staffing requirements listed in 10 CFR 50.54(m).

As discussed in the Introduction section of this SE, the NRC staff did not review the TR submittal to assess conformance with the criteria listed in NUREG-0711. The potential for a future, comprehensive review of the implementation plans, in accordance with the guidance of NUREG-0711, is addressed in the Conclusion section of this SE.

TECHNICAL EVALUATION

The regulation under 10 CFR 50.54(m), provides the current requirements for control room staffing at nuclear power reactor facilities licensed under 10 CFR Part 50, as well as reactor designs licensed, certified, and approved under 10 CFR Part 52.

In accordance with 10 CFR 50.12 and 10 CFR 52.7, when considering an exemption request, the NRC staff will determine, in part, whether granting the exemption will present an undue risk to the public health and safety. To make this determination in the case of a requested exemption from the requirements of 10 CFR 50.54(m), the NRC staff will determine whether the proposed staffing plan provides adequate assurance that public health and safety will be maintained at a level that is comparable to compliance with the current regulations. The guidance in NUREG-1791, describes a technical basis that the NRC staff has determined to adequately demonstrate the acceptability of a proposed staffing plan that deviates from the staffing levels outlined in 10 CFR 50.54(m), including acceptance criteria against which the NRC staff should consider any submitted exemption requests.

Based on X-energy's stated review objectives, the NRC staff reviewed the information contained in the TR submittal, as supplemented, to determine whether the methodologies discussed therein are consistent with the guidance contained in NUREG-1791, such that a staffing analysis completed using the proposed methodology could provide the information necessary for the NRC staff to review a proposed staffing plan and determine whether there is reasonable assurance that the plan will support the safe operation of a Xe-100 facility.

The following sections of this SE detail the NRC staff's considerations regarding the proposed methodology discussed in the TR submittal. Discussion of these considerations is provided in the form of a section-by-section discussion regarding the alignment of the proposed methodology with submittal information needs and review criteria listed throughout Part II of NUREG-1791.

1.1 Exemption Request Considerations

Section 1.2, "Applicant Submittals," of NUREG-1791, Part II, lists general information that the NRC staff reviewer should confirm is included in an exemption request submittal. Section 1.3, "Review Criteria," of NUREG-1791, Part II, lists criteria that the NRC staff reviewer should confirm are met, as applicable, by a completed control room staffing analysis.

The NRC staff notes that the methodology described in the TR submittal would potentially be implemented in support of future applicants seeking licenses to construct and operate an Xe-100 facility. The methodology would potentially be used to: (1) validate the staffing base case or (2) deviate from the staffing base case when adding additional units. To operate a facility under such circumstances, the applicant would need exemptions from 10 CFR 50.54(m),

and a completed control room staffing analysis would be used to support a request for such exemptions.

The NRC staff also notes, however, that X-energy is not pursuing the issuance of an actual exemption from the control room staffing requirements with the TR submittal but is only seeking approval of the methodology to conduct future staffing analyses. The NRC staff, therefore, determined that the submittal expectations and criteria listed in Sections 1.2, "Applicant Submittals," and 1.3, "Review Criteria," of NUREG-1791, Part II, are not applicable to the review of this submittal. Accordingly, the NRC staff did not perform a full assessment of the adherence of the information submitted by X-energy with the guidance contained in these sections of NUREG-1791. If a completed staffing analysis were to be submitted to the NRC in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that time, consider its adherence with the guidance of these sections.

The NRC staff did, however, consider two criteria that would be applicable to a future exemption request that X-energy has suggested may be supported by a staffing analysis consistent with the TR submittal. Specifically, the NRC staff considered the following criteria, listed in Section 1.3 of NUREG-1791, Part II:

1. Confirm that one or more exemptions to 10 CFR 50.54(m) is required.

2. Confirm that exemptions from other, related regulations are either unnecessary or have been appropriately identified and described by the applicant.

Regarding the first criterion, the NRC staff determined that—as discussed in Section 3.1.1, "10 CFR 50.34(f)," of the TR—for the base case being considered by X-energy (i.e., four units operated by a three-person control room staff) and given the intended performance of continuous refueling operations at Xe-100 facilities, exemptions from—at a minimum—10 CFR 50.54(m)(2)(i) and 10 CFR 50.54(m)(2)(iv) would be required.

Regarding the second criterion, the NRC staff considered the following language from Section 1.1, "Purpose," of the "Xe-100 Task Analysis Implementation Plan":

> In addition to the tasks performed by the control room staff, scenarios that involve the skill set from the Shift Technical Advisor (STA) will also be reviewed if applicable. The current interpretation of the STA policy is that operating crews need to include one person with a degree in either a physical science, engineering, or engineering technology. The goal is to evaluate the ability of the planned staffing level and include tasks that may be allocated to the STA.

The NRC staff notes that if a licensee or applicant were to pursue a staffing plan that did not include an individual fulfilling the STA role, then an exemption from the requirements of 10 CFR 50.120(b)(2)(ii) may be necessary. Additional considerations associated with the STA role, and considerations associated with potential deviation from the established Commission policy regarding the STA role, are discussed in Section 1.9 of this SE.

1.2 Concept of Operations

Section 2.2, "Applicant Submittals," of NUREG-1791, Part II, lists the elements that should be described within a concept of operations provided in conjunction with a control room staffing analysis conducted to support an exemption request. Section 2.3, "Review Criteria," of

NUREG-1791, Part II, states that the NRC staff reviewer should confirm that an applicant's description of the concept of operations is complete, and that the applicant has addressed each of the aspects of operations and roles of the control personnel. The NRC staff reviewed the TR submittal to determine whether the proposed methodology adequately addresses the elements outlined in the guidance.

Section 4.1, "Concept of Operations," of the TR describes the Xe-100 Concept of Operations as addressing all of the elements of Section 2.2 of NUREG-1791, Part II, with the exception of "modular unit operations." However, the Xe-100 design, as described in the TR submittal, is a multi-unit, continuous-refueling design. The NRC staff determined that the exclusion of discussion of modular unit operations within the Concept of Operation was appropriate because this design would not be classified as a modular reactor and because the submittal addresses the "multi-unit operations" element.

The NRC staff also audited a copy of an initial draft of the Xe-100 Concept of Operations, made available by X-energy for the NRC staff's review. The NRC staff determined that this document included a discussion of all of the applicable elements, with the exception of "operations during construction of additional units." However, by letter dated October 19, 2022, X-energy stated that the Xe-100 Concept of Operations will be revised, and that this revision will address how the aspects related to multi-unit operations and operations during the construction of additional units at the same site will be managed by the Xe-100 plant staff, including the control room operators.

Based on the commitments in the TR submittal, as supplemented, along with an audit of an initial draft of the Xe-100 Concept of Operations, the NRC staff determined that X-energy's description of the concept of operations was adequate for the purpose of supporting the proposed control room staffing analysis methodology.

If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that time, evaluate the submittal to confirm that the description of the concept of operations within the submittal is complete, and that the submittal addresses each of the aspects of operations and roles of the control personnel.

1.3 Operational Conditions

1.3.1 Applicant Submittal Considerations

Section 3.2, "Applicant Submittals," of NUREG-1791, Part II, lists information that the NRC staff reviewer should confirm is included in support of an exemption request submittal. The NRC staff reviewed the TR submittal to determine whether the proposed methodology addresses this information. The result of this assessment for each of the items from NUREG-1791, Part II, Section 3.2, is provided below.

A description of the operational conditions selected for analysis.

The following attachments to the TR submittal discuss operational conditions:

- Section 3.2.2, "Plant Functions Definition," of the "Xe-100 Functional Requirements Analysis and Function Allocation (FRA&FA) Implementation Plan";

- Section 3.2.2, “Identification of Important Operating Sequences,” of the “Xe-100 Treatment of Important Human Actions [TIHA] Implementation Plan”;

- Section 3.2.1, “Converting Functions to Operating Sequences,” of the “Xe-100 Task Analysis Implementation Plan”; and

- Section 3.2.1, “Sampling of Operational Conditions,” of the “Xe-100 Human Factors Verification and Validation [V&V] Implementation Plan.”

In addition, by letter dated August 24, 2022, X-energy responded to the NRC staff’s Preliminary Question Number 2 regarding operational conditions.

Section 4.2, “Operational Conditions Considered in the HFE Program,” of the TR states that subsequent analysis activities of the HFE Program will focus on the operational conditions chosen. The scope of the analysis will include a description of the operational conditions selected for analysis.

Based on the above, the NRC staff determined that the proposed methodology includes the identification and documentation of the operational conditions selected for analysis, consistent with the guidance in NUREG-1791.

The rationale for selecting the operational conditions analyzed and for excluding others that could have been analyzed.

Section 4.2, “Operational Conditions Considered in the HFE Program,” of the TR states that subsequent analysis activities of the HFE Program will focus on the operational conditions chosen. The scope of the analysis will include the rationale for selecting the operational conditions analyzed and for excluding others that could have been analyzed. The TR further states that the following activities may provide sources to identify the operational conditions:

- Probabilistic Risk Assessment (PRA);
- Human Reliability Analysis (HRA);

- Operating Experience (OE) Review;

- TIHA; and

- TA.

Based on the above, the NRC staff determined that the proposed methodology includes the identification of the rationale for selecting the operational conditions analyzed and for excluding others that could have been analyzed, consistent with the guidance in NUREG-1791.

1.3.2 Review Criteria Considerations

Section 3.3, “Review Criteria,” of NUREG-1791, Part II, lists criteria that the NRC staff reviewer should confirm are met, as applicable, by a completed control room staffing analysis. Specifically, NUREG-1791, Section 3.3.1, “Operational Conditions Sampling for an Advanced Reactor Design,” lists the criteria that should be considered when reviewing an analysis for an advanced reactor design (such as the Xe-100).

The NRC staff reviewed the TR submittal to determine whether the proposed methodology adequately addresses these criteria. The result of this assessment for each of the criteria is provided below.

Analyzed Operational Conditions.

Section 3.3.1, “Operational Conditions Sampling for an Advanced Reactor Design,” of NUREG-1791, Part II, states that the reviewer should confirm that the operational conditions listed in that section were analyzed or that an adequate rationale for not analyzing the conditions was provided.

Section 4.2, “Operational Conditions Considered in the HFE Program,” of the TR states, in part, the following:

> Subsequent analysis activities of the HFE Program focus on the operational conditions chosen. The scope of the analysis will include:
>
> - a description of the operational conditions selected for analysis, and
> - the rationale for selecting the operational conditions analyzed and for excluding others that could have been analyzed.
>
> The following activities may provide sources to identify the operational conditions:
>
> - PRA, Probabilistic Risk Assessment,
> - HRA, Human Reliability Analysis,
> - OER, Operating Experience Review,
> - TIHA, Treatment of Important Human Actions, and
> - TA, Task Analysis.

The NRC staff reviewed the plans within the TR submittal to document plant operational conditions and compared them with the operational conditions in Section 3.3.1, “Operational Conditions Sampling for an Advanced Reactor Design,” of NUREG-1791, Part II.

Section 3.2.1, “Sampling of Operational Conditions,” of the "Xe-100 Human Factors Verification and Validation Implementation Plan” includes the plant conditions to be considered for the Xe-100 plant V&V activities, including the following: normal operational events, failure events, and transients and accidents. Section 3.2.2, “Identification of Important Operating Sequences,” of the “Xe-100 Treatment of Important Human Actions Implementation Plan” states that the methodology for identifying important operating sequences (IOS) includes the sequences whose contribution to the core damage frequency is greater according to the most current PRA/HRA of the plant. Section 3.2.2, “Identification of Important Operating Sequences,” of the “Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan” states that plant functions needed to fulfill each plant goal will be considered, including key equipment failure.

Based on the above, the NRC staff concludes that the TR submittal includes sufficient plans to analyze operational conditions because the activities described are consistent with the criteria in NUREG-1791.

Personnel Tasks.

Section 3.3.1, “Operational Conditions Sampling for an Advanced Reactor Design,” of NUREG-1791, Part II, states that the reviewer should confirm that the listed types of personnel tasks were included in the analysis.

The NRC staff reviewed the personnel tasks in the TR submittal and compared them with the types of personnel tasks described in Section 3.3.1, “Operational Conditions Sampling for an Advanced Reactor Design,” of NUREG-1791, Part II. Section 3.2.1, “Sampling of Operational Conditions,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” states that personnel tasks will be considered, including risk-important human actions, manual initiation of protective actions, automatic system monitoring, OE review identified risk important tasks, procedure guided tasks, knowledge-based tasks, human cognitive tasks, and human interactions. Therefore, the NRC staff concludes that the TR submittal includes sufficient plans to analyze personnel tasks because the activities described are consistent with the criteria in NUREG-1791.

Situational Factors.

Section 3.3.1, “Operational Conditions Sampling for an Advanced Reactor Design,” of NUREG-1791, Part II, states that the reviewer should confirm that the analysis included listed situational factors that are known to challenge human performance.

The NRC staff reviewed the situational factors in the TR submittal and compared them with the types of situational factors described in Section 3.3.1, “Operational Conditions Sampling for an Advanced Reactor Design,” of NUREG-1791, Part II. Section 3.2.1, “Sampling of Operational Conditions,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” includes plans to include risk-important human actions, error-forcing contexts, high-workload situations, varying workload situations, and fatigue situations. By letter dated August 24, 2022, X-energy responded to the NRC staff’s Preliminary Question Number 2 stating that fatigue, circadian factors, and environmental factors will be included in the operational conditions.

Based on the above, the NRC staff concludes that the TR submittal includes sufficient plans to analyze situational factors because the activities described are consistent with the criteria in NUREG-1791.

Range and Combination of Operational Conditions.

Section 3.3.1, “Operational Conditions Sampling for an Advanced Reactor Design,” of NUREG-1791, Part II, states that the reviewer should confirm that the range and combination of operational conditions considered by the applicant are appropriate and adequate.

Section 4.2, “Operational Conditions Considered in the HFE Program,” of the TR states that analyses performed using the proposed methodology will include a description of the operational conditions and the rationale for selecting the operational conditions. The TR also

states that the selected operational conditions will provide a robust sample of those conditions that present the greatest challenges to human performance and those critical for plant safety.

Based on the above, the NRC staff concludes that the TR submittal includes adequate measures intended to ensure that the range and combination of operational conditions considered by the applicant are appropriate and adequate.

1.3.3 Conclusion

The NRC staff compared the described scope and potential sources of the operational conditions analysis in the TR submittal to the expectations and criteria listed in Section 3.2, "Applicant Submittals," and Section 3.3, "Review Criteria," of NUREG-1791, Part II. The NRC staff determined that the methodology discussed in the TR submittal is consistent with the information needs and review criteria outlined in NUREG-1791 for this review area. Therefore, the NRC staff determined the consideration of this review area within the TR submittal, to be acceptable.

If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that time, evaluate the submittal to confirm: (1) that the information listed in Section 3.2 of NUREG-1791, Part II, is included and (2) that the criteria listed in Section 3.3 of NUREG-1791, Part II, are met.

1.4 Operating Experience

1.4.1 Applicant Submittal Considerations

Section 4.2, "Applicant Submittals," of NUREG-1791, Part II, lists possible sources from which OE may be available. The NRC staff reviewed the TR submittal to determine whether the proposed methodology incorporates OE, as applicable, from the sources listed. The result of this assessment for each of the potential sources is provided below.

Predecessor plants or systems; plants or systems using similar technologies, practices, or concepts of operation.

Section 4.3, "Operating Experience," of the TR discusses the consideration of previously developed high-temperature gas reactors (HTGRs) OE noting that X-energy has conducted an initial search for OE from domestic and international HTGR plants to inform the plant design.

Section 3.1.2.1, "International Information Issues and International Databases," of the "Xe-100 Operating Experience Review Implementation Plan" lists international information issues and international databases as sources of input for the OE review. It also lists several domestic information issues and databases as information sources.

Based on the above, the NRC staff confirmed that the proposed methodology includes the incorporation of input from predecessor plants or systems and plants or systems using similar technologies or practices, consistent with the guidance in NUREG-1791.

The TR submittal did not include a discussion of incorporating OE from plants or systems using similar concepts of operation; however, based on the fact that the Xe-100 would be a first-of-its kind commercial HGTR, and based on the fact that there are currently no operating nuclear

facilities in the U.S. that rely on a staffing plan that deviates from the requirements of 10 CFR 50.54(m), the NRC staff determined that this was acceptable.

Recognized industry human performance and staffing issues.

Section 4.3, "Operating Experience," of the TR states that the OE review of the HFE Program should identify staffing issues to be avoided.

Section 3.2.1.3, "Information Screening," of the "Xe-100 Operating Experience Review Implementation Plan" states that OE will be screened by potential for error and unanticipated situations that may lead to the same undesired event.

Based on the above, the NRC staff confirmed that the proposed methodology includes the consideration of recognized industry human performance and staffing issues, consistent with the guidance in NUREG-1791.

Issues identified by predecessor or similar plant personnel.

Section 3.1.2.1, "International Information Issues and International Databases," of the "Xe-100 Operating Experience Review Implementation Plan" states that searches of data sources will be targeted to issues identified by plant operations personnel as provided in reports.
Based on the above, the NRC staff confirmed that the proposed methodology includes the consideration of issues identified by predecessor or similar plant personnel, consistent with the guidance in NUREG-1791.

Prototype or experimental plants/systems.

Section 3.2, "Methodology," of the "Xe-100 Operating Experience Review Implementation Plan" states, in part, that OE research shall be oriented to prototype reactors.

Based on the above, the NRC staff confirmed that the proposed methodology includes the incorporation of input from prototype or experimental plants/systems, consistent with the guidance in NUREG-1791.

Experience from other industries.

Section 3.1.2.2, "Non-Nuclear Industry Reports or Databases," of the "Xe-100 Operating Experience Review Implementation Plan" lists, among the inputs for the OE program, non-nuclear industry reports and databases including sources from the following:

- non-nuclear electric generating stations;
- the chemical industry; and
- the transportation industry (including marine, piping, railroad, and aviation);
- the National Transportation Safety Board; and

- the Aviation Safety Network.

Based on the above, the NRC staff confirmed that the proposed methodology includes the incorporation of OE input from other industries, consistent with the guidance in NUREG-1791.

1.4.2 Review Criteria Considerations

Section 4.3, “Review Criteria,” of NUREG-1791, Part II, lists criteria that the NRC staff reviewer should confirm are met, as applicable, by a completed control room staffing analysis. The NRC staff reviewed the TR submittal to determine whether the proposed methodology adequately addresses these criteria. The result of this assessment for each of the criteria is provided below.

Predecessor or similar plants and systems included in the analysis are identified and their similarities and differences from the exemption under consideration are described.

Section 3.2.1.3, “Information Screening,” of the “Xe-100 Operating Experience Review Implementation Plan” states that the OE review process will entail the screening of the compiled OE information and assessment of that information, under evaluator judgment, to determine whether it is considered applicable to the Xe-100 plant design concept.

Based on the above, the NRC staff determined that the proposed methodology includes the identification of predecessor or similar plants and systems included in the analysis, and the determination of the similarities and differences from the exemption associated with a completed staffing analysis, consistent with the guidance in NUREG-1791.

Any recognized industry issues with the plant or system design are identified.

Section 4.3, “Operating Experience,” of the TR states that the OE review of the HFE Program should identify staffing issues to be avoided.

Based on the above, the NRC staff determined that the proposed methodology includes the consideration of any recognized industry issues with the plant or system design, as they pertain to the assessment of the proposed staffing plan, consistent with the guidance in NUREG-1791.

Any recognized industry issues with staffing for similar plants, systems, or technologies are identified.

Section 4.3, “Operating Experience,” of the TR states that the OE review of the HFE Program should identify staffing issues to be avoided.

Based on the above, the NRC staff determined that the proposed methodology includes the consideration of any recognized industry issues with staffing for similar plants, systems, or technologies, consistent with the guidance in NUREG-1791.

Other sources of operating experience data are identified, along with any limitations of their use in performing the review for the exemption requested.

Section 3.3, “Outputs,” of the “Xe-100 Operating Experience Review Implementation Plan” includes a list of searches and relevant parameters among the outputs to be generated by the OE analysis.

Section 3.2.1.3 of the "Xe-100 Operating Experience Review Implementation Plan" states that the OE review process will entail the screening of the compiled OE information and assessment of that information, under evaluator judgment, to determine whether it is considered applicable to the Xe-100 plant design concept.

Based on the above, the NRC staff determined that the proposed methodology includes the consideration of other sources of OE data, along with any limitations of its use in performing a review for the exemption request associated with a completed staffing analysis, consistent with the guidance in NUREG-1791.

The applicant has reviewed the staffing goals and numbers of control personnel for each of the related plants or systems selected.

Section 4.3, "Operating Experience," of the TR states, in part, the following:

> X-energy has conducted an initial search for [OE] from domestic and international HTGR plants to inform the plant design. Multi-unit operational considerations were not applicable to those plants, so alternative sources of [OE] will be explored for these considerations. Specific insights from the number and qualifications of control room operators and their contributions to safe plant operation will be developed in accordance with the HFE program.

Section 3.2.1.3, "Information Screening," of the "Xe-100 Operating Experience Review Implementation Plan" states that assessments performed as part of the OE process will include the following:

> Screening by personnel role and work design, including, but not limited to, levels and types of automation, work practices and task design, task allocation to crew members, teamwork, crew communication and coordination, supervision, important human actions and potential for error, task location, and training.

Based on the above, the NRC staff determined that the proposed methodology includes review of the staffing goals and numbers of control personnel for each of the related plants or systems selected in the OE review, consistent with the guidance in NUREG-1791.

The process used by the applicant for identifying issues during the operating experience review includes a description of the assumptions, criteria, and constraints used in selecting issues and developing interviews of control personnel.

Section 3.2.1.3, "Information Screening," of the "Xe-100 Operating Experience Review Implementation Plan" addresses the following assumptions, on which constraints for OE screening/selection were based:

> It is to be expected that most 20th century OE will already be incorporated into the standards applicable to the Xe-100 plant project design and its HFE Program.
>
> Therefore, following the recommendations and requirements of these standards an assumption can be made that the lessons learned from older OE have been incorporated into more current documents whether regulatory or industry. Considering the date of publication of the standards used (e.g., NUREG-1791 …

> was published in 2005), it is more efficient to narrow the search for findings to the 21st century….

Section 3.2.1.3, "Information Screening," of the "Xe-100 Operating Experience Review Implementation Plan" further discusses the criteria to be used for screening.

Based on the comprehensiveness of the screening criteria discussed and based on a determination that the assumptions and the constraints applied in the OE screening are appropriate for the purposes of analyzing a proposed staffing plan, the NRC staff determined that the OE process to be used within the proposed methodology includes a description of the assumptions, criteria, and constraints used in selecting issues and developing interviews of control personnel, consistent with the guidance in NUREG-1791.

The NRC staff notes that the consideration of only 21st-century OE findings is appropriate for the specific circumstances of the TR submittal because deviation from the requirements of 10 CFR 50.54(m), is a relatively modern consideration, so most OE would be expected to be derived from issues that have arisen within more recent decades. This reasoning, however, may not necessarily be applicable to OE review activities conducted outside of the scope of a control room staffing analysis. For example, the OE review within the broader context of the larger HFE program, as well as a more general OE review associated with the technological considerations of the overall plant design (such as historical issues associated with HTGR technologies), may warrant review scoping that extends beyond the 21st century timeframe. Therefore, the conclusions regarding OE methodology contained in this SE should not be considered as applicable to OE programs outside of the specific context of conducting staffing plan analysis activities. If future submittals addressing the OE in other contexts were to be submitted (e.g., as part of a submitted HFE program implementation plan subject to a broader NRC review in accordance with the guidance of NUREG-0711), the NRC staff would consider such submittals on a case-by-case basis to determine whether the scope of OE considered was appropriate for the particular purpose.

The applicant has identified the risk-important actions associated with existing plants, systems, or relevant technologies that could potentially be a problem if the requested exemption is granted.

Section 3.2.2, "Results, Analysis and Review," of the "Xe-100 Operating Experience Review Implementation Plan" states, in part, the following:

> Most of the negative Oes include an assessment of the root cause of the experience determined by the organization responsible for the plant or technology involved in the OE. For Oes without an identified lesson learned, an attempt will be made to extract details, based on the information found from the event and on the reviewers' technical expertise….

Section 3.2.2, "Results, Analysis and Review," of the "Xe-100 Operating Experience Review Implementation Plan" addresses the fact that each OE shall be reviewed within each other element of the HFE Program, which would include a review within the context of assessing risk-important actions.

Based on the above, the NRC staff determined that the proposed methodology includes adequate measures for identifying risk-important actions associated with existing plants,

systems, or relevant technologies that could potentially be a problem if the requested exemption is granted, consistent with the guidance in NUREG-1791.

The operating experience review was of sufficient scope to identify the most important relevant information and that the applicant's rationale for excluding some experience that could have been analyzed is reasonable.

Based on the comprehensiveness of the OE process discussed within the TR and the "Xe-100 Operating Experience Review Implementation Plan", the NRC staff determined that the proposed methodology includes measures intended to conduct an OE review of sufficient scope to identify the most important relevant information.

Furthermore (as addressed in the above discussion regarding timeframe limitations within the OE review), the NRC staff determined, based on the appropriateness of the reasoning within the discussion in Section 3.2.1.3, "Information Screening," of the "Xe-100 Operating Experience Review Implementation Plan," that X-energy's rationale for excluding some experience that could have been analyzed is reasonable, for the purposes of conducting control room staffing plan analysis. Therefore, in this regard, the proposed methodology is consistent with the guidance in NUREG-1791.

Examples of effective implementations of technologies, practices, or concepts of operation included as support for the exemption are fully substantiated and documented.

Section 3.2.3, "Operating Experience Treatment in the HFE Program," of the "Xe-100 Operating Experience Review Implementation Plan" states, in part, the following:

> [For each reviewed OE], a statement shall be provided to determine whether the Xe-100 plant design currently incorporates an improvement that addresses the OE, or if an action needs to be taken, or whether a solution is not yet known.

Section 4.3, "Operating Experience," of the TR states that the OE review should identify staffing practices that have proven to be effective and should therefore be incorporated into the operation environment.

Based on the above, the NRC staff determined that the proposed methodology adequately includes measures intended to fully substantiate and document examples of effective implementations of technologies, practices, or concepts of operation supporting a proposed staffing plan, consistent with the guidance in NUREG-1791.

1.4.3 Conclusion

The NRC staff compared the proposed methodology for conducting OE activities for the Xe-100 facility to the expectations and criteria listed in Sections 4.2, "Applicant Submittals," and 4.3, "Review Criteria," of NUREG-1791, Part II. The NRC staff determined that the methodology discussed in the TR submittal is consistent with the information needs and review criteria outlined in NUREG-1791 for this review area. Therefore, the NRC staff determined the consideration of this review area within the TR submittal, to be acceptable.

If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that time, evaluate the submittal to confirm: (1) that the information listed in Section 4.2 of

NUREG-1791, Part II, is included and (2) that the criteria listed in Section 4.3 of NUREG-1791, Part II, are met.

1.5 Functional Requirements Analysis and Function Allocation

1.5.1 Applicant Submittal Considerations

Section 5.2, "Applicant Submittals," of NUREG-1791, Part II, lists information that the NRC staff reviewer should confirm is included in support of an exemption request submittal. The NRC staff reviewed the TR submittal to determine whether the proposed methodology addresses this information. The result of this assessment for each of the information items is provided below.

The set of functions identified as being relevant to the exemption request.

Section 1.2, "Scope," of the "Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan" states, in part, "The FRA&FA is performed to define the high-level functions that must be accomplished to meet the plant's goals and desired performance…."

Section 3.2, "Methodology," of the "Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan" states, in part, the following:

> [The FRA] will be conducted to ensure that the functions necessary to accomplish plant goals are identified and sufficiently defined. The analysis will consist of a functional breakdown, where plant goals are in the top level and plant component statuses are in the lowest level. A plant goal is met if the related plant components are operating in their specified status.

Section 3.1, "Inputs," of the "Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan" lists the following, among other items, as inputs to the FRA:

- the Xe-100 Concept of Operations;
- the Preliminary Xe-100 Plant Control Philosophy;
- the Xe-100 Systems Engineering Management Plan;
- the Xe-100 Nuclear Power Plant Modes & States;
- system design descriptions;
- piping and instrumentation diagrams;
- logic and analogic diagrams; and
- preliminary technical specifications.

Based on the above, and the comprehensiveness of the inputs into the function requirements analysis, the NRC staff determined that the proposed methodology includes the identification of the set of functions relevant to the exemption request, consistent with the guidance of NUREG-1791.

The sequence of performance of the functions, triggering events for their initiation, and conditions for their completion or suspension.

Section 3.2, "Methodology," of the "Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan" states, in part, that for each plant function identified, the following information will be identified:

- conditions indicating that the plant function is needed;
- parameters indicating that the plant function is available;
- parameters indicating that the plant function is operating;
- parameters indicating that the plant function is achieving its purpose; and
- parameters indicating that the operation of the plant function can or should be terminated.

Based on the above, the NRC staff determined that the proposed methodology includes the identification of the sequence of performance of the functions, triggering events for their initiation, and conditions for their completion or suspension, consistent with the guidance of NUREG-1791.

Minimum function performance requirements in terms of time, timing, and accuracy.

Section 3.2.3, "System Functions Identification," of the "Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan" states that descriptions of both plant and safety system functions shall be completed in a way that its accomplishment can be measured by means of quantitative and qualitative objective parameters. Section 3.2.4, "Operating Alignment Definition," states that each operating alignment will be defined by the set of plant components needed to perform its associated function.

Figure 11, "Function Allocation flowchart," of the "Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan" provides a function allocation flowchart used to determine allocations. The allocation process includes the determination of whether allocation of a function to a human performer is feasible. Furthermore, Section 1, "Introduction," of the "Xe-100 Task Analysis Implementation Plan" states that one of the purposes of the TA is that it, "[a]ssures human performance requirements do not exceed human capabilities."

Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" states that the elements that will be considered in establishing success criteria for scenarios will include applicable requirements such as the time necessary to complete a task according to engineering analyses.

The NRC staff notes that determining whether each function can reasonably be accomplished by a human operator, or whether functions need to be allocated to an automated system/component, will entail consideration of the minimum function performance requirements in terms of timing, and accuracy. Based on this reasoning, the NRC staff determined that the proposed methodology adequately includes these considerations, consistent with the guidance of NUREG-1791.

Identification of functions that include risk-important human actions and the consequences (e.g., error rates or estimates of error rates) of not performing those actions, performing them incompletely, or not performing them within the time required.

The "Xe-100 Task Analysis Implementation Plan" and the "Xe-100 Treatment of Important Human Actions Implementation Plan" discuss the process by which functions allocated to human operators during the FRA will then be evaluated during the TA, and actions identified within those tasks will be assessed to determine their risk-importance using probabilistic and deterministic measures.

Based on the outlined process for assessing functions allocated to human operators within the TA and TIHA activities, the NRC staff determined that the proposed methodology addresses the identification of functions that include risk-important human actions and the consequences of not performing those actions, performing them incompletely, or not performing them within the time required, consistent with the guidance of NUREG-1791.

Section 1.6 of this SE provides additional details regarding the NRC staff's consideration of the treatment of risk-important human actions within the proposed methodology.

A description of the allocation of functions to control personnel, automated systems, or a combination of the two.

Section 3.2.7, "Allocation Flow Chart," of the "Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan" states that the FA entails assigning a responsible agent to each part/stage of an operating alignment change, and then assessing those parts using the allocation flow chart, included as Figure 11, "Function Allocation flowchart," in the "Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan." This flow chart describes the process by which alignment changes will be allocated to either a human agent (fully manual operations), an automation agent (fully automatic operations, including passive, self-controlling phenomena where applicable), or both (shared responsibility at any degree).

Section 3.3, "Outputs," of the "Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan" lists, among the outputs from the FA&FRA activities, "[t]he final set of allocations from the methodology…."

Based on the above, the NRC staff determined that the proposed methodology includes developing a description of the allocation of functions to control personnel, automated systems, or a combination of the two, consistent with the guidance of NUREG-1791.

A description of how the allocation of functions supports integrated control staff roles across functions and systems.

Section 3.2.7, "Allocation Flow Chart," of the "Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan states that the factors to be included in determining allocations include, among others, the following considerations:

- Automation can reduce operator mental workload, especially when performing very complex tasks that require considering a large amount of information.

- Actions performed by automation and human should be balanced.

- Professional motivation and psychological well-being of the operator should be an evaluation factor.

Section 3.3, “Outputs,” of the “Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan” discusses that the following will be included among the outputs from FA activities:

- control strategy for system functions;

- performance conditions of operating alignment; and

- relationships between levels according to functional breakdown.

Based on the above, the NRC staff determined that the proposed methodology includes developing a description of how the allocation of functions supports integrated control staff roles across functions and systems, consistent with the guidance of NUREG-1791.

A description of how control personnel functions relate to the functions performed by other plant personnel.

Section 1, “Introduction,” of the “Xe-100 Task Analysis Implementation Plan” states that one purpose of the TA is to ensure that all functions allocated to operations personnel in the FA are considered in the TA. Section 3.2.3, “Developing Detailed Task Descriptions,” of the “Xe-100 Task Analysis Implementation Plan” indicates that detailed task descriptions will provide information regarding overlap of task requirements, temporal constraints (i.e., those related to the ordering of tasks), communication required, and personnel interaction when more than one person is involved in a task relied upon to fulfill a human-allocated function.

Based on the above, and the comprehensive consideration of the aspects of tasks associated with the relationship between functions being performed by different personnel, the NRC staff determined that the proposed methodology includes developing a description of how control personnel functions relate to the functions performed by other plant personnel, consistent with the criteria of NUREG-1791.

Identification of functions that can be reallocated across or between control personnel, automated systems, or other plant staff, and a description of the strategies and criteria employed for reallocation.

Section 4.4, “Functional Requirements Analysis and Function Allocation,” of the TR states, in part, the following:

> If, during the validation tests of the operational conditions, the shift crew compliment is not proven to be sufficient to achieve a safe operation of the plant, then a review of the functional analysis will be conducted and a reallocation of the functions may be required.

Section 3.2.7, “Allocation Flow Chart,” of the “Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan” provides the following clarification regarding the initial allocation determination using the allocation flow chart:

> This is the first allocation in this iterative process. Further analysis may determine that the initial allocation is incorrect and may need some level of modification.

Section 4, “Documentation,” of the “Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan” further elaborates that:

> It is important to note that the [FRA&FA] process is iterative. The [results summary report (RSR)] will unambiguously define the inputs considered for the analysis performed for a specific revision and/or date. As the design evolves, potential impacts to the original FRA/FA will be evaluated for effect on the conclusions as documented in the RSR and if appropriate, the RSR will be revised.

Section 4, “Documentation,” of the “Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan also discusses the capturing of issues using the HFE issue tracking system, through which issues would be resolved, as discussed in Section 7, “HFE Issue Tracking System,” of the “Human Factors Engineering Program Management Plan.”

Section 3.2.4, “Human Engineering Discrepancies Management,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” addresses the fact that issues identified during the performance of validation activities may affect other elements, requiring corrective revisions to the documentation. The NRC staff considered the fact that in instances where validation testing identified issues with the allocation of certain functions to operators, the iterative processes of the proposed methodology would provide an opportunity to reallocate functions if needed.

Based on the above, the NRC staff determined that the proposed methodology includes adequate processes to identify functions that can be reallocated across or between control personnel, automated systems, or other plant staff and that the proposed methodology includes adequate identification of the strategies and criteria employed for reallocation, consistent with the guidance of NUREG-1791.

Identification of functions with risk-important human actions that may be reallocated with a description of how the risks are managed through the reallocation.

The “Xe-100 Task Analysis Implementation Plan” and the “Xe-100 Treatment of Important Human Actions Implementation Plan” discuss the process by which functions are assessed to determine their risk-importance.

Section 3.2, “Methodology,” of the “Xe-100 Treatment of Important Human Actions Implementation Plan” discusses the iterative nature of the TIHA process, and states, in part, the following:

> [T]he results and conclusions are reviewed with the other HFE Program elements, including [FRA&FA]…. The results and conclusions of the TIHA may identify specific HFE Program elements whose conclusions may need analysis and revision.

Furthermore, Section 3.2, “Methodology,” of the “Xe-100 Treatment of Important Human Actions Implementation Plan” states that this iterative analysis process includes, “considering [important human actions and IOS] in designing the HFE aspects to minimize the probability of human error and to help ensure that personnel can detect and recover from any errors.”

Based on the above, the NRC staff determined that the proposed methodology includes adequate processes to identify functions with risk-important human actions that may be reallocated and to ensure that risks are managed through the reallocation, consistent with the guidance of NUREG-1791.

Identification of function allocations that may affect the roles, responsibilities, or qualifications for licensed control personnel.

Section 3.1.2, “HFE Program Related Data,” of the “Xe-100 Staffing and Qualifications Implementation Plan” states, in part, the following:

> As S&Q is part of the Xe-100 plant HFE Program, data, results, and conclusions from other HFE elements of the HFE Program need to be considered while performing S&Q activities.

Section 3.1.2, “HFE Program Related Data,” further states that:

> Staffing level and their qualification shall be defined in accordance with the functions allocated to personnel for each job position.

Based on the above, the NRC staff determined that the proposed methodology includes identification of FA that may affect the roles, responsibilities, or qualifications for licensed control personnel, consistent with the guidance of NUREG-1791.

Identification of function allocations to any new control personnel jobs.

Section 3.1.2, “HFE Program Related Data,” of the “Xe-100 Staffing and Qualifications Implementation Plan” states, in part, the following:

> Staffing level and their qualification shall be defined in accordance with the functions allocated to personnel for each job position.

The NRC staff considered the fact that this definition of the staffing qualifications would also apply to any new personnel jobs identified as part of a proposed staffing plan. Based on this consideration, the NRC staff determined that the proposed methodology includes identification of FA to any new control personnel jobs, consistent with the guidance of NUREG-1791.

Applicable supporting data from the concept of operations, the operational conditions defined, and the operating experience review.

Section 3.1, “Inputs,” of the “Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan” includes the discussion of the incorporation of input from other HFE review areas in conducting the FRA activities. Based on this discussion, the NRC staff determined that the proposed methodology includes identification of any applicable supporting data from the concept of operations, the operational conditions defined, and the OE review, consistent with the guidance of NUREG-1791.

1.5.2 Review Criteria Considerations

Section 5.3, “Review Criteria,” of NUREG-1791, Part II, lists criteria that the NRC staff reviewer should confirm are met, as applicable, by a completed control room staffing analysis.

The NRC staff reviewed the TR submittal to determine whether the proposed methodology adequately addresses these criteria. The result of this assessment for each of the criteria is provided below.

The set of functions identified as applicable to the analysis is complete and appropriately characterized.

Section 1.2, “Scope,” of the “Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan” states, in part, “The FRA&FA is performed to define the high-level functions that must be accomplished to meet the plant’s goals and desired performance….”

Section 3.2, “Methodology,” of the “Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan” states, in part, the following:

> [The FRA] will be conducted to ensure that the functions necessary to accomplish plant goals are identified and sufficiently defined. The analysis will consist of a functional breakdown, where plant goals are in the top level and plant component statuses are in the lowest level. A plant goal is met if the related plant components are operating in their specified status.

Additionally, as discussed above, Section 3.1, “Inputs,” of the “Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan” lists several inputs to the FRA.

Based on the above, and the comprehensiveness of the inputs into the function requirements analysis, the NRC staff determined that the proposed methodology includes measures intended to identify and appropriately characterize the set of functions applicable to the analysis, consistent with the guidance in NUREG-1791.

All functions have been allocated to control personnel, automated systems, or a combination of the two, and that the strategies and criteria for the allocations are clear and met.

Section 3.2.7, “Allocation Flow Chart,” of the “Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan” discusses the process of allocating functions using the process outlined in allocation flow chart.

Based on the above, and a consideration of the allocation flowchart describing the allocation process, the NRC staff determined that the proposed methodology includes an adequate process for allocating functions to control personnel, automated systems, or a combination of the two, and that the strategies and criteria for the allocations are clear, consistent with the guidance in NUREG-1791.

The function allocations support integrated control staff roles across functions, systems, and other plant personnel.

The NRC staff considered the integrated process discussed throughout the implementation plans, by which functional allocations would be incorporated into the TA, which would be used to determine the necessary staffing roles and qualifications, as well as the needs associated with interfacing with plant systems and other personnel.

Based on these considerations, the NRC staff determined that the proposed methodology includes an adequate process intended to ensure that functional allocations support integrated control staff roles across functions, systems, and other plant personnel, consistent with the guidance in NUREG-1791.

Any new or modified licensed control personnel positions resulting from the function requirements analysis and function allocation have been identified and characterized.

Section 3.1.2, "HFE Program Related Data," of the "Xe-100 Staffing and Qualifications Implementation Plan" states, in part, the following:

> Staffing level and their qualification shall be defined in accordance with the functions allocated to personnel for each job position.

The NRC staff considered the fact that this definition of staffing qualifications would also apply to any new or modified personnel positions identified within the proposed staffing plan. Based on this consideration, the NRC staff determined that the proposed methodology includes an adequate process for identifying and characterizing any new or modified licensed control personnel positions resulting from the FRA&FA, consistent with the guidance in NUREG-1791.

The data analyses were performed using appropriate parameters and methods.

The NRC staff considered the process discussed in Section 3.2, "Methodology," of the "Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan" for identifying and characterizing functions and allocating them accordingly. Based on the comprehensive nature of the proposed methodology, the NRC staff determined that it includes adequate consideration of operational considerations and other inputs and the assessment of those inputs to define and allocate functions.

Based on the above, the comprehensiveness of the inputs that will be used to define and allocate functions, and the approach described for hierarchically characterizing functions and systematically allocating them, the NRC staff determined that the proposed methodology includes appropriate parameters and methods for the data analyses that would be involved in the FRA&FA activities, consistent with the guidance in NUREG-1791.

The assumptions and estimates used in conducting the analyses were documented and appropriate.

The NRC staff considered the input and process discussed in Sections 3.1, "Inputs," and 3.2, "Methodology," of the "Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan." As discussed above, Section 3.1, "Inputs," of the "Xe-100 Functional Requirements Analysis and Function Allocation Implementation Plan" lists several inputs to the FRA.

Based on the above, the NRC staff determined that the proposed methodology calls for appropriate assumptions and estimates to be used in conducting the analyses, consistent with the guidance in NUREG-1791.

1.5.3 Conclusion

The NRC staff compared the proposed methodology for conducting FRA&FA activities for the Xe-100 facility to the expectations and criteria listed in Sections 5.2, “Applicant Submittals,” and 5.3, “Review Criteria,” of NUREG-1791, Part II. The NRC staff determined that the methodology discussed in the TR submittal is consistent with the information needs and review criteria outlined in NUREG-1791 for this review area. Therefore, the NRC staff determined the consideration of this review area within the TR submittal, to be acceptable.

If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that time, evaluate the submittal to confirm (1) that the information listed in Section 5.2 of NUREG-1791, Part II, is included and (2) that the criteria listed in Section 5.3 of NUREG-1791, Part II, are met.

1.6 Task Analysis

1.6.1 Applicant Submittal Considerations

Section 6.2, “Applicant Submittals,” of NUREG-1791, Part II, lists information that the NRC staff reviewer should confirm is included in support of an exemption request submittal. The NRC staff reviewed the TR submittal to determine whether the proposed methodology addresses this information. The result of this assessment for each of the information items is provided below.

The set of tasks identified as being relevant to the exemption request.

Section 1.2, “Scope,” of the “Xe-100 Task Analysis Implementation Plan” discusses the scope of the methodology as covering the identification of tasks directed to the full range of plant operating modes, including startup, normal operations, abnormal operations, transient conditions, and shutdown conditions.

Based on the above, the NRC staff determined that the proposed methodology includes the identification of tasks identified as being relevant to an associated exemption request, consistent with the guidance in NUREG-1791.

The sequence of performance of the tasks, triggering events for their initiation, and conditions for their completion or suspension.

Section 3.2.1, “Converting Functions to Operating Sequences,” of the “Xe-100 Task Analysis Implementation Plan” states that operating sequence initiators, or events, shall be identified, including the following:

- Plant start-up;
- Plant shutdown;

- Plant operating modes changes;
- Alternative operating alignments or functions, identified in the FRA&FA;
- Independent and supporting functions, identified in FRA&FA;
- Safety-IOS, identified in TIHA, such as Design Basis Accidents and the most likely Beyond Design Basis Accident; and
- Functional tests of safety systems.

Furthermore, Section 3.2.1, "Converting Functions to Operating Sequences," states, in part, the following:

> For unexpected events that cause a deviation from normal operation, the objective of the operating sequence is stabilizing and bringing the plant to a safe condition. For scheduled events, the objective of the operating sequence is bringing the plant to the new condition according to the schedule.

Additionally, Section 3.2.1, "Converting Functions to Operating Sequences," discusses each OE as being characterized, in part, by the following:

- related events;
- plant conditions before starting the operating sequence; and
- plant conditions after completing the operating sequence.

Based on the above, the NRC staff determined that the proposed methodology includes the identification of the sequence of performance of the tasks, triggering events for their initiation, and conditions for their completion or suspension, consistent with the guidance in NUREG-1791.

Minimum task performance requirements in terms of time, timing, accuracy, or other relevant criteria, as identified in Table 2 of NUREG-1971.

By letter dated August 24, 2022, X-energy stated that it intends for the staffing analysis to determine each of the task performance requirements listed in Table 2, "Task Performance Requirements," of NUREG-1971. Furthermore, X-energy confirmed that:

> X-energy is not currently seeking approval [i.e., through the NRC staff's review of the TR] regarding the methodologies identified in the [TA] and the Human Factors [V&V] Implementation Plans that will be used to determine the task performance requirements.

X-energy also stated that:

> Specific details relating to meeting the Categories, Data Items, and Requirements of Table 2 of NUREG-1791 will be identified during the [TA] phase

> and included in the test scenarios that will be developed for the Human Factors [V&V] process.

The NRC staff notes that—while the TR submittal, as supplemented, does not provide details regarding how the full set of task performance requirements listed in Table 2 of NUREG-1791 will be addressed—X-energy has committed to this information being included in a completed TA, which would be incorporated into the control room staffing analysis submitted to support any future exemption request.

Based on the above, the NRC staff determined that the proposed methodology adequately considers the minimum task performance requirements, as identified in Table 2 of NUREG-1791, consistent with the guidance in NUREG-1791.

If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that time, determine whether the completed analysis includes the completed determination and listing of the minimum task performance requirements, as identified in Table 2 of NUREG-1791.

Identification of tasks that include risk-important human actions and the consequences (e.g., error rates or estimates of error rates) of not performing those actions, performing them incompletely, or not performing them within the time required.

Section 3.1, "Inputs," of the "Xe-100 Treatment of Important Human Actions Implementation Plan" discusses the identification of IOS during activities performed throughout the various areas of the HFE program.

Section 3.2.3 of the "Xe-100 Treatment of Important Human Actions Implementation Plan" states that throughout TA, each IOS "is fully analyzed in terms of tasks, human-system interface requirements, staffing level, and workload." Section 3.2.3 continues by stating that:

> Moreover, by definition, all operating sequences with at least one [important human action (IHA)] are categorized as IOS; therefore, they will also be fully analyzed within TA. …TA provides additional assurance that all IHAs and IOSs identified can be carried out with the necessary task requirement….

Section 3.2, "Methodology," of the "Xe-100 Treatment of Important Human Actions Implementation Plan" discusses the steps involved in the process of assessing IHAs. This discussion states that following the identification of IHAs and IOSs, the process then entails "considering [IHAs and IOSs] in designing the HFE aspects to minimize the probability of human error and to help ensure that personnel can detect and recover from any errors."

Based on the above, the NRC staff determined that the proposed methodology includes the identification of tasks that include risk-important human actions and adequate consideration of the consequences of not performing those actions, performing them incompletely, or not performing them within the time required, consistent with the guidance in NUREG-1791.

Identification of tasks that may affect the roles, responsibilities, or qualifications for licensed control personnel.

Section 3.3, "Outputs," of the "Xe-100 Task Analysis Implementation Plan" states that the completed TA will include, among other information, the following:

- identification of personnel tasks needed;
- a narrative of the activities to be performed;
- alarms, information, controls, and task support needed to accomplish the task;
- an estimate of the time needed to perform each task;
- an estimate of the people needed; and
- designation of the knowledge and abilities needed.

Based on the above, the NRC staff determined that the proposed methodology includes the identification of tasks that may affect the roles, responsibilities, or qualifications for licensed control personnel, consistent with the guidance in NUREG-1791.

Identification of tasks for any new control personnel jobs.

Section 3.3, "Outputs," of the "Xe-100 Task Analysis Implementation Plan" lists that the outputs of the TA will include, among other information, the following:

- identification of personnel tasks needed;
- an estimate of the people needed; and
- designation of the knowledge and abilities needed.

The NRC staff determined that in identifying the knowledge and abilities needed to complete tasks, along with the people needed, X-energy would identify those tasks that would need to be performed by someone in a new control personnel role. Based on this consideration, the NRC staff determined that the proposed methodology includes the identification of tasks for any new control personnel jobs, consistent with the guidance in NUREG-1791.

Applicable supporting data from the concept of operations, the operational conditions defined, function requirements analysis and function allocation, and the operating experience review.

Section 1.3, "Relationship to other Documents," of the "Xe-100 Task Analysis Implementation Plan" and Section 1.3, "Relationship to other Documents," of the "Xe-100 Treatment of Important Human Actions Implementation Plan" discuss the integration of these activities with the other elements of the HFE program, incorporating input from the assessments performed under those elements.

Based on the above, along with the NRC staff's consideration of the applicable HFE program areas (as discussed throughout this SE), the NRC staff determined that the proposed methodology includes the identification of applicable data from the concept of operations, the operational conditions defined, FRA&FA, and the OE review, consistent with the guidance in NUREG-1791.

1.6.2 Review Criteria Considerations

Section 6.3, “Review Criteria,” of NUREG-1791, Part II, lists criteria that the NRC staff reviewer should confirm are met, as applicable, by a completed control room staffing analysis. The NRC staff reviewed the TR submittal to determine whether the proposed methodology adequately addresses these criteria. The result of this assessment for each of the criteria is provided below.

The set of tasks identified as applicable to the analysis is complete and appropriately characterized.

Section 3.2.1, “Converting Functions to Operating Sequences,” of the “Xe-100 Task Analysis Implementation Plan” discusses the process by which input from the FRA&FA will be used to define IOS, from which human tasks will be identified. Section 3.2.2, “Developing Narrative Task Descriptions,” discusses the process and provides criteria for developing narrative task descriptions, by which tasks would be characterized in a manner that ensures clarity, completeness, conciseness, and relevance. Section 3.2.3 discusses the process for developing detailed task descriptions, including a variety of aspects of the tasks that will be addressed in characterizing the tasks. Additionally, Section 3.2.3 discusses the detailed task characterization including the division of tasks into steps—a sequence of related activities that must be performed uninterruptedly—and the fact that steps are assigned to a single operator.

Furthermore, the “Xe-100 Treatment of Important Human Actions Implementation Plan” outlines the classification and treatment of those tasks that are determined to be part of an important operating sequence.

The NRC staff considered this discussion, the level of comprehensiveness with regards to the inputs that will go into identifying tasks, and the comprehensiveness of the set of characteristics to be identified while characterizing tasks. The NRC staff also considered its assessment of the proposed FRA&FA methodology (discussed in a separate section of this SE). Based on these considerations, the NRC staff determined that the proposed methodology includes an adequate process for identifying the set of tasks, as well as an adequate process for appropriately characterizing the tasks identified, consistent with the guidance in NUREG-1791.

The task performance requirements for each task were comprehensively identified.

As discussed above in Section 1.6.1 of this SE, X-energy communicated by letter dated August 24, 2022, the commitment that an analysis performed using the proposed methodology would include the minimum task performance requirements, as identified in Table 2, “Task Performance Requirements,” of NUREG-1791.

Based on the commitment to assess tasks accordingly and to provide the information listed in Table 2, “Task Performance Requirements,” of NUREG-1791 as part of any analyses completed using the proposed methodology, the NRC staff determined that the proposed methodology includes comprehensively identifying the task performance requirements for each task, consistent with the guidance in NUREG-1791.

The tasks for any new or modified licensed control personnel positions (as specified in 10 CFR Part 55) have been identified and characterized.

As discussed above, Section 3.3, “Outputs,” of the “Xe-100 Task Analysis Implementation Plan” discusses the outputs to be included in a completed TA.

The NRC staff considered this discussion and determined that, in identifying the knowledge and skills needed while also considering an estimate of the people needed to complete the identified tasks, a TA performed using the proposed methodology would provide the information needed to identify new positions resulting from the unique staffing and knowledge/skills needs. Based on this consideration, the NRC staff determined that the proposed methodology adequately addresses the identification and characterization of tasks for any new or modified licensed control personnel positions, consistent with the guidance in NUREG-1791.

The data analyses were performed using appropriate parameters and methods.

Section 3.2.1, "Identification of Important Human Actions," of the "Xe-100 Treatment of Important Human Actions Implementation Plan" discusses the process by which tasks to be characterized as IHAs will be identified, including the following:

- deterministically-identified human actions, identified as part of deterministic analyses performed to evaluate the plant response under certain transients and postulated accidents;

- risk-important human actions, identified based on their contribution to nominal core damage frequency, as determined via PRA and HRA; and

- potential important human actors, identified based on their potential impact on other HFE program elements.

Furthermore, regarding the analysis of tasks to define task performance requirements, X-energy communicated by letter dated August 24, 2022, the commitment that an analysis performed using the proposed methodology would include consideration of the minimum task performance requirements, as identified in Table 2, "Task Performance Requirements," of NUREG-1791. This table includes a listing of the dataset that needs to be considered in defining those performance requirements. Specifically, X-energy stated that:

> Specific details relating to meeting the Categories, Data Items, and Requirements of Table 2 of NUREG-1791 will be identified during the [TA] phase and included in the test scenarios that will be developed for the Human Factors [V&V] process.

Based on these considerations—specifically the reliance on established analysis and characteristics techniques and the consideration of performance measures in accordance with the established guidance—the NRC staff determined that the proposed methodology includes the use of appropriate parameters and methods for data analyses performed as part of the completed TA, consistent with the guidance in NUREG-1791.

The assumptions and estimates used in conducting the analyses were documented and appropriate.

Section 3.2.1, "Identification of Important Human Actions," of the "Xe-100 Treatment of Important Human Actions Implementation Plan" discusses the classification of identified human actions using deterministic and probabilistic inputs, including those from a completed PRA and HRA.

Section 3.2.2, “Identification of Important Operating Sequences,” of the “Xe-100 Task Analysis Implementation Plan” discusses the development of narrative task descriptions, and states that the definition of individual activities will be based on such information as the following:

- operational experience;
- data from the manufacturers of the equipment and components;
- technical design characteristics of the equipment and components;
- system design information (such as design descriptions, piping and instrumentation diagrams, process diagrams, logic diagrams, etc.);
- technical specifications; and
- procedures used in earlier HTGR plants, as applicable.

Based on the above, the NRC staff determined that the proposed methodology is intended to include reliance on appropriate assumptions and estimates and to document them accordingly, consistent with the guidance in NUREG-1791.

Also, as noted above, X-energy has communicated, to the NRC staff, the commitment that an analysis performed using the proposed methodology would include consideration of the minimum task performance requirements, as identified in Table 2 of NUREG-1791. If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would also assess any additional assumption and estimate considerations associated with the details provided regarding the assessment and determination of task performance requirements.

1.6.3 Conclusion

The NRC staff compared the proposed methodology for conducting TA activities to support a control room staffing analysis for the Xe-100 facility to the expectations and criteria listed in Sections 6.2, “Applicant Submittals,” and 6.3, “Review Criteria,” of NUREG-1791, Part II. The NRC staff determined that the methodology discussed in the TR submittal is consistent with the information needs and review criteria discussed in NUREG-1791 for this review area. Therefore, the NRC staff determined the consideration of this review area within the TR submittal, to be acceptable.

As discussed above, the NRC staff noted certain review criteria, associated with the consideration of task performance requirements, regarding which X-energy did not provide specific details at this time, but for which it committed to providing the information outlined in the applicable guidance. The NRC staff determined that the commitment to provide this information is sufficient to address consistency with the guidance in NUREG-1791 for the purposes of describing the methodology at this stage of regulatory engagement.

If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that time, evaluate the submittal to confirm: (1) that the information listed in Section 5.2, “Applicant Submittals,” of NUREG-1791, Part II—including necessary information associated with task

performance requirements, as outlined in Table 2—is included and (2) that the criteria listed in Section 5.3, “Review Criteria,” of NUREG-1791, Part II, are met.

1.7 Job Definitions

1.7.1 Applicant Submittal Considerations

Section 7.2, “Applicant Submittals,” of NUREG-1791, Part II, lists information that the NRC staff reviewer should confirm is included in support of an exemption request submittal. The NRC staff reviewed the TR submittal to determine whether the proposed methodology addresses this information. The result of this assessment for each of the information items is provided below.

A description of the scope and the impacts of the exemption request on the roles, responsibilities, and qualifications of control personnel.

Section 4.6, “Job Definitions,” of the TR states that the job definition will be addressed after the HFE TA by the Systematic Approach to Training (SAT) process.

Section 4.9, “Staffing Plan Validation,” of the TR provides that the SPV will test and validate the defined job roles. If issues with the job definitions are identified, they will be captured within the HFE issue tracking system and addressed through the established process for issue resolution, as discussed in Section 7, “HFE Issue Tracking System,” of the “Human Factors Engineering Program Management Plan.” If a completed staffing analysis were submitted, the NRC staff would review the validation data to confirm that job roles are adequate.

Based on the above, the NRC staff determined that the proposed methodology addresses the determination of the scope and the impacts of the exemption request on the roles, responsibilities, and qualifications of control personnel, consistent with the guidance in NUREG-1791.

Identification of any new or modified roles, responsibilities, and qualifications for licensed control room personnel (under the current requirements) included in the exemption request.

The base case discussed in the TR submittal addresses the anticipated number of control room staff (i.e., four units operated by three operators in the control room); however, it does not explicitly discuss new or modified roles, responsibilities, or qualifications for personnel under the current requirements.

The NRC staff notes, however, that—as discussed in Section 3.3, “Outputs,” of the “Xe-100 Task Analysis Implementation Plan”—the completed TA will include, among other information, identification of personnel tasks needed, an estimate of the people needed, and designation of the knowledge and abilities needed by operators to perform individual tasks. Through this process, new or modified roles, responsibilities, or qualifications could be identified.

Furthermore, as discussed in Section 4.9, “Staffing Plan Validation,” of the TR, the SPV will test and validate the defined job roles. If issues are identified that warranted the development of new or modified roles, responsibilities, or qualifications, they would be captured within the HFE issue tracking system and addressed through the established process for issue resolution, as discussed in Section 7 of the “Human Factors Engineering Program Management Plan.”

If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that time, evaluate the submittal to determine whether any new or modified roles, responsibilities, or qualifications were included and whether they were adequately identified, consistent with the guidance in NUREG-1791.

Identification of the roles, responsibilities, and qualifications for any new jobs included in the exemption request.

The base case discussed in the TR submittal does not explicitly discuss any new jobs included within the X-energy control room staffing plan.

As discussed in Section 3.2.4 of the "Xe-100 Human Factors Verification and Validation Implementation Plan", if any issues were identified during the SPV that warrant a re-assessment of job definitions, such issues would be captured and addressed through the established HFE issue tracking system discussed in Section 7 of the "Human Factors Engineering Program Management Plan."

Based on the above, the NRC staff determined that the proposed methodology includes measures to address the identification of roles, responsibilities, and qualifications for any new jobs that would potentially need to be included in an associated exemption request, consistent with the guidance in NUREG-1791.

Applicable data from the concept of operations, operational conditions, operating experience, functional requirements analysis and function allocation, and task analysis for each of the jobs affected that support the roles and responsibilities identified in the exemption request.

Section 4.6, "Job Definitions," of the TR states that by following the SAT process for the training material development, matching between the Knowledge, Skills, and Abilities (KSAs) list, job definition, and S&Q is ensured, as all of the activities are connected and take the same TA as input.

Furthermore, Section 3.2.2.1, "Results from HFE Program Elements," of the "Xe-100 Staffing and Qualifications Implementation Plan" states that applicable data from OE, FRA&FA, and TA activities will be used to determine the qualifications, roles, and responsibilities of personnel in the control room. Specifically, Section 3.3, "Outputs," of the "Xe-100 Task Analysis Implementation Plan" states that the completed TA (which incorporates input from the OE and FRA&FA activities) will include, among other information, an estimate of the people needed and designation of the knowledge and abilities needed.

Based on the above, the NRC staff determined that the proposed methodology includes adequate consideration of the applicable data for each of the jobs affected that support the roles and responsibilities identified in an exemption request, consistent with the guidance in NUREG-1791.

Applicable data from the KSA analysis for each of the jobs affected that support the qualifications identified in the exemption request.

Section 5, "Developing the Control Room Staffing Analysis," of the TR states that a KSA analysis will be provided for the control room staffing analysis. Furthermore, Section 3.3,

"Outputs," of the "Xe-100 Task Analysis Implementation Plan" indicates that the completed TA will include, among other information, an estimate of the people needed, and designation of the knowledge and abilities needed by operators to perform individual tasks.

Based on the above, the NRC staff determined that the proposed methodology includes adequate consideration of the applicable data from the KSA analysis for each of the jobs affected that support the qualifications identified in an exemption request, consistent with the guidance in NUREG-1791.

A final job description for each job impacted by the exemption request.

The TR states that the staffing and qualifications activities will describe and define the scope and impacts on the roles, responsibilities, and qualifications of control room personnel.

Based on the above, the NRC staff determined that the proposed methodology addresses the development of final job descriptions for each job impacted by an exemption request, consistent with the guidance in NUREG-1791.

Job definitions which appropriately prioritize the responsibilities of each position and that do not incorporate role conflicts.

By letter dated October 19, 2022, X-energy stated that the job definitions of the Xe-100 plant staff will be reviewed for role conflicts. Potential conflicts will be identified, evaluated, and corrected as necessary.

Based on the above, the NRC staff determined that the proposed methodology includes adequate consideration of the prioritization of responsibilities and the resolution of any identified role conflicts, consistent with the guidance in NUREG-1791.

If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that time, evaluate the submittal to confirm that job definitions within the proposed staffing plan do indeed appropriately prioritize the responsibilities of each position, and that the job definitions do not incorporate any role conflicts.

1.7.2 Review Criteria Considerations

Section 7.3, "Review Criteria," of NUREG-1791, Part II, lists criteria that the NRC staff reviewer should confirm are met, as applicable, by a completed control room staffing analysis. The NRC staff reviewed the TR submittal to determine whether the proposed methodology adequately addresses these criteria. The result of this assessment for each of the criteria is provided below.

The scope and impact of the exemption request is adequately addressed for control personnel jobs.

Section 4.6, "Job Definitions," of the TR states that the job definition will be addressed after the HFE TA by the SAT process. The TR further states that the S&Q activities will describe and define the scope and impacts on the roles, responsibilities, and qualifications of control room personnel.

Based on the above, the NRC staff determined that the proposed methodology includes sufficient plans to adequately address the scope and impact of an exemption request for control personnel jobs, consistent with the guidance in NUREG-1791.

Applicable data from the concept of operations, operational conditions, operating experience, functional requirements analysis and function allocation, and task analysis support the roles and responsibilities assigned to each impacted job in the exemption request.

Section 4.6, "Job Definitions," of the TR states that by following the SAT process for the training material development, matching between the KSAs list, job definition, and S&Q is ensured, as all of the activities are connected and take the same TA as input.

Furthermore, Section 3.2.2.1, "Results from HFE Program Elements," of the "Xe-100 Staffing and Qualifications Implementation Plan" describes how applicable data from OE, FRA&FA, and TA will be used to determine the qualifications, roles, and responsibilities of personnel in the control room. Specifically, Section 3.2.2.1.1, "Operating Experience Review," of the "Xe-100 Staffing and Qualifications Implementation Plan" states that OE related to human performance errors due to staffing or qualification level will be addressed and factored into the preliminary design and become part of the planned testing and evaluation.

Section 3.2.2.1.3, "Functional Requirement Analysis and Function Allocation," of the "Xe-100 Staffing and Qualifications Implementation Plan" states that the role of the operator in a monitoring and/or control role shall be clearly identified and if mismatches are identified during evaluation, then the staffing level and operator's qualifications shall be reviewed accordingly.

Section 3.2.2.1.4, "Task Analysis," of the "Xe-100 Staffing and Qualifications Implementation Plan" states that the TA includes an assignment of operators to task, an estimation of task duration, and the relationship among tasks. In addition, Section 3.2.2.1.4 of the "Xe-100 Staffing and Qualifications Implementation Plan" states that the TA will also input the KSAs required to meet personnel task performance requirements to the S&Q plan.

Based on the above, the NRC staff determined that the proposed methodology includes sufficient plans to ensure that applicable data would support the roles and responsibilities assigned to each impacted job in an exemption request, consistent with the guidance in NUREG-1791.

The KSA analysis is complete, and the KSAs are consistent with the qualifications required for each impacted job identified in the exemption request.

Section 5, "Developing the Control Room Staffing Analysis," of the TR states that a KSA analysis will be provided for the control room staffing analysis. Furthermore, Section 4.6, "Job Definitions," of the TR states that by following the SAT process for the training material development, matching between the KSAs list, job definition, and S&Q is ensured, as all of the activities are connected and take the same TA as input. Finally, Section 3.2.2.1, "Results from HFE Program Elements," of the "Xe-100 Staffing and Qualifications Implementation Plan" describes how applicable data from OE, FRA&FA, and TA will be used to determine the qualifications, roles, and responsibilities of personnel in the control room.

Based on the above, the NRC staff determined that the proposed methodology includes sufficient plans to ensure that the KSA analysis will be completed and that the KSAs will be

consistent with the qualifications required for each impacted job in an exemption request, consistent with the guidance in NUREG-1791.

Coherent job descriptions are maintained for licensed control room personnel (under the current requirements), or are defined for any new jobs included as a part of the exemption request.

The base case discussed in the TR submittal addresses the anticipated number of control room staff (i.e., four units operated by three operators in the control room); however, the submittal does not discuss any new jobs expected to be included in a potential control room staffing plan.

Section 4.6, "Job Definitions," of the TR states that the job definition will be addressed after the HFE TA by the SAT process. The TR further states that the S&Q activities will describe and define the scope and impacts on the roles, responsibilities, and qualifications of control room personnel.

By letter dated October 19, 2022, X-energy stated that the job definitions of the Xe-100 plant staff will be reviewed for role conflicts. Potential conflicts will be identified, evaluated, and corrected as necessary.

Section 3.2.2.2, "Additional information," of the "Xe-100 Staffing and Qualifications Implementation Plan" discusses the process by which any issues identified throughout the S&Q evaluation will be captured and addressed using the HFE issue tracking system, discussed in Section 7, "HFE Issue Tracking System," of the "Human Factors Engineering Program Management Plan."

Based on the above, the NRC staff determined that the proposed methodology includes provisions intended to adequately address any potential challenges to the coherency of job descriptions included as a part of an exemption request, consistent with the guidance in NUREG-1791.

The job definitions for control personnel who will work in crews are coordinated.

By letter dated October 19, 2022, X-energy stated that the job definitions of the Xe-100 plant staff will be reviewed for role conflicts. Potential conflicts will be identified, evaluated, and corrected as necessary.

Based on the above, the NRC staff determined that the proposed methodology includes sufficient plans to ensure that the job definitions for control personnel who will work in crews are coordinated, consistent with the guidance in NUREG-1791.

1.7.3 Conclusion

The NRC staff compared the described scope and potential sources of the job definitions to the expectations and criteria listed in Sections 7.2, "Applicant Submittals," and 7.3, "Review Criteria," of NUREG-1791, Part II. The NRC staff determined that the methodology discussed in the TR submittal is consistent with the information needs and review criteria outlined in NUREG-1791 for this review area. Therefore, the NRC staff determined the consideration of this review area within the TR submittal to be acceptable.

If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that

time, evaluate the submittal to confirm: (1) that the information listed in Section 7.2 of NUREG-1791, Part II, is included and (2) that the criteria listed in Section 7.3 of NUREG-1791, Part II, are met.

1.8 Staffing Plan

1.8.1 Applicant Submittal Considerations

Section 8.2, "Applicant Submittals," of NUREG-1791, Part II, lists information that the NRC staff reviewer should confirm is included in support of an exemption request submittal. The NRC staff reviewed the TR submittal to determine whether the proposed methodology addresses this information. The result of this assessment for each of the information items is provided below.

The set of operational conditions considered for the staffing plan, to the extent that they differ from those submitted for other elements of the exemption request.

Section 4.7, "Staffing Plan," of the TR states that the S&Q element of the HFE Program involves a theoretical assessment of the staffing plan under the operational conditions selected in terms of response time. Section 4.9, "Staffing Plan Validation," of the TR and the "Xe-100 Human Factors Verification and Validation Implementation Plan" provides extensive discussion of the operational conditions considerations.

The discussion within the TR submittal does not explicitly address the extent to which the set of operational conditions considered for the staffing plan will differ from those submitted for other elements of an associated exemption request. However, X-energy confirmed by letter dated October 19, 2022, that the full scope of the integrated system validation will be credited towards the completion of the SPV, suggesting that the operational conditions considered will not differ between elements of an exemption request.

The NRC staff considered this discussion and determined that, while differences were not addressed, this was acceptable, based on the comprehensive nature of the discussion of the TR submittal, as supplemented, of the set of operational conditions, and the fact that—as discussed in Section 3.2.1, "Sampling of Operational Conditions," of the "Xe-100 Human Factors Verification and Validation Implementation Plan"—these conditions include error-forcing contexts, including those essential to validation of a proposed staffing plan such as continuous monitoring with minimum staff in high-workload situations.

Based on the above, the NRC staff determined that the proposed methodology adequately addresses identifying the set of operational conditions considered for the staffing plan, despite the discussion thereof not explicitly addressing differences between the staffing plan and other elements of any future exemption requests. Therefore, the NRC staff determined that the proposed methodology is consistent with this information item in NUREG-1791.

The proposed staffing levels, shift composition, and shift schedules for the identified operational conditions.

Section 4.7, "Staffing Plan," of the TR states that the staffing plan will provide information about the operational staff shift composition and shift scheduling. Section 4.7 further states that the SPV will validate the staffing levels. Finally, Section 4.7 states that the S&Q element of the HFE Program involves a theoretical assessment of the staffing plan under the operational conditions selected in terms of response time.

Based on the above, the NRC staff determined that the proposed methodology includes identification and documentation of proposed staffing levels, shift composition, and shift schedules for the identified operational conditions, consistent with the guidance in NUREG-1791.

A description of how the staffing plan supports integrated staff roles across shifts and operational conditions.

Section 3.1.2, "HFE Program Related Data," of the "Xe-100 Staffing and Qualifications Implementation Plan" states that detailed TA results, along with challenging operational conditions, shall be considered as a key input to the staffing plan as it includes time needed to perform a task, the workload involved, and personnel communication and coordination with other control room crew members or even other location staff.

Based on the above, the NRC staff determined that the proposed methodology includes determination of how the staffing plan supports integrated staff roles across shifts and operational conditions, consistent with the guidance in NUREG-1791.

Identification of the types of control personnel who can be substituted within each job, given the concept of operations.

Section 4.6, "Job Definitions," of the TR states that the S&Q activities describe and define the scope and impacts on the roles, responsibilities, and qualifications of control room personnel. While the TR does not explicitly discuss substituting personnel within jobs, the NRC staff considered this discussion and determined that the control room personnel will have documented roles, responsibilities, and qualifications, and so the ability to substitute other types of control personnel will also be available if they meet those roles, responsibilities, and qualifications. Therefore, the NRC staff determined that the proposed methodology is consistent with this information item in NUREG-1791.

Expected travel times or response times for control personnel who need to move to new locations (e.g., home to the plant or office) or provide other support (e.g., to log in to system control computers from home), when applicable.

Section 4.7, "Staffing Plan," of the TR states that in the case of operations that take place outside the control room, the location and personnel will be specified. By letter dated August 24, 2022, X-energy stated that the completed staffing analysis will also provide information to confirm that if control room operators are required to perform any action outside of the control room, the travel and response times, locations, and personnel required to perform the action will be sufficient and not trigger adverse conditions for the safety of the Xe-100 plant.

Based on the above, the NRC staff determined that the proposed methodology includes the determination of expected travel times or response times for control personnel who need to move to new locations or provide other support, consistent with the guidance in NUREG-1791.

A description of how control personnel staffing relates to the larger plant staffing and the support roles that control personnel may play in the larger staffing context.

Section 3.1.2, "HFE Program Related Data," of the "Xe-100 Staffing and Qualifications Implementation Plan" states that detailed TA results shall be considered as a key input to the

staffing plan as it includes coordination with other control room crew members or even other location staff.

Based on the above, the NRC staff determined that the proposed methodology includes a description of how control personnel staffing relates to the larger plant staffing and the support roles that control personnel may play in the larger staffing context, consistent with the guidance in NUREG-1791.

Applicable supporting data from the concept of operations, the set of operational conditions considered, the functional requirements analysis and function allocation, task analysis, job definitions, and the operating experience review.

Section 4.7, “Staffing Plan,” of the TR states that the staffing plan is supported by the results of the preceding analyses.

Based on the above, the NRC staff determined that the proposed methodology describes that applicable supporting data will be available from the concept of operations, the set of operational conditions considered, the FRA&FA, TA, job definitions, and the OE review, consistent with the guidance in NUREG-1791.

1.8.2 Review Criteria Considerations

Section 8.3, “Review Criteria,” of NUREG-1791, Part II, lists criteria that the NRC staff reviewer should confirm are met, as applicable, by a completed control room staffing analysis. The NRC staff reviewed the TR submittal to determine whether the proposed methodology adequately addresses these criteria. The result of this assessment for each of the criteria is provided below.

The set of operational conditions identified as applicable to the staffing plan is complete and representative of the exemption request.

Section 4.7, “Staffing Plan,” of the TR submittal states that the S&Q element of the HFE Program involves an assessment of the staffing plan under the operational conditions selected in terms of response time.

Based on the above, the NRC staff determined that the proposed methodology includes sufficient plans intended to ensure that the set of operational conditions identified as applicable to the staffing plan will be complete and representative of an exemption request, consistent with the guidance in NUREG-1791.

The staffing plan will provide an adequate number of qualified personnel to operate the plant safely under the operational conditions considered.

Section 4.7, “Staffing Plan,” of the TR states that the staffing plan provides information about the operational staff shift composition and shift scheduling. Section 4.7 further states that the SPV will validate the staffing levels. Finally, Section 4.7 states that the S&Q element of the HFE Program involves a theoretical assessment of the staffing plan under the operational conditions selected in terms of response time.

Based on the above, the NRC staff determined that the proposed methodology includes sufficient plans intended to ensure that the staffing plan will provide an adequate number of

qualified personnel to operate the plant safely under the operational conditions considered, consistent with the guidance in NUREG-1791.

Roles and responsibilities are integrated across shifts and among personnel.

Section 4.6, “Job Definitions,” of the TR states that the S&Q activities describe and define the scope and impacts on the roles, responsibilities, and qualifications of control room personnel. Section 3.1.2, “HFE Program Related Data,” of the “Xe-100 Staffing and Qualifications Implementation Plan” states that detailed TA results, along with challenging operational conditions, shall be considered as a key input to the staffing plan as it includes time needed to perform a task, the workload involved, and personnel communication and coordination with other control room crew members or even other location staff.

Based on the above, the NRC staff determined that the proposed methodology includes sufficient plans intended to ensure that roles and responsibilities are integrated across shifts and among personnel, consistent with the guidance in NUREG-1791.

Travel and response times are adequate and do not trigger adverse conditions for the safety of the plant.

Section 4.7, “Staffing Plan,” of the TR states that in the case of operations that take place outside the control room, the location and personnel will be specified. By letter dated August 24, 2022, X-energy stated that the completed staffing analysis will also provide information to confirm that if control room operators are required to perform any action outside of the control room, the travel and response times, locations, and personnel required to perform the action will be sufficient and not trigger adverse conditions for the safety of the Xe-100 plant.

Based on the above, the NRC staff determined that the proposed methodology includes sufficient plans intended to ensure that travel and response times are adequate and do not trigger adverse conditions for the safety of the plant, consistent with the guidance in NUREG-1791.

The staffing plan uses data from previous sections in a logical/rational manner.

Section 4.7, “Staffing Plan,” of the TR states that the staffing plan is supported by the results of the preceding analyses. In addition, the TR submittal describes how the staffing plan will be integrated with the human factors program that is developed in accordance with NUREG-0711.

Based on the above, the NRC staff determined that the proposed methodology includes sufficient plans intended to ensure that the staffing plan uses data from previous sections in a logical/rational manner, consistent with the guidance in NUREG-1791.

1.8.3 Conclusion

The NRC staff compared the proposed methodology for conducting an SPV for the Xe-100 facility to the expectations and criteria listed in Sections 8.2, “Applicant Submittals,” and 8.3, “Review Criteria,” of NUREG-1791, Part II. The NRC staff determined that the methodology discussed in the TR submittal is consistent with the information needs and review criteria outlined in NUREG-1791 for this review area. Therefore, the NRC staff determined the consideration of this review area within the TR submittal to be acceptable.

If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that time, evaluate the submittal to confirm: (1) that the information listed in Section 8.2 of NUREG-1791, Part II, is included and (2) that the criteria listed in Section 8.3 of NUREG-1791, Part II, are met.

1.9 Additional Data and Analyses

Section 9, "Review of Additional Data and Analyses," of NUREG-1791, Part II, lists additional data and analyses that the applicant may provide as part of an exemption request if the materials are applicable to the requested exemption. The NRC staff reviewed the TR submittal to determine whether additional data and analyses may be needed to support a potential exemption request associated with a control room staffing analysis completed using the proposed methodology. Considerations regarding each of the categories of potential additional data and analyses are provided below.

Human reliability analysis used to demonstrate the impacts of risk-important human actions.

Section 4.8, "Additional Data and Analyses," of the TR states that HRAs used to demonstrate how risk-important human actions affect staffing levels may be provided. In addition, Section 3.2.3, "Treatment in the HFE Program," of the "Xe-100 Treatment of Important Human Actions Implementation Plan" states that the inclusion of IHAs into the HFE program elements will ensure that the final Human-System Interface (HSI) design supports these important human actions.

Section 3.2.1, "Sampling of Operational Conditions," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" states that risk important human actions (extracted from the TIHA element execution) shall be included in the sampled operational conditions.

Section 3.2.2, "S&Q Levels Evaluation and Refining," of the "Xe-100 Staffing and Qualifications Implementation Plan" states that the impact of alternative changes to the baseline staffing levels and qualification requirements will be evaluated, and adjustments will be made, where appropriate, to the HRA assumptions and quantification.

Based on the above, the NRC staff determined that an HRA is expected to be applicable to a staffing plan completed using the proposed methodology. If such a submittal were provided for NRC review, the NRC staff would, at that time, assess any associated HRA as applicable.

Human-system integration data used to demonstrate that the design of the HSIs supports the concept of operations, functional requirements analysis and function allocation, task analysis, staffing plan, and operating experience.

Section 4.8, "Additional Data and Analyses," of the TR states that data from the HSI development and verification may be provided to demonstrate that the design supports the previous HFE analysis.

In addition, Section 1.1, "Purpose," of the "Xe-100 Staffing and Qualifications Implementation Plan" states that staffing and qualifications development activities include re-examination of the initial baseline staffing assumptions during the HSI design activities.

Section 3.1, “Inputs,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” states that the HSI design (for all of the interfaces, either software or hardware based) will be an input to the V&V.

Based on the above, the NRC staff determined that HSI data is expected to be applicable to a staffing plan completed using the proposed methodology. If such a submittal were provided for the NRC staff’s review, the NRC staff would, at that time, assess any associated HSI data as applicable.

KSA analysis used in support of new or changing job definitions.

Section 4.8, “Additional Data and Analyses,” of the TR states that the KSA analysis and list of KSAs to support TA and job definitions may be provided in support of a submitted exemption request.

In addition, Section 3.2.2.2, “Additional Information,” of the “Xe-100 Staffing and Qualifications Implementation Plan” states that as new information is available in the training program regarding KSAs associated with each job position, a new iteration of the S&Q evaluation shall be performed.

Based on the above, the NRC staff determined that a KSA analysis in support of new or changing job definitions may be applicable to a staffing plan completed using the proposed methodology. If such a submittal were provided for the NRC staff’s review, the NRC staff would, at that time, assess any KSA analysis as applicable.

KSA analysis is used to support modified tasks or human-system interfaces.

Section 3.3, “Outputs,” of the “Xe-100 Task Analysis Implementation Plan” indicates that the completed TA will include, among other information, designation of the KSA needed by operators to perform individual tasks.

Section 3.2.2, “S&Q Levels Evaluation and Refining,” of the “Xe-100 Staffing and Qualifications Implementation Plan” states that consideration was given to the minimum qualifications of plant personnel in terms of education and training, skill, knowledge, experience, and fitness for duty, including verifying that information is easily available through the HSIs under various postulated accident conditions and potential plant situations and verifying that feedback from corrective actions is available.
Based on the above, the NRC staff determined that a KSA analysis used to support modified tasks or HSIs may be applicable to a staffing plan completed using the proposed methodology. If such a submittal were provided for the NRC staff’s review, the NRC staff would, at that time, assess any KSA analysis as applicable.

Procedures and training documentation used to demonstrate the implementation of components of the concept of operations, functional requirements analysis and function allocation, or task analysis.

Section 4.8, “Additional Data and Analyses,” of the TR states that procedures and training program documentation demonstrating the implementation of concepts from the HFE program that support the staffing exemption may be included in an exemption request.

Based on the above, the NRC staff determined that procedures and training documentation is expected to be applicable to a staffing plan completed using the proposed methodology. If such a submittal were provided for the NRC staff's review, the NRC staff would, at that time, evaluate procedures and training documentation as applicable.

Additional submittals that would be expected, based on the character of the exemption request.

The NRC staff reviewed the discussion of the proposed staffing analysis methodology and considered the expected exemption request submittals discussed.

As discussed in Section 1.1 of this SE, the NRC staff considered the possible manner in which the Xe-100 staffing plan may handle the STA role. Section 1.1, "Purpose," of the "Xe-100 Task Analysis Implementation Plan" states, in part, the following:

> In addition to the tasks performed by the control room staff, scenarios that involve the skill set from the Shift Technical Advisor (STA) will also be reviewed if applicable. The current interpretation of the STA policy is that operating crews need to include one person with a degree in either a physical science, engineering, or engineering technology. The goal is to evaluate the ability of the planned staffing level and include tasks that may be allocated to the STA.

As discussed in Section 1.1 of this SE, the NRC staff notes that if a licensee or applicant were to pursue a staffing plan that did not include an individual fulfilling the STA role, then an exemption from the training requirements of 10 CFR 50.120(b)(2)(ii) may be necessary. Alternatively, if a licensee or applicant were to pursue a staffing plan wherein the STA role was maintained but was filled by one of the dedicated control room staff members (i.e., if the STA role was not served by an individual separate from the proposed three-person control room contingent), such a circumstance would not require an exemption from the NRC's regulations. However, such a circumstance could deviate from established NRC policy and could warrant additional NRC consideration in its review of the proposed staffing plan.

In the "Policy Statement on Engineering Expertise on Shift" (50 FR 43621; October 28, 1985), the Commission communicated continued support for ensuring that adequate engineering and accident assessment expertise is possessed by the operating staff at nuclear power plants, and for this expertise to be provided by a designated STA. The Commission also communicated the expectation that the STA role be fulfilled by a dedicated individual, preferably serving a dual role as STA and SRO. This policy, however, was established within the context of the existing 10 CFR 50.54(m) requirements, wherein there would be more than one SRO assigned to a facility, thereby allowing the STA role to be fulfilled by an SRO who is not also serving in a dedicated control room operator capacity.

If the only designated SRO on shift were serving as part of the dedicated contingent of control room operators and was also designated as fulfilling the STA role, this would constitute a deviation from the Commission's policy regarding fulfillment of the STA role, and such a deviation would be subject to the NRC staff's review. If a completed staffing analysis reflecting such a proposed approach to the STA role were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would evaluate the submittal to confirm that the proposed approach was appropriate (i.e., that there was reasonable assurance that the plant could still be safely operated with a dedicated control room operator also serving in the role as designated STA).

1.10 Staffing Plan Validation

1.10.1 Operational Conditions Sampling

1.10.1.1 Applicant Submittal Considerations

Section 10.2.1, "Operational Conditions Sampling," of NUREG-1791, Part II, lists information that the NRC staff reviewer should confirm is included in support of an exemption request submittal. The NRC staff reviewed the TR submittal to determine whether the proposed methodology addresses this information.
The result of this assessment for each of the information items is provided below.

A description of each of the scenarios used in validating the staffing plan.

By letter dated October 19, 2022, X-energy stated that a staffing analysis conducted using the proposed methodology "will use the full scope of the integrated system validation (ISV) towards the completion of the staffing plan validation (SPV)."

Section 3.2.1, "Sampling of Operational Conditions," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses the range of operational conditions to be sampled throughout validation testing, which include the following:

- normal operations such as normal events, plant mode changes, multi-unit monitoring and control, load-following operations, and novel refueling methods;
- instrumentation and control system and HSI failures;
- degraded conditions (e.g., of one unit while the others are operating normally);
- off-normal conditions and emergencies including unplanned shutdowns, handling of off-normal conditions at multiple sites, monitoring passive safety systems, and loss of control room habitability;
- transients such as reactor trip, turbine trip, loss of offsite power, stuck-open primary relief valve, and loss of coolant accident; and
- maintenance, including HSI maintenance activities in the control room.

Section 3.2.1, "Sampling of Operational Conditions," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" also discusses personnel tasks to be included in the sampling of operational conditions, which include the following:

- risk important human actions;
- manual initiation of protective actions;
- monitoring automated systems; and
- procedure-guided tasks and knowledge-based tasks.

The NRC staff determined that specific details regarding the scenarios to be tested would need to be provided within a completed staffing analysis, and that those details would be subject to further NRC evaluation at that time. As discussed below in Section 1.10.1.2 of this SE, if a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would review the submittal to ensure that the set of scenarios selected for validating the proposed staffing plan address a range of sufficiently challenging circumstances and conditions to truly demonstrate that the facility can be safely operated—under all design-basis conditions—with the proposed staffing plan in place.

While, as noted above, additional details would be needed in any future submittal, the NRC staff determined that the overall framework and scoping for the scenarios discussed within the TR submittal is appropriate and that the proposed methodology discussed in the submittal includes developing descriptions of each of the scenarios used in validating the staffing plan, consistent with the guidance in NUREG-1791.

A description of how the scenarios incorporate the operational conditions relevant to the exemption request.

Section 3.2.1, “Sampling of Operational Conditions,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” states that HFE tests and evaluations will follow a sampling strategy to ensure that tests conducted include conditions representative of the range of events that could be encountered during the operation of the Xe-100 plant.

Section 3.2.3.1.2, “Test Objectives,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” lists, among the V&V test objectives, the following:

- Validate that specific personnel tasks can be accomplished within the time and performance criteria, with effective situational awareness, and acceptable workload levels that balance vigilance and personnel burden.

Additionally, Section 4.9, “Staffing Plan Validation,” of the TR lists the following test objectives, specific to the SPV:

- Validate the acceptability of the shift staffing level(s), the assignment of tasks to crew members, and crew coordination within the control room, between the control room and local control stations and support centers, and with individuals performing tasks locally.

- Validate that specific personnel tasks can be accomplished within the time and performance criteria, with effective situational awareness and acceptable workload levels that balance vigilance and personnel burden.

Section 3.2.3.1.5, “Selected scenarios,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” states that the ISV will detail the goals for each scenario tested, as well as the tasks involved and expected operator actions.

Section 4, “Documentation,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” states the following regarding the documentation of the sampling of operational conditions:

> Sampling of Operational Conditions … do not have specific reports. The results of the Sampling of Operational Conditions are inputs to provide context to the remainder of the V&V activities, supporting them by the selection of HSIs for verification and scenarios for validations. Therefore, each of the corresponding reports of the V&V activities will include the HSI subject to be analyzed and the basis.

The NRC staff considered the information provided regarding the goals of the sampling to be used, along with the commitment to document, within the ISV report, information regarding the bases of the scenarios to be tested. Based on these considerations, the NRC staff determined that the proposed methodology includes development and documentation of a description of how the scenarios incorporate relevant operational conditions, consistent with the guidance in NUREG-1791.

A description of system and key plant parameters relevant to the scenarios.

Section 4.9, "Staffing Plan Validation," of the TR lists, among the validation criteria to be considered, confirmation that plant parameters are kept inside normal operational range during testing.

Section 3.2.1, "Sampling of Operational Conditions," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses the sampling for V&V activities as reflecting the characteristics expected to contribute to variations in the system's performance. Section 3.2.3.1.5, "Selected scenarios," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" states that based on the sampling of operational conditions, the ISV shall detail—among other aspects of a scenario—relevant data/parameter information.

Furthermore, Section 3.1, Inputs," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses the incorporation of inputs from other HFE review areas into the development of the V&V activities. This would include relevant plant parameters, as they pertain to the functional requirements identified throughout FRA activities and the performance criteria established by the TA.

Based on the above, the NRC staff determined that the proposed methodology includes the development and documentation of a description of system and key plant parameters relevant to the scenarios selected for validation testing, consistent with the guidance in NUREG-1791.

Relevant criteria for evaluating successful performance.

Section 4.9, "Staffing Plan Validation," of the TR states that data collected during validation testing will be analyzed and processed by considering a set of performance measurements that are established prior to the validation. Examples of measurements to be considered include time to complete actions, timeliness of actions, accuracy and completeness of actions, and omission of actions.

Section 4.9 further states that applicable criteria will be identified in advance to determine the acceptability of the validation results. Examples of criteria to be provided include keeping plant parameters within normal operation range, finishing scenarios with the plant in a stable condition, not exceeding performance times by more than an acceptable amount, timely transition from one action to another, and not omitting necessary actions.

Based on the above, the NRC staff determined that the proposed methodology includes the identification of relevant criteria for evaluating successful performance during validation testing, consistent with the guidance in NUREG-1791.

Scenarios that challenge personnel, plant, and system performance.

Section 3.2.1, "Sampling of Operational Conditions," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses the error-forcing contexts to be incorporated into validation testing. This discussion states that, to evaluate how HSIs support the operators under challenges of performance, situations captured within the array of validation testing scenarios will include high workload (e.g., multi-unit operations and teamwork), varying workload (e.g., from normal operation to specific situations of higher workload during refueling monitoring), and fatigue (e.g., continuous monitoring with minimum staff).

Based on the above, the NRC staff determined that the proposed methodology includes the development of scenarios intended to challenge personnel, plant, and system performance, consistent with the guidance in NUREG-1791.

1.10.1.2 Review Criteria Considerations

Section 10.3.1, "Operational Conditions Sampling," of NUREG-1791, Part II, lists criteria that the NRC staff reviewer should confirm are met, as applicable, by a completed control room staffing analysis. The NRC staff reviewed the TR submittal to determine whether the proposed methodology adequately addresses these criteria. The result of this assessment for each of the criteria is provided below.

The scenarios fully incorporated the operational conditions relevant to the exemption request.

Section 3.2.1, "Sampling of Operational Conditions," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" states that the sampling strategy used for selecting tests and evaluations to be performed during validation should ensure that the selections include conditions representative of the range of events that could be encountered during the operation of the Xe-100 plant. Section 4.9, "Staffing Plan Validation," of the TR states, regarding the SPV, that "The assessment should demonstrate that the proposed Xe-100 plant shift crew, three operators in one control room operating multiple reactor units, can satisfy the plant and human performance requirements…." Furthermore, Section 4.9 of the TR and Section 3.2.1 of the "Xe-100 Human Factors Verification and Validation Implementation Plan" provide details regarding the operational conditions that should be considered, including error-forcing contexts such as high-workload simulations, varying workload situations, and fatigue situations.

Based on the above, the NRC staff determined that the proposed methodology addresses the incorporation of operational conditions relevant to an associated exemption request, consistent with the guidance in NUREG-1791.

If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would review the submittal to ensure that the set of operational conditions selected include those necessary to demonstrate that the facility can be safely operated with the proposed staffing plan in place.

Relevant criteria were used to evaluate successful performance.

Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" states that the measures chosen to evaluate personnel task performance will reflect those aspects of the task that are important to system performance. Additionally, it includes the following discussion:

> The basis for the performance criteria can be a combination of factors related to the corresponding measure that identifies the acceptability of performance. Therefore, the following shall be considered:
>
> - Rating established in the different metrics used (e.g., for workload, situation awareness and teamwork with the minimum, maximum and intermediate scores)
>
> - Requirements, if applicable (e.g., required time to complete a task according to engineering analyses)
>
> - Expert judgement (e.g., recommendations based on V&V team experience and operation personnel knowledge)
>
> - Norms, if applicable (e.g., specific performance required according to a predecessor system).

Based on the above, the NRC staff determined that the proposed methodology includes the use of criteria intended to be relevant to the evaluation of successful performance, consistent with the guidance in NUREG-1791.

Scenarios relevant to the exemption request were used.

Section 4.9, "Staffing Plan Validation," of the TR states, regarding the SPV, the following:

> The assessment should demonstrate that the proposed Xe-100 plant shift crew, three operators in one control room operating multiple reactor units, can satisfy the plant and human performance requirements identified in the [FRA, FA, and TA]. This assessment should include the range of operational conditions identified as relevant.

Section 3.2.1, "Sampling of Operational Conditions," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" provides details regarding the operational conditions that should be considered, including plant conditions associated with normal conditions, instrumentation and control system failures, off-normal conditions, emergencies, and transients. Furthermore, Section 4.9, "Staffing Plan Validation," of the TR states, regarding the SPV, that "The assessment should demonstrate that the proposed Xe-100 plant shift crew, three operators in one control room operating multiple reactor units, can satisfy the plant and human performance requirements."

Section 3.2.3.1.5, "Selected scenarios," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" states, in part, the following:

> The scenarios selected for the V&V may be adjusted for the fidelity of the test bed being used. The test bed may not have the functionality and fidelity to allow for the performance of all the scenarios. The specific ISV procedure will identify the characteristics of the test bed and what scenarios will be performed.

However, by letter dated October 19, 2022, X-energy provided the following clarification:

> X-energy will use the Xe-100 full scope simulator for all the final HFE validations, including the integrated system validation (ISV) which includes the final [SPV]…. During the ISV and SPV, complex operational evolutions and off-normal activities such as multi-unit startup and shutdown, and the identified licensing basis events, which include the Xe-100 postulated accident and emergency conditions, will be available realistically simulated.

Based on the above, the NRC staff determined that the proposed methodology includes the incorporation of scenarios intended to be relevant to an exemption request, consistent with the guidance in NUREG-1791.

Scenarios that challenge the personnel, plant, and system were used.

Section 4.9, “Staffing Plan Validation,” of the TR and Section 3.2.1, “Sampling of Operational Conditions,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” provide details regarding the operational conditions that should be considered, including error-forcing contexts such as high-workload situations, varying workload situations, and fatigue situations.

Based on the above, the NRC staff determined that the proposed methodology includes the selection of scenarios intended to challenge the personnel, plant, and system, consistent with the guidance in NUREG-1791.

The NRC staff notes that while X-energy has communicated that the full scope of ISV testing will be credited towards conduct of SPV activities, the specific scenarios relied upon for SPV should focus particularly on challenging circumstances that test the limits of the capabilities of the proposed minimum staffing complement, to ensure that the proposed staffing plan is appropriate. If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would review the submittal to ensure that the set of scenarios selected for validating the proposed staffing plan address a range of sufficiently challenging circumstances and conditions to truly demonstrate that the facility can be safely operated—under all design-basis conditions—with the proposed staffing plan in place.

1.10.2 Human Performance Measures and Criteria

1.10.2.1 Applicant Submittal Considerations

Section 10.2.2, “Human Performance Measures and Criteria,” of NUREG-1791, Part II, lists information that the NRC staff reviewer should confirm is included in support of an exemption request submittal. The NRC staff reviewed the TR submittal to determine whether the proposed methodology addresses this information. The result of this assessment for each of the information items is provided below.

A listing of the human performance measures and criteria identified for the validation and a discussion of the rationale for their inclusion, as well as for the exclusion of other reasonable measures for the individual and the crew.

Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" states that the measures chosen to evaluate personnel task performance will reflect those aspects of the task that are important to system performance. These measures will include objective measures (such as time, accuracy, frequency, and amount accomplished) as well as subjective measures (such as reports of the participants and observations from observers). Section 3.2.3.1.6 also discusses considerations associated with workload, situation awareness, and teamwork.

Based on the above, the NRC staff determined that the proposed methodology includes adequate consideration of human performance measures and criteria for the validation and the rationale for their inclusion, consistent with the guidance in NUREG-1791. Furthermore, despite the fact that the exclusion of measures was not explicitly discussed, the NRC staff determined that the discussion provided is comprehensive enough to warrant not discussing exclusions.

Descriptions of relationships for those measures and criteria specific to the data sources or methods used or whose definitions vary across the methods.

Section 4.9, "Staffing Plan Validation," of the TR and Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discuss the human performance measurements to be used. Section 3.2.3.1.6 of the "Xe-100 Human Factors Verification and Validation Implementation Plan" also explains, in detail, the specific methods for measuring constructs including workload, situation awareness, and teamwork.

Based on the above, the NRC staff determined that the proposed methodology includes adequate descriptions of the relationships between the measures and criteria specific to the data sources or methods used, consistent with the guidance in NUREG-1791.

Identification, description, and definition of any measures and criteria specific to methods or constructs (e.g., cognitive workload or situation awareness measurement).

Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses the measures and criteria to be considered in the staffing analyses. This discussion addresses the consideration of such measures as workload, teamwork, situation awareness, and anthropometric and physiological measures. Specifically, the "Xe-100 Human Factors Verification and Validation Implementation Plan" includes discussion of the use of the NASA-TLX metric to assess workload and the Situation Awareness Rating Technique (SART) metric to assess situational awareness.

Based on the above, the NRC staff determined that the proposed methodology, including the comprehensive nature of its discussion and its reliance on state-of-the-art measures, includes adequate identification, description, and definition of measures and criteria specific to methods or constructs, consistent with the guidance in NUREG-1791.

Descriptions of environmental or external influences that could impact human performance and how they are integrated into the assessment.

Section 3.2.3.1.3, "Validation Testbed," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses the consideration of environmental fidelity when assessing the fidelity of the test bed to be used for validation testing. Section 3.2.3.1.5 states that ISV procedures will identify test bed characteristics.

Additionally, section 3.2.2, "Developing Narrative Task Descriptions," of the "Xe-100 Task Analysis Implementation Plan" discusses the consideration of interactions with personnel outside of the control room, stating that tasks will be evaluated to ensure that successful task performance can be achieved when considering such communications.

Section 3.2.1, "Evaluation of Aspects not Addressed in V&V," of the "Xe-100 Design Implementation Plan," acknowledges the following:

> Some aspects of the standard design may not have been addressed in the V&V activities of the HFE Program, due to the impossibility of accurately simulating them with the available tools. Examples of these kinds of aspects are environmental conditions, such as lighting and noise, and control means outside the main control room but within the HFE Program scope, such as the reserve shutdown station or other safety-related local control stations….
>
> The purpose of the DI at this stage is to evaluate all those aspects not addressed in the V&V activities, and to explain how they were covered in implementing the design. The methods and methodology described in the V&V [Implementation Plan] can be appropriately adapted and used for this stage of the DI.
>
> The objective is accomplished when all [human engineering discrepancies (HEDs)] that may arise in the evaluation process are addressed and resolved.

The NRC staff considered the discussion of environmental or external influences that could impact human performance. While there may be environmental and external factors that cannot be fully captured within an SPV performed using the proposed methodology, the NRC staff determined the scope of the considerations that will be incorporated into the analyses to be acceptable. Based on the discussion within the TR submittal, reasonable descriptions are expected to be incorporated into the TA and identification of validation test bed characteristics.

While certain outstanding considerations may need to be addressed in later stages—after the completion of the SPV—any identified issues can be reasonably expected to be resolved though the applicant's HED resolution program (i.e., the HFE issue tracking system, discussed in Section 7.1, "Availability," of the "Human Factors Engineering Program Management Plan"). This approach is aligned with the overall iterative nature of the proposed HFE design program.

Based on the above, the NRC staff determined that the proposed methodology includes the identification of environmental or external influences that could impact human performance and how they are to be integrated into the assessment, consistent with the guidance in NUREG-1791.

Time and information processing standards and how they are incorporated into the assessment.

As discussed in Section 10.1.2, “Human Performance Measures and Criteria,” of NUREG-1791, Part II, the impact of time and information processing demands can be assessed using measures of cognitive workload and situation awareness. Section 3.2.3.1.6, “Performance Measurement,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” discusses the use of the NASA-TLX metric to assess workload and the SART metric to assess situational awareness.

Based on the above, the NRC staff determined that the proposed methodology, including the comprehensive nature of its discussion and its reliance on state-of-the-art measures, includes adequate description of how time and information processing standards will be incorporated into assessments performed using the proposed methodology, consistent with the guidance in NUREG-1791.

The type of data source.

Section 3.2.3.1.6, “Performance Measurement,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” discusses the use of objective and subjective measures to measure the performance of operators during SPV testing. These measures will be collected by the validation team during scenario execution of test scenario. Additionally, Section 3.2.3.1.7, “ISV Design,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” includes a discussion of the use of an ISV procedure to control the execution of testing, as well as a discussion of the use of checklists, questionnaires, data collection tables, and audio and visual recording for collecting and documenting performance data.

Based on the above, the NRC staff determined that the proposed methodology, including the comprehensive nature of its data sources discussed and its reliance on controlled processes for the collection of the data, includes adequate description of the type of data source that will be used during analyses performed using the proposed methodology, consistent with the guidance in NUREG-1791.

1.10.2.2 Review Criteria Considerations

Section 10.3.2, “Human Performance Measures and Criteria,” of NUREG-1791, Part II, lists criteria that the NRC staff reviewer should confirm are met, as applicable, by a completed control room staffing analysis. The NRC staff reviewed the TR submittal to determine whether the proposed methodology adequately addresses these criteria. The result of this assessment for each of the criteria is provided below.

The human performance measures and criteria are relevant to the plant/system concept of operations.

Section 3.1, “Inputs,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” states that the plant concept of operations will serve as an input in planning validation activities. Section 3.2.3.1.6, “Performance Measurement,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” discusses the basis for the performance criteria as involving a combination of factors related to the corresponding measure that identifies the acceptability of performance.

Based on the above, the NRC staff determined that the proposed methodology addresses the use of human performance measures and criteria intended to be relevant to the plant/system concept of operations, consistent with the guidance in NUREG-1791.

At a minimum, the selected human performance measures represent the most important outcome behaviors.

Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" states that the measures chosen to evaluate personnel task performance will reflect those aspects of the task that are important to system performance. Furthermore, Section 3.2.3.1.6 states that:

> The basis for the performance criteria can be a combination of factors related to the corresponding measure that identifies the acceptability of performance. Therefore, the following shall be considered:
>
> - Rating established in the different metrics used (e.g., for workload, situation awareness and teamwork with the minimum, maximum and intermediate scores)
>
> - Requirements, if applicable (e.g., required time to complete a task according to engineering analyses)
>
> - Expert judgement (e.g., recommendations based on V&V team experience and operation personnel knowledge)
>
> - Norms, if applicable (e.g., specific performance required according to a predecessor system)

Based on the above, the NRC staff determined that the proposed methodology includes the selection of human performance measures that are intended to represent the most important outcome behaviors, consistent with the guidance in NUREG-1791.

The rationale for excluding some potential human performance measures is reasonable. The NRC staff reviewed those measures discussed within Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" and found that the set of measures discussed was comprehensive. Additionally, the TR submittal did not identify any human performance measures that were excluded; therefore, the NRC staff determined that this criterion is not applicable.

The selected measures assess both individual and crew performance, where appropriate.

Section 3.2.1, "Sampling of Operational Conditions," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses the consideration of error-forcing contexts within the sampling of operational conditions to evaluate how the system will support the operators under challenging conditions, including high-workload situations involving multi-unit operations and teamwork.

Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" provides extensive discussion of the measurement to be used

to assess teamwork, including the use of the Behaviorally Anchored Rating Scale (BARS) metric. This discussion further states that results will be captured for several behavioral categories, including:

- communication;
- openness;
- coordination; and
- task focus and decision making.

Based on the above, the NRC staff determined that the proposed methodology includes the assessment of both individual and crew performance, consistent with the guidance in NUREG-1791.

Measures specific to data collection methods or constructs have been used appropriately.

Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" provides extensive discussion of measures and data collection methods, including measures specific to data collection methods such as those used for assessing workload, situational awareness, and teamwork.

Based on the above, the NRC staff determined that the proposed methodology includes the appropriate use of measures specific to data collection methods or constructs, consistent with the guidance in NUREG-1791.

The criteria defined for acceptable human performance on each measure are reasonable.

The TR submittal provides that the criteria for acceptable human performance would be established based on actions completed as part of various elements of the Xe-100 HFE program, such as the TA.

Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" states, in part, the following:

> The basis for the performance criteria can be a combination of factors related to the corresponding measure that identifies the acceptability of performance. Therefore, the following shall be considered:
>
> - Rating established in the different metrics used (e.g., for workload, situation awareness and teamwork with the minimum, maximum and intermediate scores)
> - Requirements, if applicable (e.g., required time to complete a task according to engineering analyses)
> - Expert judgement (e.g., recommendations based on V&V team experience and operation personnel knowledge)

- Norms, if applicable (e.g., specific performance required according to a predecessor system)

Based on the above, along with the consideration of the adequacy of the methodology proposed for the various elements of HFE program (as discussed throughout this SE), the NRC staff determined that the proposed methodology relies on criteria that are intended to be reasonable for assessing the acceptability of performance on each measure, consistent with the guidance in NUREG-1791.

Any identified environmental conditions, external conditions, or staffing practices that could potentially degrade individual or crew performance, are effectively addressed by the staffing plans.

Section 3.2.4, "Human Engineering Discrepancies Management," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses the management of HEDs using the HFE issue tracking system, discussed in Section 7, "HFE Issue Tracking System," of the "Human Factors Engineering Program Management Plan." This discussion outlines an iterative process through which issues will be identified and addressed throughout and across the HFE program element activities. Through this process, issues would be resolved where feasible through changes to HSIs or through necessary changes to any supporting documentation or justification would be provided in instances where it is determined that issues can be left unresolved.

The NRC staff determined that, based on the above and the process established for addressing identified issues, the proposed methodology includes addressing any identified environmental conditions, external conditions, or staffing practices that could potentially degrade individual or crew performance, and any necessary staffing plan reconsiderations would be incorporated into the resolution of identified issues, consistent with the guidance in NUREG-1791.

Valid methods and criteria have been identified.

The overall methods for conducting the SPV are discussed throughout the "Xe-100 Human Factors Verification and Validation Implementation Plan". By letter dated October 19, 2022, X-energy stated, in part, the following:

> X-energy will use the full scope of the integrated system validation (ISV) towards the completion of the [SPV]. The [V&V] Implementation Plan describes how X-energy will use performance-based tests on the integrated system (hardware, software, procedures, and personnel elements) to verify that safe operation of the plant is supported for the proposed staffing plan.

The NRC staff determined that the proposed methodology is valid for the purposes of conducting SPV activities for the Xe-100 facility, consistent with the guidance in NUREG-1791. Furthermore, as discussed previously in this SE, criteria for acceptable performance will be established throughout the completion of activities under the various HFE program elements, in a manner consistent with the guidance in NUREG-1791.

Additional NRC considerations regarding the differentiation between ISV activities and SPV is discussed in Section 1.10.1.2 of this SE.

The data analyses were performed using appropriate parameters and methods.

Section 3.2.3.1.8, "Data Analysis and HED Identification," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses the analysis of data obtained during validation testing, including a consideration of the following:

- quantitative and qualitative measures of the relationship between the observed performance and the established performance criteria;
- the degree of convergence/consistency between related measures;
- margins of error to account for variance expected in actual performance versus validation-test performance; and
- independent verification of analyses.

Based on the above, the NRC staff determined that the proposed methodology includes performing data analyses using appropriate parameters and methods, consistent with the guidance in NUREG-1791. If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would review the submittal to ensure that additional specific details provided regarding the parameters and methods used throughout the conduct of V&V activities are also appropriate.

Furthermore, if the "Xe-100 Human Factors Verification and Validation Implementation Plan" (or a future revision) were to be submitted for a full-scope HFE program review (e.g., as a separate TR or as part of an application for licensing or design certification), the NRC staff would review that submittal against the criteria in NUREG-0711, which would be expected to warrant more detailed discussion of the parameters and methods used.

The assumptions and estimates used in conducting the analyses are documented and appropriate.

By letter dated October 19, 2022, X-energy stated the following assumptions regarding the fidelity of the simulator that will be used as the validation test bed for SPV:

> When the full scope simulator is completed, the simulation of complex operational evolutions will be available, and the software will be updated to reflect this. During the ISV and SPV, complex operational evolutions and off-normal activities such as multi-unit startup and shutdown, and the identified licensing basis events, which include the Xe-100 postulated accident and emergency conditions, will be available realistically simulated.

Furthermore, Section 3.2.3.1.3, "Validation Testbed," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" communicates an assumption that the full scope simulator, "assures that the integrated system clearly represents with a high functional and physical fidelity to the Xe-100 plant design." This discussion further assumes that the simulator will include the following:

- interface physical fidelity;

- interface functional fidelity;
- environmental fidelity;
- data completeness fidelity;
- data content fidelity; and
- data dynamics fidelity.

Additionally, the executive summary of the TR discusses the base case of three operators as the control room staffing complement for operating four reactor units. Furthermore, Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" states, regarding the expected workload associated with a three-person control room staffing complement, the following:

> In the Xe-100 plant main control room, it is planned that one or two reactor operators will be monitoring and controlling four units.

The NRC staff considered this assumption and determined it to be appropriate, given that there would be certain periods (e.g., when one of the three operators takes a brief break) wherein the control room may be temporarily covered by only one operator at the controls, in addition to an SRO in an oversight role.

Additionally, the NRC staff considered the fact that, as addressed in Section 3.1, "Inputs," of the "Xe-100 Human Factors Verification and Validation Implementation Plan", input regarding the qualifications of the operators derived from the concept of operations and completed job definition activities (discussed in Sections 1.2 and 1.8 of this SE, respectively) would be included as assumptions on the development and conduct of V&V activities. The NRC staff considered this assumption and determined it to be appropriate, particularly given the fact that the SPV would provide an opportunity to verify that the established qualification level going into validation testing was indeed appropriate.

The NRC staff considered the discussion of assumptions captured within the TR submittal, along with the expectation that any issues identified when the actual analyses are completed will be captured through the HFE issue tracking system, as discussed in Section 7, "HFE Issue Tracking System," of the "Human Factors Engineering Program Management Plan." Based on these considerations, the NRC staff determined that the proposed methodology includes the documentation of assumptions and estimates used in conducting the analyses, as well as the determination of whether those assumptions and estimates are appropriate, consistent with the guidance in NUREG-1791, or whether any associated issues need to be resolved.

1.10.3 Data Sources or Demonstration Methods

1.10.3.1 Applicant Submittal Considerations

Section 10.2.3, "Data Sources or Demonstration Methods," of NUREG-1791, Part II, lists information that the NRC staff reviewer should confirm is included in support of an exemption request submittal. The NRC staff reviewed the TR submittal to determine whether the proposed methodology addresses this information. The result of this assessment for each of the information items is provided below.

A description of the integrated design and execution of the validation using the selected sources and methods, validation method, or implementation plan description.

The “Xe-100 Human Factors Verification and Validation Implementation Plan” discusses the overall methodology for validating the integrated design, including a description of the types of information to be collected and assessed, the sources of that information, the conduct of scenario tests on an established test bed, and other details associated with validation methodology. Additionally, by letter dated October 19, 2022, X-energy confirmed that the full scope of the ISV will be used towards the completion of the SPV.

By letter dated October 19, 2022, X-energy stated that complex operational evolutions and off-normal activities, as well as identified licensing basis events, will be available realistically simulated. X-energy also stated that the Xe-100 full scope simulator will be used as the test bed for the conduct of ISV and SPV testing, and that this test bed will be of sufficient fidelity to allow for realistic simulation of high workload demand.

Based on the above, the NRC staff determined that the proposed methodology, including the comprehensive nature of its description of the validation program and the commitment to conducting validation on a simulator of a fidelity appropriate to serve the validation objective, includes adequate description methodology for executing the validation using the selected sources and methods, consistent with the guidance in NUREG-1791.

A description of the data sources and methods used, the parts of the validation each supports, and how they have been integrated.

Section 3.2.3.1.6, “Performance Measurement,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” discusses the use of objective and subjective measures to measure the performance of operators during SPV testing. These measures will be collected by the validation team during scenario execution of test scenarios. Additionally, Section 3.2.3.1.7, “ISV Design,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” includes a discussion of the use of an ISV procedure to control the execution of testing, as well as a discussion of the use of checklists, questionnaires, data collection tables, and audio and visual recording for collecting and documenting performance data.

Section 3.1, “Inputs,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” discusses the inputs that will be used to develop and conduct validation testing, including input from other elements of the overall HFE program. Section 3.2.3.1.8, “Data Analysis and HED Identification,” discusses the analysis of the data collected during validation and that data will be used to assess performance. Section 3.2.3.1.9, “ISV Conclusions,” discusses the drawing of conclusions from the data assessment, including assessment of the validity of and any limitations associated with the ISV itself.

Based on the above, the NRC staff determined that the proposed methodology, including the comprehensive nature of its discussion and its reliance on controlled processes for data collection, includes adequate description of the data sources and methods used, the parts of the validation supported by the data, and how the data and methods will be integrated into the overall validation of operator performance with the staffing levels included in a proposed staffing plan, consistent with the guidance in NUREG-1791.

A description of limitations in the scope and data quality (e.g., plant/system similarities and differences, assumptions, estimates, algorithms, numbers, and qualifications of subjects) for each source.

Section 3.2.3.1.9, "ISV Conclusions," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" states that any limitations identified in the ISV, the possible effects of any identified limitations on the validation conclusions, and the impact of any identified limitations on implementing the design will be documented. Furthermore, Section 3.2.4, "Human Engineering Discrepancies Management," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses the iterative resolution of identified issues (i.e., HEDs) throughout the validation process.

Based on the above, the NRC staff determined that the proposed methodology includes the identification and documentation of limitations in the scope and data quality for data sources, consistent with the guidance in NUREG-1791.

A description of how dynamic interactions were assessed.

Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses assessment of interpersonal dynamics through the measurement of teamwork, using the BARS metric, as well as anthropometric and psychological measures, to be used throughout the validation, addressing the dynamics of interpersonal and human-system interactions.

Section 3.2.3.1.3, "Validation Testbed," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses the use of the full scope simulator to conduct validation testing, which, "assures that the integrated system clearly represents with a high functional and physical fidelity to the Xe-100 plant design." This discussion further assumes that the simulator will include the following:

- interface physical fidelity;
- interface functional fidelity;
- environmental fidelity;
- data completeness fidelity;
- data content fidelity; and
- data dynamics fidelity.

The SPV will thus provide an opportunity to assess the interaction of the operators with the fully dynamic and representative set of instrumentation and controls.

Based on the above, the NRC staff determined that the proposed methodology, including the comprehensive nature of its discussion and its reliance on state-of-the-art measures, includes adequate description of how dynamic interactions will be assessed, consistent with the guidance in NUREG-1791.

1.10.3.2 Review Criteria Considerations

Section 10.3.3, “Data Sources and Demonstration Methods,” of NUREG-1791, Part II, lists criteria that the NRC staff reviewer should confirm are met, as applicable, by a completed control room staffing analysis. The NRC staff reviewed the TR submittal to determine whether the proposed methodology adequately addresses these criteria. The result of this assessment for each of the criteria is provided below.

The selected design of the staffing plan validation, the data sources, and the demonstration methods comprehensively address the dynamic aspects of the staffing plan and support the requested exemption.

By letter dated October 19, 2022, X-energy stated that it will use the full scope of the ISV towards the completion of the SPV. The overall methods for conducting these validation activities are discussed throughout the “Xe-100 Human Factors Verification and Validation Implementation Plan”.

Section 3.2.3.1.6, “Performance Measurement,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” discusses measurement of teamwork, situational awareness, anthropometric and psychological measures, overall operator performance, and addressing the dynamics of interpersonal and human-system interactions.

The NRC staff notes that, with regards to the dynamic aspects of the staffing plan, the proposed base case of three operators operating four reactor units did not include potential adjustments or augmentation of the staffing level during periods of higher-workload activities (such as certain refueling operations or significant maintenance). However, as discussed in Section 1.10.1 of this SE, Section 3.2.1, “Sampling of Operational Conditions,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” discusses applying the base-case minimum staffing complement for all selected scenarios, covering the full range of challenging conditions. Based on this consideration and the fact that the SPV will verify that the minimum staffing complement (without any dynamic adjustment or augmentation) is capable of maintaining safe plant operation during the selected scenarios, the absence of a discussion of potential dynamic adjustments to the proposed staffing plan at this stage in the methodology development is not unacceptable.

Based on the above, the NRC staff determined that the proposed methodology includes adequate measures within the SPV, the data sources, and the demonstration methods intended to comprehensively address the dynamic aspects of an analyzed staffing plan, consistent with the guidance in NUREG-1791.

The data sources and demonstration methods were used appropriately.

By letter dated October 19, 2022, X-energy stated that the ISV—conducted in accordance with the “Xe-100 Human Factors Verification and Validation Implementation Plan”—will be the primary source of validation data. Section 3.2.3, “Validation activities,” of the “Xe-100 Human Factors Verification and Validation Implementation Plan” details the information sources and methods to be used, including a description of the personnel to be involved (which will include an independent validation team), the test bed to be used for scenario execution, and the methods to be used for gathering performance data. X-energy also provided additional clarification on the test bed to be used, confirming that, “X-energy will use the Xe-100 full scope

simulator for all the final HFE validations," and that it will have, "sufficient fidelity to allow realistic simulation of high workload demands."

Based on the above, the reliance on the full-scope simulator for use in obtaining validation data, the comprehensive nature of the methods to be used, and the conduct of activities by an independent validation team and appropriately trained operations crew members, the NRC staff determined that the proposed methodology includes adequate measures intended to ensure the appropriate use of data sources and demonstration methods, consistent with the guidance in NUREG-1791.

The appropriate quantitative, objective measures and criteria were defined and captured.

Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" states that objective measures that would be used to evaluate personnel task performance, include measures such as time, accuracy, frequency, and amount accomplished.

Section 3.2.3.1.6 of the "Xe-100 Human Factors Verification and Validation Implementation Plan" also establishes criteria, stating the following:

> The basis for the performance criteria can be a combination of factors related to the corresponding measure that identifies the acceptability of performance. Therefore, the following shall be considered:
>
> - Rating established in the different metrics used (e.g., for workload, situation awareness and teamwork with the minimum, maximum and intermediate scores)
>
> - Requirements, if applicable (e.g., required time to complete a task according to engineering analyses)
>
> - Expert judgement (e.g., recommendations based on V&V team experience and operation personnel knowledge)
>
> - Norms, if applicable (e.g., specific performance required according to a predecessor system)

Based on the above, the NRC staff determined that the proposed methodology includes adequate measures intended to ensure that appropriate quantitative, objective measures and criteria are defined and captured, consistent with the guidance in NUREG-1791.

The data collection and analysis were conducted appropriately.

Section 4.9, "Staffing Plan Validation," of the TR and Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discuss the collection of data through observation, questionnaires, and other techniques.

Section 3.2.3.1.8, "Data Analysis and HED Identification," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses the analysis of data obtained during validation testing, including a consideration of the following:

- quantitative and qualitative measures of the relationship between the observed performance and the established performance criteria;
- the degree of convergence/consistency between related measures;
- margins of error to account for variance expected in actual performance versus validation-test performance; and
- independent verification of analyses.

Based on the above, the NRC staff determined that the proposed methodology describes an appropriate process for conducting data collection and analysis, consistent with the guidance in NUREG-1791. If a completed staffing analysis were submitted, the NRC staff would, at that time, review the submittal to verify that the collection and analysis were indeed conducted appropriately, in accordance with the outlined methodology.

The scope and data quality were adequate.

Section 3.2.3.1.6, "Performance Measurement," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses the scope of data to be obtained during validation testing. Section 3.2.3.1.7, "ISV Design," of the "Xe-100 Human Factors Verification and Validation Implementation Plan" discusses controls on data collection, including the use of specific instructions for the conduct of testing and data collection and the analysis performed being conducted by an independent validation team.

Based on the above, the NRC staff determined that the proposed methodology includes the appropriate measures intended to ensure adequate scope and quality of collected data, consistent with the guidance in NUREG-1791. If a completed staffing analysis were submitted, the NRC staff would, at that time, review the data quality to ensure that it was indeed adequate, and that the scope of the data aligned appropriately with the scope outlined in the proposed methodology.

The outcomes were reasonable and valid.

Based on the discussion of the testing and analysis methodologies discussed throughout the "Xe-100 Human Factors Verification and Validation Implementation Plan", the NRC staff determined that the proposed methodology includes adequate measures intended to ensure that outcomes from a completed analysis would be reasonable and valid. If a completed staffing analysis were submitted, the NRC staff would, at that time, review the submittal outcomes to verify that they were indeed reasonable and valid.

1.10.4 Staffing Plan Validation Outcomes

Section 10.2.4, "Staffing Plan Validation Outcomes," of NUREG-1791, Part II, lists information regarding the outcomes of the SPV that the NRC staff reviewer should confirm is included in support of an exemption request submittal. Section 10.3.4, "Staffing Plan Validation Outcomes,"

of NUREG-1791, Part II, lists criteria associated with SPV outcomes that the NRC staff reviewer should confirm are met, as applicable, by a completed control room staffing analysis.

Based on the applicable considerations addressed in preceding sections of this SE, the NRC staff determined that the methodology discussed in Section 4.9, “Staffing Plan Validation,” of the TR and throughout the supporting “Xe-100 Human Factors Verification and Validation Implementation Plan” includes measures intended to ensure that SPV outcomes will provide the information outlined in the NUREG-1791 guidance, and that the outcomes will meet the listed criteria.

The NRC staff, however, determined that—because the TR submittal discusses only the methodology for conducting analysis and because the submittal does not include an actual completed analysis—the information needs and review criteria in Sections 10.2.4 and 10.3.4 of NUREG-1791, Part II, are not applicable to the review of the submittal. If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that time, evaluate the submittal to confirm that the necessary information was included and that the review criteria were met.

1.10.5 Conclusion

The NRC staff compared the proposed methodology for conducting an SPV for the Xe-100 facility to the expectations and criteria listed in Sections 10.2, "Applicant Submittals,” and 10.3, “Review Criteria,” of NUREG-1791, Part II. The NRC staff determined that the methodology discussed in the TR submittal is consistent with the information needs and review criteria outlined in NUREG-1791 for this review area. Therefore, the NRC staff determined the consideration of this review area within the TR submittal to be acceptable.

If a completed staffing analysis were to be submitted in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that time, evaluate the submittal to confirm: (1) that the information listed in Section 10.2 of NUREG-1791, Part II, is included and (2) that the criteria listed in Section 10.3 of NUREG-1791, Part II, are met.

CONCLUSION

The NRC staff considered the acceptability of the methodology proposed within the TR and enclosed HFE program implementation plans, as supplemented, as this methodology pertains to conducting control room staffing analyses for the Xe-100 reactor facility design in accordance with the guidance in NUREG-1791. The NRC staff determined that the proposed methodology is consistent with the guidance in NUREG-1791, in that it adequately addresses the information that would be necessary for a completed control room staffing analysis to meet the established acceptance criteria. Based on this determination, the NRC staff finds the control room staffing analysis methodology discussed in the TR submittal to be acceptable for the purposes of evaluating a proposed facility staffing plan to determine whether the proposed plan can be expected to adequately support safe operations, and to determine whether the plan thereby warrants approval of a requested exemption from the control room staffing requirements of 10 CFR 50.54(m), in accordance with the exemption provisions of 10 CFR 50.12 or 10 CFR 52.7, as appropriate.

As stated in the Introduction of this SE, X-energy has, to date, not provided to the NRC a completed staffing analysis for the Xe-100 design. Therefore, the NRC staff did not develop any conclusions regarding the actual proposed staffing levels (e.g., the base case of three control room staff members operating four reactor units, as discussed in the Executive Summary of the TR), nor did the NRC staff consider any actual results obtained from the implementation of any of the analyses or methodologies described in the TR submittal. If a completed control room staffing analysis using the methodology described in the TR submittal were to be submitted to the NRC in the future (e.g., as part of a submittal requesting an exemption from control room staffing requirements), the NRC staff would, at that time, consider the conclusions drawn from the completed analysis to determine whether the completed analysis conforms with the guidance of NUREG-1791 and whether an exemption from the control room staffing requirements is justified.

As discussed in the Introduction of this SE, based on X-energy's discussion of a "base case" for staffing plan analysis (i.e., four units operated by a three-person control room staff), the NRC staff determined that the conclusions regarding the methodologies proposed in the TR submittal should be considered applicable only to this base case. If these methodologies were to be applied for the analysis of a proposed staffing plan that included a different minimum staffing complement (e.g., three operators operating more than four units, or less than three operators operating four units), then the submitted staffing analysis should provide justification regarding the applicability of the methodologies to that particular case, and the applicability of the methodologies to that particular case would be subject to further NRC review at the time of submittal.

As discussed in the Introduction of this SE, X-energy has not formally submitted the "Human Factors Engineering Program Management Plan" or the HFE program implementation plans for the NRC staff's review in accordance with the guidance of NUREG-0711. Therefore, the NRC staff did not review the submitted materials against the criteria contained in NUREG-0711, and conclusions in this SE do not constitute an overall approval of X-energy's HFE program, outside of the context of the SPV and the guidance in NUREG-1791. If a future submittal requests the NRC staff's review of the full HFE program in accordance with the guidance of NUREG-0711 (e.g., as part of the review of a separate TR or a license application), the NRC staff would consider conducting a full HFE program review regarding conformance with the NUREG-0711 criteria at that time.

The NRC staff also notes that—because the HFE program implementation plans provided were developed and submitted prior to the submittal of an actual application for a license, design certification, or standard design approval—those implementation plans may be revised between now and the time at which a future application may be submitted. Future submittals using the methodology reviewed in this SE should include a description of any deviations from the reviewed methodology, including any deviation from the enclosed implementation plans. If, while reviewing such a submittal, the NRC staff were to determine that any identified deviations were substantial, the NRC staff would assess those deviations to determine whether they affect the applicability of the methodology to the submittal being considered.

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