Xe-100 Licensing Topical Report
Plume Exposure Pathway Emergency Planning Zone Sizing Methodology

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SYNOPSIS

This licensing topical report (LTR) describes the methodology to be used to establish site-specific plume exposure pathway (PEP) emergency planning zone (EPZ) size for Xe-100 advanced reactor plants. Upon approval by the Nuclear Regulatory Commission (NRC), the PEP EPZ sizing methodology described herein is intended for use by future applicants of Xe-100 advanced reactor plants in performing site-specific PEP EPZ sizing analyses as required by 10 CFR 50.33(g)(2). This methodology provides a risk-informed approach for determining a PEP EPZ size based on the area within which public dose, as defined in 10 CFR 20.1003, is projected to exceed 10 mSv (1 rem) total effective dose equivalent over 96 hours from the release of radioactive materials from the facility, considering accident likelihood and source term, timing of the release sequence, and meteorology.

The methodology utilizes the approach laid out in Appendix A, General Methodology for Establishing Plume Exposure Pathway Emergency Planning Zone Size, of proposed Regulatory Guide 1.242, "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities," the approach outlined in NEI 24-05, “An Approach for Risk-Informed Performance-Based Emergency Planning,” as well as supporting information from NUREG-0396, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants."

Release sequences (events that lead to a radiological release) to be considered in the PEP EPZ methodology are selected based on risk information from the design and site-specific Xe-100 reactor probabilistic risk assessment (PRA). The PRA addresses all modes and hazards, using the guidance in Regulatory Guide 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors," Nuclear Energy Institute 18-04, “Risk-Informed Performance-Based Guidance for Non-Light Water Reactor Licensing Basis Development,” and American Society of Mechanical Engineers/American Nuclear Society RA-S-1.4-2021, "Probabilistic Risk Assessment Standard for Advanced Non-Light Water Reactor Nuclear Power Plants."

The PEP EPZ sizing methodology draws upon inputs from the Xe-100 Probabilistic Risk Assessment (PRA), Radiological Consequence Assessment Methodology, and Source Term Methodology, which are beyond the scope of this LTR. Key elements of the methodology, such as assumptions and criteria, to Regulatory Guide 1.242 Appendix A, are detailed within this report to provide transparency and clarity on the approach. The methodology utilizes the site-specific RIPB Licensing Basis Event (LBE) information from the LMP approach as part of the spectrum of events. The methodology includes cumulative dose-versus-distance analyses to determine appropriate EPZ boundaries, with specific attention to the 1 rem and 200 rem dose criteria. The evaluation process ensures that the derived EPZ size is appropriately conservative, accounting for uncertainties and cliff-edge effects.

For non-seismic LBEs, the PEP EPZ methodology applies a screening criterion of 5E-7 per plant-year for selecting relevant events. The seismic criteria are based on the NEI seismic white paper and associated flowchart, which guide the assessment of seismic events and establish a bounding Peak Ground Acceleration (PGA) value to limit the range of seismic hazards under consideration.

The Xe-100 PEP EPZ methodology is designed to ensure that the EPZ size is optimized for public health and safety, taking into consideration the need for predetermined protective measures based on potential radiological events. The approach balances effective emergency response with efficient resource allocation, providing a well-justified emergency planning strategy.

CONFIGURATION CONTROL/DOCUMENT CHANGE HISTORY

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Abbreviations/Acronyms

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Short Form	Phrase
ANS	American Nuclear Society
AOO	Anticipated Operational Occurrence
ARRD	Advanced Reactor Regulatory Development
ASME	American Society of Mechanical Engineers
BDBE	Beyond Design Basis Event
CDC	Complementary Design Criteria
CFR	Code of Federal Regulations
CPA	Construction Permit Application
DBA	Design Basis Accident
DBE	Design Basis Event
DBHL	Design Basis Hazard Level
DBT	Design Basis Threat
DID	Defense-in-Depth
DOE	Department of Energy
EAB	Exclusion Area Boundary
EP	Emergency Preparedness
EPA	Environmental Protection Agency
EPZ	Emergency Preparedness Zone
FEMA	Federal Emergency Management Agency
FOM	Figure of Merit
GMRS	Ground Motion Response Spectra
ISG	Interim Staff Guidance
LBE	Licensing Basis Event
LMP	Licensing Modernization Project
LTR	Licensing Topical Report
LWR	Light Water Reactor

Short Form	Phrase
NE	Nuclear Energy
NEI	Nuclear Energy Institute
NLWR	Non-Light Water Reactor
NRC	U.S. Nuclear Regulatory Commission
NSRST	Non-Safety Related with Special Treatment
NUREG	Nuclear Regulatory Guide
OLA	Operating License Application
ONT	Other New Technology
ORO	Offsite Response Organization
PAG	Protective Action Guides
PEP	Plume Exposure Pathway
PGA	Peak Ground Acceleration
PRA	Probabilistic Risk Assessment
PSF	PRA Safety Functions
RA	Risk Assessment
RG	Regulatory Guide
RFDC	Required Functional Design Criteria
RSF	Required Safety Function
RIPB	Risk-Informed Performance-Based
SAR	Safety Analysis Report
SB	Site Boundary
SECY	U.S. NRC Secretary Letter
SMR	Small Modular Reactor
SPRA	Seismic Probabilistic Risk Assessment
SRDC	Safety-Related Design Criteria
SSC	Structures, Systems, and Components
TICAP	Technology-Inclusive Content of Applications Project
TED	Total Effective Dose

Short Form	Phrase
TEDE	Total Effective Dose Equivalent

Definitions

Phrase	Definition	Source
Anticipated Operational Occurrence	Anticipated event sequences expected to occur one or more times during the life of a nuclear power plant, which may include one or more reactor modules. Event sequences with mean frequencies of 1×10-2/plant-year and greater are classified as AOOs. AOOs take into account the expected response of all SSCs within the plant, regardless of safety classification.	LMP (NEI 18-04)
Beyond Design Basis Event	Rare event sequences that are not expected to occur in the life of a nuclear power plant, which may include one or more reactor modules, but are less likely than a DBE. Event sequences with frequencies of 5×10-7/plant-year to 1×10-4/plant -year are classified as BDBEs. BDBEs take into account the expected response of all SSCs within the plant regardless of safety classification.	LMP (NEI 18-04)
Defense-in-Depth	An approach to designing and operating nuclear facilities that prevents and mitigates accidents that release radiation or hazardous materials. The key is creating multiple independent and redundant layers of defense to compensate for potential human and mechanical failures so that no single layer, no matter how robust, is exclusively relied upon. Defense-in-depth includes the use of access controls, physical barriers, redundant and diverse key safety functions, and emergency response measures.	NRC Glossary
Design Basis Accident	Postulated accidents that are used to set design criteria and performance objectives for the design of Safety-Related SSCs. DBAs are derived from DBEs based on the capabilities and reliabilities of Safety-Related SSCs needed to mitigate and prevent accidents, respectively. DBAs are derived from the DBEs by prescriptively assuming that only SR SSCs classified are available to mitigate postulated accident consequences to within the 10 CFR 50.34 dose limits.	LMP (NEI 18-04)
Design Basis Event	Infrequent event sequences that are not expected to occur in the life of a nuclear power plant, which may include one or more reactor modules, but are less likely than AOOs. Event sequences with mean frequencies of 1×10-4/plant-year to 1×10-2/plant-year are classified as DBEs. DBEs take into account the expected response of all SSCs within the plant regardless of safety classification. The objective and scope of DBEs form the safety design basis of the plant	LMP (NEI 18-04)
Design Basis (External) Hazard Level	A design specification of the level of severity or intensity of an (external) hazard for which the SR SSCs are designed to withstand with no adverse impact on their capability to perform their RSFs	LMP/TICAP (NEI 18-04, NEI 21-07)

Phrase	Definition	Source
Event Sequence Family	A grouping of event sequences with similar challenges to the plant safety functions, response of the plant in the performance of each safety function, response of each radionuclide transport barrier, and end state. An event sequence family may involve a single event sequence or several event sequences grouped together. Each release category may include one or more event sequence families. When event sequence models are developed in great detail, identification of families of event sequences with common or similar source, initiating event and plant response facilitates application of the event sequence modeling requirements in this Standard and development of useful risk insights in the identification of risk contributors. Each event sequence family involving a release is associated with one and only one release category.	ASME/ANS-RA-S-1.4-2021
Frequency-Consequence Target	A target line on a frequency-consequence chart that is used to evaluate the risk significance of LBEs and to evaluate risk margins that contribute to evidence of adequate defense-in-depth.	LMP (NEI 18-04)
Integrated Decision-Making Process	Risk-informed and performance-based integrated decision-making (RIPB-DM) process used for establishing special treatments and evaluating the adequacy of DID.	LMP (NEI 18-04)
Licensing Basis Event	The entire collection of event sequences considered in the design and licensing basis of the plant, which may include one or more reactor modules. LBEs include AOOs, DBEs, BDBEs, and DBAs	LMP (NEI 18-04)
Mechanistic Source Term	The characteristics of a radionuclide release at a particular location, including the physical and chemical properties of released material, release magnitude, heat content (or energy) of the carrier fluid, and location relative to local obstacles that would affect transport away from the release point and the temporal variations in these parameters (e.g., time of release duration) that are calculated using models and supporting scientific data that simulate the physical and chemical processes that describe the radionuclide inventories and the time-dependent radionuclide transport mechanisms that are necessary and sufficient to predict the source term.	ASME/ANS-RA-S-1.4-2021
Non-Safety-Related with Special Treatment SSC	Non-safety-related SSCs that perform risk-significant functions or perform functions that are necessary for defense-in-depth adequacy.	LMP (NEI 18-04)
Performance-Based	An approach to decision-making that focuses on desired objective, calculable or measurable, observable outcomes, rather than prescriptive processes, techniques, or procedures. Performance-based decisions lead to defined results without specific direction regarding how those results are to be obtained. At the NRC, performance-based regulatory actions focus on identifying	Adapted from NRC Glossary definition of performance-based regulation (page updated

Phrase	Definition	Source
	performance measures that ensure an adequate safety margin and offer incentives and flexibility for licensees to improve safety without formal regulatory intervention by the agency. For EP, the performance-based approach focuses on licensee demonstration of required emergency response functions.	March 9, 2021) in order to apply to both design decisions and regulatory decision-making
Plant	The collection of site, buildings, radionuclide sources, and SSCs seeking a single design certification or one or more operating licenses under the LMP framework. The plant may include a single reactor unit or multiple reactor modules as well as non-reactor radionuclide sources.	LMP (NEI 18-04)
Plume Exposure Pathway EPZ	As defined in 10 CFR 50.33(g)(2), the area within which: (A) Public dose, as defined in 10 CFR 20.1003, is projected to exceed 10 mSv (1 rem) total effective dose equivalent over 96 hours from the release of radioactive materials from the facility considering accident likelihood and source term, timing of the accident sequence, and meteorology; and (B) Pre-determined, prompt protective measures are necessary.	10 CFR 50.33(g)(2)
PRA Safety Function	Reactor design specific SSC functions modeled in a PRA that serve to prevent and/or mitigate a release of radioactive material or to protect one or more barriers to release. In ASME/ANS-Ra-S-1.4-2013 these are referred to as "safety functions." The modifier PRA is used in the LMP GD to avoid confusion with safety functions performed by Safety- Related SSCs.	LMP (NEI 18-04), ASME/ANS-RA-S-1.4-2021
Required Functional Design Criteria	Reactor design-specific functional criteria that are necessary and sufficient to meet the RSFs.	LMP (NEI 18-04)
Required Safety Function	A PRA Safety Function that is required to be fulfilled to maintain the consequence of one or more DBEs or the frequency of one or more high-consequence BDBEs inside the F-C Target.	LMP (NEI 18-04)
Risk-Informed	An approach to decision-making in which insights from probabilistic risk assessments are considered with other sources of insights.	Adapted from NRC Glossary definition of risk-informed regulation (page updated March 9, 2021) in order to apply to both design decisions and regulatory decision-making

Phrase	Definition	Source
Safety-Related Design Criteria	Design criteria for SR SSCs that are necessary and sufficient to fulfill the RFDCs for those SSCs selected to perform the RSFs.	LMP (NEI 18-04)
Safety-Related SSCs	SSCs that are credited in the fulfillment of RSFs and are capable to perform their RSFs in response to any Design Basis External Hazard Level.	LMP (NEI 18-04)
Site Boundary	The line beyond which the land or property is not owned, leased, or otherwise controlled by the licensee.	10 CFR 20.1003
Technology-Inclusive	The principle of establishing performance requirements developed using methods of evaluation that are flexible and practicable for application to a variety of power reactor and nonpower production or utilization facilities technologies.	LMP (NEI 18-04)
Total Effective Dose Equivalent	The sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).	NRC Glossary

1. Introduction

1.1 Purpose

The purpose of this licensing topical report (LTR) is to describe the methodology to establish a design- and site-specific plume exposure pathway (PEP) emergency planning zone (EPZ) size for Xe-100 reactor plant. Upon approval by the U.S. Nuclear Regulatory Commission (NRC), the PEP EPZ sizing methodology described herein is intended for use by future applicants using the Xe-100 plant design in performing site-specific PEP EPZ sizing analyses as required by 10 CFR 50.33(g)(2).

1.2 Scope

The PEP EPZ methodology in this report follows the approach as described in Appendix A, *General Methodology for Establishing Plume Exposure Pathway Emergency Planning Zone Size*, of Regulatory Guide (RG) 1.242, "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities," [1] as well as building on the approach described in the Nuclear Energy Institute (NEI) risk-informed EPZ methodology as described in the proposed NEI 24-05, “An Approach for Risk-Informed Performance-Based Emergency Planning” [2] that incorporates concepts from NUREG-0396, “Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plant.” [3]

This report is based on the following technical considerations:

- Methodology is designed to be structured and repeatable
- Risk-informed methods are used to determine the spectrum of release sequences to be evaluated, including internal, external, and seismic events
- Analysis of uncertainties

This PEP EPZ methodology uses results from the Probabilistic Risk Assessment (PRA) [7], Radiological Consequence Assessment Methodology [4] and Source Term Methodology [5] as input, which are outside the scope of this LTR. The associated uncertainty with each input will be quantified within their own respective assessments; however, the overall uncertainty will be addressed in the PEP EPZ analysis submitted for an Operating License Application (OLA) using this methodology. The methodology for the uncertainty analysis within the scope of this LTR is described within this report.

1.3 Interfacing Documents

This LTR is one of several reports covering key regulatory issues and provided to the NRC staff as part of the Xe-100 pre-application process. This is an independent report and does not provide inputs to other preapplication documents. This LTR uses information from the Mechanistic Source Term Approach LTR [5], Transient Safety Analysis Methodology LTR [16], and Atmospheric Dispersion and Dose Calculation Methodology LTR [17].

1.4 Document Layout

The document is organized as follows:

- Section 2 provides an overview of applicable regulatory requirements and other guidance pertaining to the plume exposure pathway emergency planning zone sizing.
- Section 3 provides an overview of the event screening methodology and criteria for inclusion of LBEs into the PEP EPZ analysis process.
- Section 4 discusses how the radiological source term evaluation methodology relates to the remainder of the PEP EPZ methodology.
- Section 5 discusses how the radiological dose evaluation methodology and its considerations relate to the rest of the PEP EPZ methodology.
- Section 6 discusses the methodology developed for the radiological dose aggregation analysis, including the LBE criteria, uncertainty and cliff-edge analysis, and treatment for seismic hazards for evaluating the PEP EPZ size. This design by analysis methodology addresses all anticipated loading conditions and degradation mechanisms to be experienced during normal operations of the plant and all LBEs.
- Section 7 summarizes the conclusions of the LTR and describes the applicable limitations and conditions.
- Section 8 lists the references and cross references used in this LTR.

The overview of the methodology and the corresponding LTR section number for each step is provided in Figure 1. Each step that will be implemented to determine the final PEP EPZ distance is also presented below with corresponding LTR section number:

- Compile LBEs from the PRA for all internal and external initiators (Sections 3.3 and 3.4).
- Perform screening of non-seismic LBEs based on estimated dose or timing, including uncertainty (Section 3.5).
- Perform screening and selection of seismic LBEs based on NEI Guidance criteria [14], including uncertainty (Section 3.6).
- Meteorological data will be collected and incorporated into the radiological consequence analysis (Section 5.1). (Outside the scope of this LTR.).
- Source term and radiological consequence analysis will be performed with projected PEP EPZ boundary and 30-day event timing (Sections 4 and 5.3). (Outside the scope of this LTR.)
- Evaluate radiological dose consequences against the PEP EPZ dose and frequency criteria established from proposed RG 1.242 and NEI 24-05 [1] (Sections 3.3 and 6.1).

- Develop distances from 1 rem and 200 rem cumulative curves based on the criteria for non-Seismic LBEs (Sections 6.1.1, 6.1.2).
- Perform uncertainty and cliff-edge analysis, (Section 6.2).
- Seismic LBEs are compared to the proposed dose criteria (Sections 3.3, 6.3).
- Repeat accident and consequence analysis if necessary.
- Perform event evaluation and dose assessment and resulting protective measures evaluation from resulting distances (Section 6.4 and 6.5).
- Determine the final PEP EPZ distance based on results (Section 6.6).

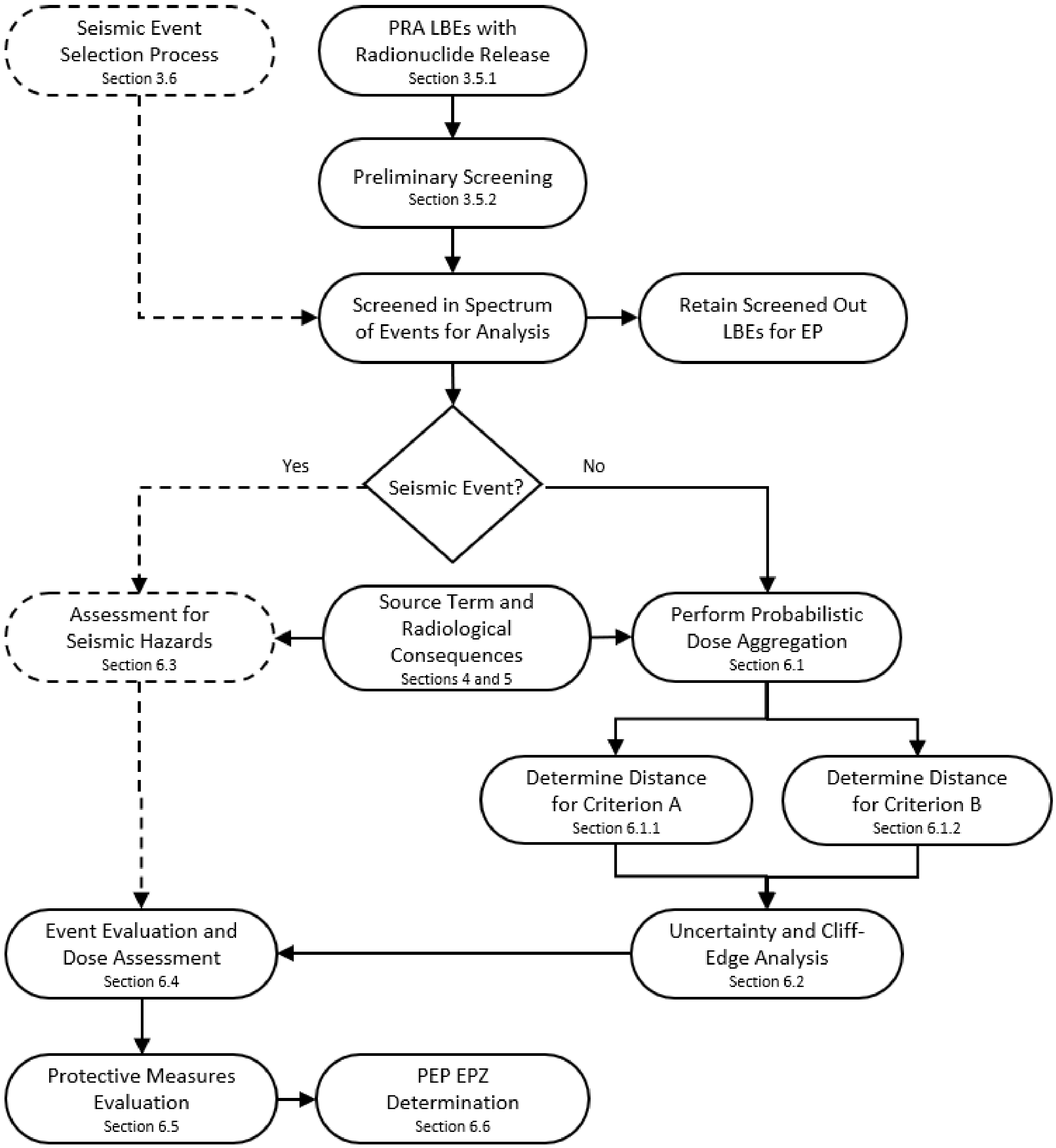

Figure 1: Overall Methodology to Determine PEP EPZ Distance

1.5 Outcome Objectives

X-energy is requesting NRC review and approval of the Xe-100 PEP EPZ sizing methodology to support future PEP EPZ sizing analysis required by 10 CFR 50.33(g)(2).

2. Regulatory Requirements and Associated Guidance

This section provides a description of the regulatory basis that supports the Xe-100 PEP EPZ sizing methodology to demonstrate compliance with the SMR/ONT EP rule under 10 CFR 50.160 and 10 CFR 50.33(g)(2). This includes discussion of recent industry and NRC documents that address evaluation of PEP EPZ size and planning for small modular reactors (SMRs) and other new technologies (ONTs).

2.1 Regulatory Requirements and Associated Guidance

As nuclear technology continues to evolve, and recognizing the limitations of existing regulations and guidance, along with the availability of improved methods and data, the NRC staff took steps to modernize emergency preparedness (EP) regulations for SMRs and ONTs. This effort was initiated through SECY-15-0077, where the NRC sought the Commission's approval to initiate a rulemaking process. Following approval through SRM-SECY-15-0077, the formal rulemaking began in 2016. In January 2022, NRC staff completed the final rule and submitted it to the Commission as SECY-22-0001, titled "Final Rule: Emergency Preparedness for Small Modular Reactors and Other New Technologies." [6] This final rule was approved by the Commission in August 2023 and subsequently published in the Federal Register in November 2023. The final rule had some significant changes in the context of SMRs and ONTs, in particular the addition of §50.33(g)(2), which contains criteria for determining the area of a PEP EPZ, and 10 CFR 50.160, "Emergency preparedness for small modular reactors, non-light-water reactors, and non-power production or utilization facilities.".

The methodology outlined in this LTR is constructed around the new requirements for SMRs and ONTs as described in the final rule and RG 1.242. The final rule introduces a flexible, scalable approach for determining the size of the PEP EPZ based on both the projected off-site public doses from a spectrum of events and the need for predetermined, prompt protective measures. RG 1.242, titled "Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities", developed concurrently with the rulemaking offers methods and procedures deemed acceptable to demonstrate compliance within this new SMR and ONTs EP framework. Appendix A of RG 1.242, titled "General Methodology for Establishing Plume Exposure Pathway Emergency Planning Zone Size," offers an example methodology considered acceptable by the NRC for analyzing and determining the size of the PEP EPZ as required by 10 CFR 50.33(g)(2) that was part of the 10 CFR 50.160 rulemaking. Further guidance is discussed in the following subsection.

Key aspects of the final rule include the introduction of §50.33(g)(2), which establishes criteria for determining the PEP EPZ area, and 10 CFR 50.160, which outlines emergency preparedness requirements specific to SMRs, non-light-water reactors, and other non-power facilities. This new EP framework is designed to be risk-informed and performance-based (RIPB), giving applicants greater flexibility and encouraging innovation as an alternative to using the existing, deterministic EP requirements in 10 CFR 50. One notable change in the rule is the revision of §50.47, which now allows licensees to bypass the 16 traditional planning standards if §50.160 is utilized or if the PEP EPZ remains confined within the site boundary. Moreover, for applicants using §50.160, Appendix E to 10 CFR 50 is no longer applicable, removing the need to request exemptions from outdated regulatory requirements, particularly those not relevant to non-light-water reactor (NLWR) designs.

In developing this methodology, several regulatory documents and guidance materials were considered:

- NUREG-0396/EPA 520/1-78-016, "Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plants" (referred to as NUREG-0396)[3], offers the foundational planning basis for off-site emergency preparedness. Originally developed for large power reactor facilities, NUREG-0396 continues to inform the current emergency planning zone (EPZ) regulations, including the standard 10-mile EPZ for operating reactors under 10 CFR 50.47. The insights and technical basis from NUREG-0396 are also critical to the methodology used in the final rule for SMRs and ONTs.
- EPA-400/R-17/001, “PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents” [8] (referred to as the EPA PAG Manual), establishes protective action criteria for addressing radiological incidents that would require considerations of protective actions. Section 1.4, Radiological Incident Phases and Applicability of Protective Actions, discusses the phases of such incidents, notably the "Early Phase," which requires rapid decision-making regarding protective measures. This phase may last from hours to days and considers dose projections ranging from 1 to 5 rem total effective dose (TED)[1] over a four-day period.
- NUREG-1855, "Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decision Making," [9] provides a comprehensive approach for the treatment of uncertainties within risk-informed applications. The guidance provides an understanding on PRA related uncertainties and the impact on the results of PRAs, and offers practical approaches for addressing these uncertainties into the decision-making process.
- RG 1.233, "Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors," [10] provides a framework for using a technology-inclusive, risk-informed, and performance-based approach to inform the licensing basis and content of applications for non-light-water reactors (non-LWRs). This guide endorses the Licensing Modernization Project (LMP) approach as described in NEI 18-04, “Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development,” [11] and helps developers of advanced reactor designs navigate the licensing process by providing criteria for selecting licensing basis events (LBEs), while ensuring that safety margins and defense-in-depth (DID) are maintained.
- RG 1.247, "Acceptability of Probabilistic Risk Assessment Results for Advanced Non-Light Water Reactor Risk-Informed Activities," [12] outlines and endorses the criteria found in the ASME/ANS NLWR PRA Standard, “Probabilistic Risk Assessment Standard for Advanced Non-Light Water Reactor Nuclear Power Plants,” [13] for determining the acceptability of probabilistic risk assessments (PRAs) specifically for advanced non-light-water reactors. It

[1] The NRC staff notes that the EPA defined TED is different than the NRC defined TEDE, as it utilizes different dosimetry methodologies. As such, the NRC uses its definition of TEDE for regulatory activities under its statutory authority

provides guidance on how PRAs should be developed, reviewed, and used in risk-informed regulatory activities, ensuring that uncertainties, event sequences, and risk are thoroughly considered in the licensing process.

The various regulatory guidance from RG 1.242 that inform the methodology and their requirements are described in the following Table 1.

Table 1: Conformance with Regulatory Guidance

Guidance Document	Requirements	Conformance
RG 1.242 App A	Identify events for the facility and radiological release scenarios as described in Appendix A-3.1. - For non-LWRs, the applicant may opt to use the technology-inclusive, risk-informed, and performance-based methodology endorsed by Regulatory Guide 1.233. - To ensure that radiological releases with large potential consequences that may affect the size of the EPZ are not inappropriately scoped out of the consequence assessment based on low likelihood, the applicant should consider the uncertainty of the accident likelihood. - The applicant should consider internal and external initiating events, multi-module and multiunit accidents and interactions, and all sources of radioactive material whose release may result in the need to take prompt protective actions. - Timing of the radiological release to the environment, as justified, may be used to determine whether an accident scenario should be included in the consequence assessment to determine the size of the plume exposure pathway EPZ.	Fully Conforms - by following NEI 24-05 methodology and developed screening criteria for developing Spectrum of Events, as described in Section 3
RG 1.242 App A	Evaluate source-term information as described in Appendix A-3.2 and Appendix B. - For each release scenario for which doses are assessed, a quantitative radiological source term would be developed by specifying atmospheric release characteristics such as the time-dependent isotopic release rates to the atmosphere, release durations, release locations, physical/chemical form, and plume buoyancy. The accident radiological source terms can be referenced from the safety analysis for the facility.	Fully conforms - source term requirements as described in Section 4 and 5
RG 1.242 App B	- B-1. Each applicant should develop potential source terms from licensing basis events for its facility. - B-2. If the applicant intends to use a probabilistic risk assessment (PRA) to define the accidents used in the radiological dose assessment, the applicant should apply a risk - informed integrated decision making process. - B-3. A technical basis for the screening of any identified release scenarios from quantitative consideration (for example, on the	Fully Conforms to B-1, B-2, and B-3 by using safety analysis information and following NEI 24-05 guidance for screening and treatment of

Guidance Document	Requirements	Conformance
	basis of low likelihood or very long accident progression times) would need to be provided. - B-4. The accident radiological source terms should be estimated for the specific facility using accepted analysis methods and codes, such as the MELCOR or MAAP codes. - The PRA and source - term models should be as realistic as possible so that the values and limitations of any mechanism or barrier are not obscure.	uncertainties as described in Section 3 and 6 Conforms with Modifications - For Source Term estimation requirements in B-4 and B-5, XSTERM is used for a bounding analysis with assumptions detailed in Section 5. PRA limitations are detailed in Section 3
RG 1.242 App A	Develop meteorological data for atmospheric transport and dispersion modeling as described in Appendix A-3.3. - An analysis to develop meteorological data may be needed to evaluate a range of meteorological conditions in a probabilistic fashion. Alternately, conservative transport and dispersion conditions may be assumed, although the conservatism of the selected conditions should be evaluated to ensure that the combination of parameters selected for transport and dispersion modeling was in fact conservative.	Fully Conforms - with usage of conservative transport and dispersion conditions as detailed in Section 5
RG 1.242 App A	Identify and parameterize an atmospheric transport, dispersion, and deposition model as described in Appendix A-3.4. - An atmospheric transport model appropriate for the range of distances under consideration should be identified.	Conforms with Modifications - Conservative atmospheric transport assumptions are used as described in Section 5
RG 1.242 App A	Model the potential exposures to offsite populations as described in Appendix A-3.5. - The relevant exposure pathways should be identified. - Assumptions about the geographic distribution of the receptor population, if any, should be identified. - In order to assess the dose, the exposure parameters (e.g., shielding factors, breathing rates, exposure durations) would need to be characterized.	Conforms with Modifications - Conservative exposure assumptions are used as described in Section 5
RG 1.242 App A	Estimate potential doses to offsite populations as described in Appendix A-3.6.	Fully conforms - Conforms with dose aggregation from NEI

Guidance Document	Requirements	Conformance
	- The dose estimation is carried out by combining the results of the release, transport, and exposure assessment with a recognized source of dose conversion factors to estimate dose-distance curves for comparison to the 10 mSv (1 rem) TEDE criterion.	24-05 as described in Section 5 and 6
RG 1.242 App A	Aggregate dose distance information as described in Appendix A-3.7. - The method for aggregating doses from different source terms, given consideration of their frequencies, should be identified. - The likelihood of exceeding a TEDE of 10 mSv (1 rem) due to the combined effect of accident frequency and variability in meteorological conditions should be discussed. - The likelihood of exceeding a TEDE of 10 mSv (1 rem) at the proposed EPZ boundary should be consistent with the evaluation in Appendix I to NUREG-0396, which provides relative probabilities of exceeding certain critical doses as a function of distance from the facility for a spectrum of severe accidents. - The probabilistic dose aggregation in NUREG-0396 demonstrated that the plume exposure pathway EPZ was of sufficient size such that all of the following conditions were met: a. Projected doses from the traditional design-basis accidents would not exceed Protective Action Guide levels outside the EPZ. b. Projected doses from most core melt sequences would not exceed Protective Action Guide levels outside the EPZ. c. For the worst core melt sequences, immediate life-threatening doses would generally not occur outside the EPZ. - The methodologies used for event selection, identification of source terms, modeling of releases, and aggregation of potential offsite doses should provide similar confidence that appropriate offsite planning will be identified for small modular reactors, non-light-water reactors, and non-power production or utilization facilities. - Because each of the analyses supporting the evaluation can contain uncertainties, any significant uncertainties that could affect this comparison should be identified and characterized.	Fully conforms - Conforms by following Dose Aggregation methodology from NEI 24-05 as described in Section 6

2.2 NEI 24-05

In July 2024, the Nuclear Energy Institute (NEI) submitted NEI 24-05, "An Approach for Risk-Informed Performance-Based Emergency Planning," [2] to the NRC for endorsement. NEI 24-05 is an initiative taken under the U.S. Department of Energy (DOE), Office of Nuclear Energy (NE), Advanced Reactor Regulatory Development (ARRD) program, specifically under the Regulatory Framework Modernization area. Its purpose is to establish guidance for utilizing RIPB insights as part of EP efforts to supplement RG 1.242, including the application of outcomes from the NRC-endorsed LMP through RG 1.233 [10].

The overarching goal of NEI 24-05 is to develop an approach that incorporates technology-inclusive RIPB design and licensing methods to create an EP strategy that provides reasonable assurance of public health and safety protection while allocating resources efficiently to achieve dose savings. By aligning with a RIPB approach, the guidance aims to streamline the determination of site-specific emergency planning capabilities based on the attributes and safety case of the facility.

NEI 24-05 and this LTR's approach is also designed to align with the recent SMR and ONT EP final rule, which includes the revised §50.33 and new §50.160. The revised §50.33(g)(2) provides criteria for determining the PEP EPZ area, while §50.160 outlines the emergency preparedness requirements for SMRs, non-light-water reactors, and other facilities that do not produce power. Historical considerations regarding the implementation of the requirements in §50.47 and Appendix E are also taken into account when developing appropriate levels of protection for emergency workers and the public. The methodology detailed in the LTR aims to ensure compliance with these new regulatory requirements by offering a scalable and adaptable EP approach. This LTR models much of its approach after NEI 24-05, incorporating its systematic framework to expedite the review process for the PEP EPZ sizing strategy. Because NEI 24-05 was developed with input from industry experts—including collaborations with Argonne National Laboratory and other NEI industry organizations—and is being actively reviewed by the NRC, it forms a strong foundation for the LTR approach. The LTR seeks to gain a similar endorsement by following an industry-developed, RIPB methodology that emphasizes transparency, thoroughness, and consistency with previously NRC-approved frameworks, such as the LMP.

The approach described in this LTR will utilize site-specific RIPB information from the LMP process, ensuring that emergency planning is tailored to the unique characteristics and requirements of each facility. This flexibility allows for a more precise determination of EP needs and helps to optimize resources.

Given that the LMP framework is a well-established, NRC-endorsed approach for RIPB safety case development, this LTR builds on top of that by using existing LMP information and develop a methodology to determine site-specific EP requirements as an integral part of an RIPB safety case. The approach leverages insights gained from the LMP process, including the use of Licensing Basis Events (LBEs) and their associated attributes (e.g., frequency, timing, consequences) to guide:

- Determination of the Plume Exposure Pathway (PEP) Emergency Planning Zone (EPZ): The approach involves a detailed assessment of site-specific attributes and LBEs to identify the appropriate extent of the PEP EPZ, ensuring alignment with the EP requirements under 10 CFR 50.33(g)(2) and §50.160.
- Development of Emergency Plans: The document also provides guidance on the development of comprehensive emergency plans, encompassing the necessary actions, resources, coordination, and consideration of ingestion pathways for any radiological incident.

Furthermore, the process described in the LTR aligns with the high-level guidance provided in RG 1.242 Appendix A. RG 1.242 offers a general methodology for establishing PEP EPZ size and developing emergency plans that are consistent with RIPB principles, whereas NEI 24-05 builds on and develops detailed instructions on the implementation of the PEP EPZ process in RG 1.242 Appendix A with LMP-related information. The conformance with the NEI 24-05 guidance is outlined in Table 2.

The LTR's modeling after NEI 24-05 is intended to accelerate the review process by demonstrating that the EP approach is based on sound, expert-driven methodologies that are already under NRC review. Additionally, the LTR benefits from the transparent, consistent, and predictable framework provided by NEI 24-05, allowing for efficient determination of EP capabilities tailored to specific reactor types and facility attributes. This alignment helps demonstrate a clear, well-supported safety case, thereby enhancing regulatory confidence and promoting faster regulatory acceptance.

Table 2: Conformance with NEI 24-05 Guidance

Guidance Document	Requirements	Conformance
NEI 24-05	Spectrum of Events	Conforms with modifications - Conforms with developed screening criteria as proposed by NEI 24-05 as described in Section 3
NEI 24-05	Event Evaluation and Dose Assessment	Conforms with modifications - Usage of conservative dose assessments as described in Section 5
NEI 24-05	Protective Measures Evaluation	Fully conforms - Conforms with guidance from NEI 24-05 as described by Section 6.5
NEI 24-05	PEP EPZ Determination	Fully conforms - Conforms with same criteria as described in Section 6.6

2.3 NEI Seismic EPZ White Paper

This Licensing Topical Report (LTR) utilizes the NEI White Paper, titled "Selection of a Seismic Scenario for an EPZ Boundary Determination" [14], to provide a risk-informed, technology-inclusive framework for the selection of a seismic scenario to use in an analysis for establishing the PEP EPZ boundary. The NEI Seismic EPZ Whitepaper, which is currently under NRC review, aims to develop a technology-inclusive framework that sets reasonable seismic scenario selection criteria based on a sound technical basis and supports regulatory efficiency and stability.

The objectives of the NEI Seismic EPZ Whitepaper are to ensure the framework is consistent with the philosophy discussed in NUREG-0396 [3] for developing radiological emergency response plans, allows the definition of a site-specific plant damage state for radiological dose assessment, avoids over-reliance on uncertain hazard curve extremes, and does not require a site-specific PRA to be completed prior to scenario selection. The approach detailed in NEI 24-05 is also designed to integrate with this seismic scenario framework.

The scope of the NEI Seismic EPZ Whitepaper focuses on excluding gigawatt-scale light water reactors and applicants opting for the maximum hypothetical accident approach under RG 1.242. 10 CFR 50.160 and RG 1.242 provide an option for plants to use a bounding source term to simplify the process of selecting the scenario used for determining the EPZ. This targeted scope helps ensure that the framework is tailored to advanced reactor technologies that require early EPZ determination during the site selection process, using available seismic margin studies and Ground Motion Response Spectrum (GMRS) data.

By incorporating the framework found in the NEI Seismic EPZ Whitepaper, the approach discussed in subsequent sections in this LTR ensures that seismic considerations are adequately represented in the EPZ sizing process. The conformance of the Seismic Whitepaper is outlined below in Table 3. This approach is also supported by the alternative hazards treatment as outline in NEI 24-05. The approach promotes regulatory efficiency and stability, enhances the robustness of the EPZ methodology, and maintains consistency with established regulatory requirements. This alignment with an industry-recognized approach also facilitates regulatory acceptance by incorporating well-supported, industry-standard guidance.

Table 3: Conformance with NEI Seismic White Paper Guidance

Guidance Document	Requirements	Conformance
NEI Seismic EPZ White Paper	EPZ boundary determination for a facility being licensed under the requirements in 10 CFR 50.160 should consider an earthquake of two (2) times the site-specific Ground Motion Response Spectrum (GMRS) or with a 1.0g Peak Ground Acceleration (PGA), whichever is lower.	Fully conforms - Conforms with seismic EPZ event cutoff as described in Section 3.6
NEI Seismic EPZ White Paper	The plant state used for the dose calculation should assume that all structures, systems, and components (SSCs) whose C 10% is less than the selected earthquake, when evaluated in accordance with the guidance in Section H.5 of NEI 12-06, "Diverse and Flexible Coping Strategies (FLEX) Implementation Guide," have failed in the way that would result in the highest calculated dose. All other SSCs would be considered functional. No credit for operator actions in the first 24 hours following the earthquake is assumed in this evaluation unless analyzed to show the Human Error Probability (HEP) less than 0.1.	Does not use, further discussed in Section 3.6

3. Event Screening Methodology

This section provides a description of the methodology for determining appropriate licensing basis event sequences to be evaluated for the PEP EPZ.

3.1 Application of Risk-Informed Methods

As outlined in RG 1.242, sufficient information on LBEs, radiological source terms, and PRA are available and utilized in the PEP EPZ sizing methodology described in this LTR. Event selection is risk-informed, using information from the PRA and dose consequences, ensuring a thorough and appropriate determination of EPZ requirements.

The application of risk-informed methods in this LTR is built on the NEI 24-05 framework, utilizing a structured approach to incorporate risk insights into PEP EPZ sizing for advanced reactors. The determination of the PEP EPZ (using the methodology described herein) relies on site-specific RIPB information developed as part of the LMP approach. This ensures that emergency planning requirements are commensurate with the actual risks associated with different reactor technologies and sites.

The PEP EPZ determination process utilizes a spectrum of events derived from the identified LBEs, which include Anticipated Operational Occurrences (AOOs), Design Basis Events (DBEs), and Beyond Design Basis Events (BDBEs). These LBEs are defined in terms of event sequence families from the plant's PRA. Consistent with the LMP approach, all PRA event sequence families with a frequency of 5E-7 per plant year or greater, assessed at the 95th percentile, are included in the PEP EPZ determination. This process focuses on LBEs that involve radionuclide releases to ensure adequate protection of public health and safety during a radiological emergency.

The PRA supporting the PEP EPZ determination must be technically adequate and acceptable for defining LBEs. In accordance with Regulatory Guide 1.242, the PRA should consider internal and external hazards, all modes of operation, and significant radionuclide sources. It should also include event sequences involving single or multiple modules/units, where applicable, to provide comprehensive risk insights. The PRA must also address uncertainties through quantitative uncertainty analyses supported by sensitivity analyses, ensuring that the selection of LBEs is robust and well-supported. If aspects of the analysis are beyond the PRA scope, supplemental analyses are conducted to evaluate their impact on EP and the PEP EPZ.

The NEI 24-05 framework that serves as a basis in this methodology follows the guidance of Regulatory Guide 1.242, which includes:

- Applying a probabilistic dose aggregation framework with a consideration of frequencies, selecting events with an acceptable spectrum of consequences, and using a "spectrum of accidents" as a basis for developing emergency response plans and determining PEP EPZ size as described in Section 3.
- Design and operational features that provide multiple, independent DID and very low release sequence frequencies, with consideration of uncertainty.

- Use of mechanistic models to calculate source terms and doses, which greatly reduces uncertainty compared to older quantitative methods as described in Section 4 and 5.
- Integrated uncertainty and cliff edge analysis to increase confidence in the best estimate source term and consequence results as discussed in Section 6.2.
- Timing considerations may be used to determine if scenario should be included in PEP EPZ assessment as discussed in Section 3.5.2.

3.2 Criteria for PEP EPZ Determination

The methodology provided in proposed RG 1.242 has been adapted from the dose assessment methodologies that informed the PEP EPZ size determinations in NUREG-0396. In line with the updated criteria from NEI 24-05, the evaluation of the PEP EPZ is based on the cumulative dose-versus-distance curves for different risk levels, ensuring that appropriate protective measures are defined for various event scenarios. The criteria are as follows:

- Criterion A: An assessment of the 1 rem cumulative dose-versus-distance curve at a frequency of 1E-5 per plant year is performed to derive an associated distance. This criterion aligns with §50.33(g)(2)(i)(A), specifying a Total Effective Dose Equivalent (TEDE) value of 1 rem over 96 hours. As the 1 rem criterion is derived from the EPA PAGs, this evaluation also demonstrates compliance with §50.33(g)(2)(i)(B), indicating that protective measures are not expected to be needed beyond the derived distance. If the cumulative curve is below the frequency criteria, no PEP EPZ distance is derived from the comparison.
- Reasoning for Criterion A:
  - Compliance with the §50.33(g)(2)(i)(A) requirement to identify the area where public dose is projected to exceed 1 rem TEDE over 96 hours from the release of radioactive material.
  - Compliance with §50.33(g)(2)(i)(B) that predetermined, prompt protective actions are not necessary beyond the PEP EPZ, as doses exceeding the EPA PAGs are not expected.
  - Maintain consistency with the threshold for current large LWR EPZ basis (NUREG-0396).
- Criterion B: An evaluation of the 200 rem cumulative dose-versus-distance curve at a frequency of 1E-6 per plant year is conducted to determine the appropriate distance. This criterion ensures consistency with early health effects thresholds used in NUREG-0396, providing additional assurance regarding the need for protective actions for LBEs with lower frequencies but potentially significant consequences. The analysis ensures an equivalent level of protection for radiological emergencies that may result in early health effects.
- Reasoning for Criterion B:
  - Maintain consistency with early health effects thresholds in the current large LWR EPZ basis (NUREG-0396).
- Provide assurance that the need for predetermined protective measures will be assessed for rarer radiological release events with possible early health effects.

In scenarios where both Criterion A and Criterion B yield derived distances for each respective assessments, the largest of the two distances is utilized for subsequent assessments. If one of the cumulative curves falls below the frequency criteria, only a single distance may be derived, or no distance if both curves are below the criteria.

The use of these criteria ensures that the PEP EPZ is adequately sized, maintaining consistency with the established thresholds for current large light water reactors (LWRs) as described in NUREG-0396. The frequency criteria are used as evaluation metrics to guide PEP EPZ determination rather than strictly defining quantitative thresholds of acceptability. The behavior of the cumulative dose-versus-distance curves near the frequency criteria, as well as the results of uncertainty and cliff-edge analyses, may influence the final determination of the derived distances. The limiting distance is then applied to ensure robust protective actions in the event of radiological emergencies.

3.3 Development of the Probablistic Risk Assessment

The PRA being developed is both design-specific and site-specific, addressing all modes of operation and external hazards, including seismic events. It follows the guidance provided in RG 1.233 [10] and NEI 18-04 [11]. RG 1.233 endorses NEI 18-04 as an acceptable method for non-LWR designers to use when selecting LBEs. The PRA is developed using the ASME/ANS RA-S-1.4-2021 standard, "Probabilistic Risk Assessment Standard for Advanced Non-Light Water Reactor Nuclear Power Plants." [13] This standard ensures that the PRA encompasses the full spectrum of internal events and external hazards that could challenge the plant's capabilities.

Before submitting the final PEP EPZ sizing analysis, the PRA will undergo a peer review and meet all the requirements specified within the PRA standard. This review will ensure the identification of facility radiological sources and events, with specific hazards either screened or addressed in a documented manner within the final PEP EPZ sizing calculation, as described in Section 3.5.1.

NEI 18-04 describes a systematic process for identifying and categorizing event sequences as Anticipated Operational Occurrences (AOOs), Design Basis Events (DBEs), and Beyond Design Basis Events (BDBEs) for non-LWRs. Design Basis Accidents (DBAs) are derived from DBEs by assuming only safety-related structures, systems, and components (SSCs) are available to mitigate the events. It is important to note that DBAs in the context of NEI 18-04 do not have associated frequencies and are used as deterministic criteria for designing safety-related SSC capability. Further discussion of DBAs is found in Section 3.4.2. The primary criterion for categorizing events is the estimated release frequency of the event sequence.

The event sequences used in the screening process are expected to be defined by an initiating event and the failures of specific SSCs representing the success or failure of mitigating systems at the system level. All sequences are treated individually within the PEP EPZ event selection process, which eliminates ambiguity in performing source term and dose analyses. However, screened-in sequences may be grouped into release categories to reduce the number of required source term and dose consequence simulations, as discussed in Section 3.4.5. Grouping of sequences into release categories will be identified and justified in the PRA documentation.

The methodology in NEI 18-04 includes plotting event sequence families on the frequency-consequence (F-C) target and assessing margins based on event frequency and estimated 30-day dose at the Exclusion Area Boundary (EAB). The mean values of the frequencies are used to classify the LBEs into AOO, DBE, and BDBE categories. When the uncertainty bands defined by the 5th percentile and 95th percentile of the frequency estimates straddle a frequency boundary, the LBE is evaluated in both categories, as outlined in NEI 18-04, Section 3.2.2.

The PRA will be used to identify applicable event sequences to be considered in the PEP EPZ methodology. To support this, event sequences for all internal and external events, as well as all operating modes, will be compiled. A review of the assumptions and sources of uncertainty in the underlying PRA will be completed to identify and address any potential impact on the PEP EPZ sizing method. The key uncertainty issues that can impact PEP EPZ sizing include:

- Key assumptions in the PRA: Assumptions that significantly affect the risk profile and impact event sequence evaluations.
- Model uncertainty: Uncertainty due to limitations or approximations in the PRA models used to characterize plant responses.
- Completeness uncertainty: Uncertainty arising from the omission of potential scenarios, failure modes, or hazards that may influence PEP EPZ determination.

3.4 Hazards and Initating Events

3.4.1 Hazard Groups

As stated above, the evaluation of events for the determination of PEP EPZ sizing requires that initiators from screened in event sequences include a broad spectrum of events, including internal and external events. Evaluated hazards will include the hazard groups from ASME/ANS RA-S-1.4-2021 [13]:

- Internal events
- Internal floods
- Internal fires
- Seismic events
- High winds
- External floods
- High-Energy Line Breaks (HELBs)
- Other hazards

In addition to these defined hazard groups, other hazards such as industrial and transportation accidents, extreme weather events, and soil and slope failures will also be evaluated, with their inclusion or exclusion documented in the associated PRA and PEP EPZ sizing calculation. Events will be assessed across all modes of operation and for all radiological sources, including full power, low power, refueling, and shutdown conditions.

Accident phenomena will be analyzed as part of the PRA to provide input for the PEP EPZ sizing methodology. The PRA will comprehensively address all hazards, operational modes, and radiological sources, with events screened based on specific criteria outlined in Sections 3.6 and 3.7. Events that are screened out will be clearly identified and justified in the documentation. The PEP EPZ sizing analysis will include the relevant accident phenomena applicable to the Xe-100 reactor design, ensuring that all significant contributors to risk are adequately considered.

3.4.2 Design Basis Accidents

Regarding the assessment of DBAs, the developed PEP EPZ determination process accounts for DBAs through the inclusion of analogous event sequences within the PRA. Therefore, DBAs are evaluated by their corresponding event sequence frequencies and consequences. This approach differs from past methods, such as that used in NUREG-0396, which assessed the consequence associated with DBAs regardless of their estimated frequency of occurrence. There are multiple reasons why the approach was selected in the PEP EPZ determination process described here.

First, the nature of DBAs within the LMP approach is fundamentally different when compared to traditional LWR licensing. For the LWRs assessed as part of NUREG-0396, DBAs were deterministically selected and were the primary driver for plant design and associated safety analysis. Only later in the development of the operating LWR fleet was PRA and the use of risk insights introduced as supplementary information. Under the LMP, the approach is essentially reversed, with PRA insights leading the assessment of plant safety and DBAs acting as supplemental information. This approach is possible due to the comprehensive nature of the PRA and the maturation of PRA technology. With LMP, DBAs are derived from DBEs by only crediting safety-related SSCs. For the PEP EPZ determination process, event sequences that are analogous to the DBAs are included within the PRA and addressed at their appropriate frequency level during LBE categorization, ensuring that such events are not neglected.

In the LMP approach to defining DBAs, each DBA is not selected or directly associated with a frequency, but rather is defined by a set of deterministic rules linked to the user selection of which SSCs available on all the DBEs are selected as safety-related for the performance of the Required Safety Functions (RSFs). The purpose of the DBAs in the LMP approach is to demonstrate that 10 CFR 50.34 and 10 CFR 100 dose criteria can be satisfied for the DBEs modified to only rely on safety-related SSCs in the performance of the RSFs. As these events are not selected on the basis of LBE frequency, they cannot be evaluated on the F-C target and they do not contribute to the cumulative risk targets.

Secondly, one of the objectives of the NEI 24-05 approach is to allocate resources in an efficient and effective manner for dose savings to workers and the public. The utilization of best-estimate risk information and associated LBE attributes is the best available pathway to accomplish this objective. If DBAs are included within the PEP EPZ determination process as postulated scenarios without consideration of the frequency of occurrence, their inclusion could lead to a distortion of the analysis findings and a misallocation of resources. In addition, the consequence assessment of DBAs typically differs from that of LBEs in terms of codes, assumptions, etc. These inconsistencies introduce practical challenges to the inclusion of DBAs within the PEP EPZ determination process.

3.4.3 Security Events

Security events have been removed from detailed consideration in the PEP EPZ technical basis. This decision is supported by documenting the following:

- The LBEs that were used to establish the basis for the EPZ size.
- Compliance with regulatory requirements to protect against applicable design-basis and beyond-design-basis threats.
- Security will be required to perform an independent site-specific analysis to determine radiation doses at the exclusion area boundary and the outer boundary of the low population zone from postulated radiological releases and will demonstrate applicability for using alternative security measures found in 10 CFR 73.55(s) for the physical protection program.

It is important to note that the NEI 24-05 approach does not account for security events in determining the PEP EPZ. Instead, these events are addressed separately through robust security measures and regulatory compliance. As noted in 10 CFR 50.33 and 10 CFR 50, Appendix E, the basis for the 10-mile PEP EPZ applied to large LWRs licensed under Part 50 or Part 52 is described in NUREG-0396. The determination of the 10-mile distance was based on the assessment of dose-distance curves derived from a "spectrum of accidents"; however, this spectrum did not include security-initiated events.

Following the attacks of September 11, 2001, the NRC conducted studies to determine if hostile actions warranted changes to the EPZ basis or size. These studies found that the consequences from hostile actions were no more severe than those considered in NUREG-0396. Therefore, no regulatory changes were made affecting the 10-mile EPZ basis or size (as discussed in NSIR/DPR-ISG-01, "Interim Staff Guidance – Emergency Planning for Nuclear Power Plants") [15]. Consequently, EP is comprehensive in addressing the potential consequences from a spectrum of accidents, including internal events and internal and external hazards, but does not specifically cite security-related events as an EPZ sizing consideration.

While the LMP approach does not evaluate security-related initiating events, the LBEs for the site provide a comprehensive assessment of potential accident sequences and associated consequences. For this reason, accidents resulting from security events may be eliminated from detailed consideration in the facility's PEP EPZ technical basis.

Additionally, the evaluation includes a comprehensive discussion of the security-by-design features and the available capabilities for mitigating beyond-design-basis events. These features are designed to enhance the plant's ability to effectively respond to potential threats and ensure that any security-related impacts are minimized.

Security events are also analyzed under the new proposed Alternative Physical Security Requirements for Advanced Reactors, where a site-specific analysis is performed to evaluate the potential offsite radiological consequences for security related events and demonstrate how the performance requirements in 10CFR 73.55(b)(3) are met to protect against applicable design basis threats (DBT) and beyond DBT threats.

Based on the above information, it is concluded that the consequences from security-related events are adequately considered in determining the PEP EPZ. Security considerations are also integrated into the development of the emergency plan, ensuring a cohesive and comprehensive approach to emergency preparedness, discussed in Section 5.

3.4.4 Event Groupings

The PRA process supports the categorization and evaluation of PEP EPZ events in terms of estimated frequencies and consequences of event sequences or event families (i.e., groupings of event sequences having similar initiating events, challenges to plant safety functions, plant response, end state, and mechanistic source term). The event sequences and related estimations of frequencies and consequences include equipment malfunctions caused by internal and external hazards. The groupings will be consistent with ASME/ANS RA-S-1.4-2021 [13] and will be identified and justified in PRA documentation. PEP EPZ events will be identified utilizing the PRA event sequences, event sequence families, and groupings. These events will be used for selection of sequences for the radiological consequence analysis.

3.4.5 Defense-in-Depth

The Defense-in-Depth (DID) evaluation will follow the approach described in Section 5, Evaluation of Defense-In-Depth, of NEI 18-04. [2] The LMP approach provides a comprehensive examination of plant safety by considering all radionuclide sources within the plant. For each source, RSFs are identified to ensure that the consequences of LBEs remain within acceptable limits. The LMP uses a "layers of defense" framework to minimize or prevent radionuclide releases across all modeled event sequences.

This evaluation ensures that sufficient independent and redundant functions are in place to provide adequate DID for event response. The PEP EPZ is not credited as a defense line but instead serves to inform emergency response actions, and emergency planning is part of the 5th layer of DID as defined in NEI 18-04. Emergency Planning is an integral part of the LMP layers of defense framework, with the identified set of LBEs, RSFs and associated Required Functional Design Criteria (RFDC), Safety-Related Design Criteria (SRDC), and Complementary Design Criteria (CDC), and Non-Safety Related with Special Treatment (NSRST) PRA Safety Functions (PSFs) providing essential insights for developing the core elements of an emergency plan. The specific DID methodology is addressed separately and is beyond the scope of this PEP EPZ LTR.

3.5 Selection of Non-Seismic LBEs

The PEP EPZ determination process uses site-specific RIPB information created as part of the LMP approach, and the spectrum of events for consideration primarily consists of previously identified LBEs with radionuclide release. Specifically, the PEP EPZ determination assessment utilizes the LBEs from the AOO, DBE, and BDBE categories, which have been defined as event sequence families from the PRA.

In accordance with the screening criteria from NEI 18-04 and RG 1.233, all non-seismic event sequence families from the PRA with a frequency of 5E-7 per plant year or greater, when assessed at the 95th percentile, are included in the PEP EPZ determination process. This screening ensures that all relevant sequences are included, capturing the range of potential radiological release scenarios while providing a conservative approach to EPZ sizing. Seismic events are treated separately under an alternative approach as allowed in NEI 24-05 and as described in Section 3.6.

Regarding event frequency, there is significant regulatory precedent for using 1E-7 per plant-year[2] mean frequency as the threshold for evaluating less probable, severe events. The NRC recently approved the use of a 1E-7 per module-year screening threshold for non-seismic events as part of the NuScale EPZ approach [20], as it aligns with NUREG-0396. The use of 5E-7 per year at the 95th percentile is generally consistent with this regulatory precedent.

The PEP EPZ sizing analysis follows a consistent methodology to capture the spectrum of accidents, ensuring that significant contributors to risk, even at very low frequencies, are evaluated appropriately. This approach supports a comprehensive and conservative determination of the PEP EPZ that aligns with regulatory expectations and public safety requirements. The overview of the approach is shown in Figure 2.

[2] To cover multi-unit considerations. Plant-wide frequency = single unit frequency x4 for unit-specific LBEs

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3.5.1 Identify LBEs with Radionuclide Release

The PEP EPZ determination process focuses only on LBEs that involve radionuclide releases, and the criteria align with the frequency-consequence (F-C) target established within NEI 18-04. Because the PEP EPZ assessment is focused on the protection of public health and safety during a radiological emergency, only those LBEs with a radionuclide release are included in the evaluation. By utilizing these screening criteria, the approach ensures consistency with the RIPB methodology, maintaining a robust assessment of potential event sequences that contribute to the overall risk profile of the facility.

3.5.2 Preliminary Screening

A preliminary LBE screening analysis may be performed to identify LBEs that do not require further consideration in the PEP EPZ determination process. This preliminary screening process is outlined in Figure 3-2. This preliminary screening can help reduce the number of LBEs that require subsequent consequence and dose assessments, thereby conserving effort and resources. It is important to note that screened-out LBEs are still retained for consideration as part of emergency plan development.

Preliminary screening will be conducted based on several key factors, including:

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Bounding or conservative dose estimates, such as those derived from accident analyses performed for other parts of the application, can be used to screen out LBEs with radionuclide releases that are unlikely to influence the PEP EPZ determination. An LBE may also be screened out based on the time available for implementing protective measures for the public, considering both the timing of the accident sequence as required by §50.33(g)(2)(i)(A) and the need for predetermined, prompt protective measures as stated in §50.33(g)(2)(i)(B).

- LBE Estimated Exposure Timing: LBEs with very long times to an appreciable radiological release can be screened out if sufficient time is available to implement protective measures for the public without the need for predetermined, prompt actions. If there is no adequate LBE timing and Offsite Response Organization (ORO) response data, the LBE will be screened in. However, if adequate data indicates that the timing of the LBE provides sufficient time for the ORO to implement ad hoc protective measures, the LBE can be screened out.

If an offsite response organization (ORO) would have sufficient time to take protective actions without needing those actions to be predetermined, then the LBE can be screened out from the remainder of the PEP EPZ determination process. Typically, these sequences are those that take many hours to progress to the point where a member of the public could be exposed to 1 rem TEDE over 96 hours from the release of radioactive materials.

Timing assessments should consider the following:

- The time from event initiation until emergency response personnel recognize that a significant radiological release is likely or has occurred.
- The elapsed time needed for emergency response personnel to notify an ORO and for the ORO to formulate protective measures for the public.
- The time required by an ORO to implement protective measures for the public in the affected areas.

LBEs may be screened out if sufficient time is available, considering these factors, for an ORO to implement ad hoc protective measures for the public in the areas projected to receive a dose exceeding 1 rem TEDE over 96 hours. If the timing assessment does not provide adequate LBE timing and ORO response data, the LBE will remain screened in for further consideration. The LBE event sequence progression and source term/consequence assessment can provide critical information for this assessment.

The protective actions taken by an ORO would typically be guided by a community's comprehensive or all-hazards emergency plan, developed in accordance with state or Federal Emergency Management Agency (FEMA) guidance. The elapsed time needed for an ORO to implement protective measures can be determined through various methods, such as reviews of actual emergency responses, use of analytical techniques like evacuation time estimates, and interviews with ORO personnel.

While this analysis focuses on preliminary screening, a detailed assessment of event timing will also be conducted as part of the protective measures evaluation discussed in Section 6.5. The event timeline used to assess whether predetermined, prompt protective measures are needed should consider all key recognition and decision points, from initiation to the implementation of protective actions for the public.

The total time sufficient for the implementation of ad hoc protective measures is LBE- and site-specific, considering factors such as the plant location and neighboring population. Key recognition and decision points include the time of event initiation, the time needed to diagnose the event and attempt preventive or mitigative actions, and the time of recognition of the need for protective measures.

3.6 Selection of Seismic LBEs

The PEP EPZ determination for seismic events utilizes the NEI seismic event selection method as outlined in the white paper from May 2024. [14] The process is depicted in Figure 3 and follows a systematic approach to ensure seismic scenarios are selected for proper emergency planning.

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The use of SPRA insights and a limiting PGA value helps identify a specific set of events for PEP EPZ sizing based on site-specific characteristics and design. This aligns with RG 1.242, Appendix A, and ensures that the seismic scenario used for PEP EPZ determination is bounding for most radiological release sequences and adequately addresses the high consequence credible events for the site.

It is critical that the seismic approach is accepted by the NRC and remains consistent with the overall LMP framework. This consistency ensures that non-core sources of radioactivity and impacts across all operational modes are appropriately considered, maintaining a thorough and risk-informed assessment of seismic events for PEP EPZ sizing.

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4. Radiological Source Term Evaluation Methodology

The source term methodology will be used to develop mechanistic source terms associated with the release scenarios. The mechanistic source terms are a direct input into the radiological consequences methodology. This input will establish the specific radionuclide inventory and the quantity released for the events that will be assessed in the PEP EPZ analysis. The methodology for source term development for the PEP EPZ analysis will be consistent with overall Xe-100 reactor assessment and projections. This methodology is addressed separately in the Mechanistic Source Term Approach LTR [5] and Transient Safety Analysis Methodology LTR [16].

5. Radiological Dose Evaluation Methodology

This section describes the methodology for performing the evaluation of the radiological doses for the event sequences determined (using the methodology in Section 3) to be appropriate as part of the EPZ sizing basis.

5.1 Meteorological Input

Meteorological data is required for dispersion calculations of atmospheric releases. The data must be valid and representative for the intended site and application. Initially, meteorological data is treated in a prescriptive and conservative manner rather than a probabilistic best estimate approach. Hourly weather data from a specific site is not used; instead, conservative assumptions are made—specifically, a stability class of F (stable atmospheric conditions) and a wind speed of 1 m/s. These assumptions minimize atmospheric mixing and dispersion, thereby maximizing the release concentration downwind, and are used to support a bounding site. Site-specific meteorology collected at future sites is expected to result in more dispersion, and therefore lower doses, compared to the conservative assumptions currently used.

A bounding atmospheric dispersion factor approach is applied based on these assumed weather conditions, as discussed separately in the Atmospheric Dispersion and Dose Calculation Methodology LTR [17]. The dispersion factors applied, based on the assumed weather conditions, are estimated to be conservatively bounding.

The methodologies associated with the collection of meteorological data and determination of radiological consequences are out of scope for this LTR. Meteorological data will be utilized within the radiological consequence analysis to properly assess doses at the PEP EPZ boundary.

5.2 Radiological Consequence Analysis

The radiological consequence analysis, and its associated inputs, assumptions, and uncertainty analysis, is addressed separately in the Atmospheric Dispersion and Dose Calculation Methodology LTR. [17] The outcomes of this analysis, however, will be directly incorporated into the PEP EPZ sizing analysis for use in the dose aggregation evaluation described in Section 6.1. The radiological consequence analysis for the PEP EPZ methodology will quantify the dose to the public from the identified events, consistent with the LBE consequence analyses. The methodology for the radiological consequence analysis for the PEP EPZ analysis will be consistent with the LBE consequence analyses, except instead of a 30-day dose consequence calculation a 96-hour (4-day) or 24-hour dose calculation will be assessed. In addition, no protective actions are modeled including, no evacuation, relocations, or sheltering. The public is assumed to continue normal activities during the event. As the PRA matures and site-specific data is collected, these assumptions and methods will need refinement and potential adjustments to reflect as-built and operational data. Furthermore, all precautionary and bounding assumptions, will be tracked and updated to ensure that the radiological consequence analysis is accurate and reflects best practices for emergency preparedness.

5.3 Dose Estimation for Pathway Contributors

Each of the postulated LBEs for the Xe-100 were evaluated for released source terms in different calculations and reports. The NRC requires the completion of a PRA for new reactor designs, specified in regulation 10 CFR 52.47, Contents of Applications; Technical Information [18]. Activities and off-site doses are calculated for the LBEs using bounding considerations, and the inputs, assumptions, and software methodology is described in the Atmospheric Dispersion and Dose Calculation Methodology LTR. [17] To support this evaluation, the released activities for each of these LBEs and DBAs are being compiled in a Dose Summary Report.

X-energy uses a suite of codes including Flownex and GOTHIC for the system-level thermal hydraulics portion of the analysis and XSTERM for the radionuclide production, transport, dispersion, and ultimate offsite release characterization. Together these codes are used to calculate the offsite dose Figure of Merit (FOM) for each transient event. The FOM for Xe-100 safety analyses needs to take the form of a dose quantified at a point offsite distance from the plant.

Radiological consequences are evaluated for each release category in terms of dose to an individual (i.e., total effective dose equivalent (TEDE)) from atmospheric releases at distances over a time period of 96 hours. The radiological consequences are currently assessed in a conservative manner to support future site-specific assessments with margin. Finally, the radiological dose is calculated for each LBE, taking into account the impact to each affected reactor unit.

6. Radiological Dose Aggregation

This section describes the methodology for aggregating the doses from different source terms with consideration for their frequencies. To provide a level of confidence that the appropriate PEP EPZ size has been established, the projected doses of various events derived from the PRA are evaluated against a set of specific criteria to minimize risk to the public. Those criteria and the methodology used to evaluate them are described in this section.

6.1 Probablistic Dose Aggreation

A probabilistic dose aggregation is performed for those LBEs with radionuclide releases that are screened in after the preliminary screening analysis as described in Section 3.5.2. The probabilistic dose aggregation supports compliance with both §50.33(g)(2)(i)(A) and (B), as it identifies distances at which the 1 rem TEDE dose will be exceeded and provides insights for determining whether predetermined, prompt protective measures are needed.

The probabilistic dose aggregation assesses the potential consequences associated with the identified spectrum of LBEs and the likelihood of occurrence. In this process, the dose associated with each LBE that includes a radionuclide release is evaluated at different distances from the plant, resulting in dose-versus-distance curves. These curves are developed for specific dose values and represent the frequency of an individual receiving a given dose (or greater) at various distances for each LBE. Distances will range from directly beyond the facility[3] to the site boundary.

Of particular importance for the PEP EPZ determination process are the dose-versus-distance curves for 1 rem and 200 rem. The 1 rem curve aligns with §50.33(g)(2)(i)(A), which indicates exceedance of the EPA PAGs [8], while the 200 rem curve serves as an indicator of the potential for early health effects, aligning with historical criteria from NUREG-0396. These curves are created using mean values of LBE frequency and consequence, with further consideration of uncertainties in subsequent analyses.

Cumulative frequency curves for the plant are developed by summing the frequencies of the individual LBE curves, providing a comprehensive assessment of the potential dose consequences for the spectrum of LBEs along with an integrated perspective on their likelihood of occurrence. These cumulative curves provide a holistic view of the potential doses associated with the plant and help alleviate any potential differences caused by the discretization of events within the plant PRA or LBE structure.

[3] Utilizing a definition similar to that of the “operations boundary” in ANSI/ANS-15.16-2015 [21], which refers to the area within the SB such as the reactor building (or the nearest physical personnel barrier in cases where the reactor building is not a principal physical personnel barrier) where the reactor chief administrator has direct authority over all activities. The term “reactor facility” is not used, as the assessed radionuclide release may originate from a building not directly associated with the reactor, such as a fuel handling or rad waste building.

6.1.1 LBE Dose Criterion A

LBE Dose Criterion A involves assessing the 1 rem cumulative dose-versus-distance curve at a frequency of 1E-5 per plant year to derive an associated distance. This criterion aligns with §50.33(g)(2)(i)(A), which specifies a Total Effective Dose Equivalent (TEDE) value of 1 rem over a 96-hour period. The 1 rem criterion is derived from the EPA PAGs, and this evaluation also demonstrates compliance with §50.33(g)(2)(i)(B) by indicating that protective measures are not expected to be needed beyond the derived distance.

If the cumulative dose-versus-distance curve is below the frequency criteria, no PEP EPZ distance is derived from the comparison. The selection of the frequency value for Criterion A is partially based on the analysis performed for NUREG-0396. The derived distance from Criterion A serves as a baseline for establishing whether protective measures are required for the public.

6.1.2 LBE Dose Criterion B

LBE Dose Criterion B performs an evaluation of the 200 rem cumulative dose-versus-distance curve at a frequency of 1E-6 per plant year. This criterion aligns with the approach utilized in NUREG-0396 and ensures an equivalent level of protection for radiological emergencies that may result in early health effects.

Criterion B provides additional assurance regarding the need for protective actions when considering LBEs with lower frequencies but potentially larger consequences. The frequency criteria are used as evaluation metrics to guide PEP EPZ determination rather than delineating specific quantitative thresholds of acceptability. If the cumulative frequency comparison results in two derived distances—one from the 1 rem curve and another from the 200 rem curve—the larger distance is utilized for subsequent assessments.

6.2 Uncertainty and Cliff-Edge Analyses

To ensure that the PEP EPZ events are properly assessed, Monte Carlo sampling will be performed on the PRA event frequencies to ensure that correct percentiles are accurately captured. This process builds confidence in the specific mean and 95th percentile values used in the evaluation. The Monte Carlo sampling is part of the overall PRA process.

The methodology used to determine uncertainties in radiological consequences, including those related to meteorological conditions, is described in the Atmospheric Dispersion and Dose Calculation Methodology LTR [17]. These uncertainties are incorporated into the radiological consequence analyses. Similarly, the methodology for source term uncertainty analysis is detailed in the Mechanistic Source Term Approach LTR [5] and Transient Safety Analysis Methodology LTR [16], and source term uncertainties are included in the source term analyses.

The uncertainty assessment examines the impact of uncertainties in both frequency and consequence on the derived distances during the frequency criteria evaluation. The general influence of uncertainties on the location and shape of the cumulative dose-versus-distance curves is assessed with an evaluation of supplemental curve of 5 rem in frequency space. The uncertainty evaluation considers factors discussed in NUREG-1855 [9], including parameter, modeling, and completeness uncertainties. Insights gained from previous uncertainty evaluations conducted by the applicant as part of LMP analyses are also utilized.

The cliff-edge evaluation, which is closely related to the uncertainty assessment, specifically focuses on significant changes to the derived distance resulting from small changes in the cumulative dose-versus-distance curve. Evaluations of cliff-edge effects are likely to be performed as part of the broader uncertainty assessment, but specific justification may be required for distances derived from cumulative dose-versus-distance curves that have flat regions near the frequency criteria. There are no specific criteria for what is considered a “dramatic change, this is based on engineering judgement as part of the event analysis. Cliff-edge effect evaluations will be documented in the PEP EPZ sizing calculation.

6.3 Assessment for Seismic Hazards

In addition to the non-seismic LBE analysis, an assessment of dose-versus-distance is for the seismic analysis, as described in Section 3.6 and referenced in Figure 1-3. This alternative approach helps address uncertainties and offers a different perspective on certain hazards not fully characterized by the PRA.

For this assessment, the 96-hour dose-versus-distance curve is determined for the selected event(s), as these events do not have an associated frequency like LBEs. The resulting dose-versus-distance curve is then compared to the 1 rem threshold to determine an associated distance for potential protective measures, as required by §50.33(g)(2)(i)(A). This analysis also includes an evaluation of dose uncertainty, akin to the approach described in Section 6.2, but with a specific focus on the consequence analysis.

Depending on the number of hazards addressed through alternative methods, multiple distances may be derived from the analysis, each represented by a different dose-versus-distance curve. If none of the dose-versus-distance curves exceed 1 rem at any distance—with proper consideration of uncertainty—then no distance is derived from the analysis. However, the events selected through the alternative hazard approach are retained for further consideration in the emergency plan development.

6.4 Event Evaluation and Assessment

The event evaluation and dose assessment yield several potential results. First, the analysis of non-seismic LBEs may produce one or more distances depending on the results of the 1 rem and 200 rem cumulative dose-versus-distance curves. If both curves fall sufficiently below the frequency thresholds, it is possible that no distance is derived from these analyses. This outcome could result from low estimated doses or the low frequency of the LBEs considered.

Second, for the seismic approach, one or more additional distances may be derived based on the 1 rem value on the dose-versus-distance curve(s). Similar to the non-seismic LBE analysis, it is also possible that no distance is derived if the resulting dose-versus-distance curve falls below 1 rem.

If a distance is derived from either the LBE analysis or an alternative hazard assessment, a protective measures evaluation is conducted, as discussed in the following subsection. However, if no distance is derived from any of the analyses, the conclusion is that no PEP EPZ is required, as the criteria specified in §50.33(g)(2)(i)(A) are not met beyond the boundaries of facility structures.

6.5 Protective Measures Evaluation

As stated in Section 3.5.2, the timing of radionuclide release will be captured for analyzed events where applicable. This timing information will be used to determine whether prompt protective measures are necessary for PEP EPZ events and will inform the emergency plan and response procedures.

The evaluation will be conducted by the interdisciplinary LMP integrated decision-making process (IDP) panel to determine whether predetermined, prompt protective measures are warranted as part of the plant's defense-in-depth (DID) adequacy assessment. Within the context of emergency planning (EP) activities, the term "predetermined, prompt protective measures" refers to actions taken by an ORO to protect the public in offsite locations. Protective measures for onsite individuals, including members of the public and plant workers, are taken by the licensee under the requirements of §50.160(b)(1)(iii)(B).

The need for predetermined, prompt protective measures will be assessed individually for each event, incorporating specific event details, including timing, population distribution, and the characteristics of the radionuclide release. If the derived distance from an LBE or alternative hazard analysis extends beyond the SB and exceeds 1 rem, a detailed protective measures evaluation will be conducted, including considerations of site-specific attributes. If such measures are deemed warranted, these findings will be incorporated into the PEP EPZ calculation.

If any PEP EPZ event is identified as requiring predetermined prompt protective measures and exceeds any of the dose criteria, modifications to the plant design or an extension of the PEP EPZ boundary will be considered, following the process described in Section 6.1. This evaluation will aim to reduce either the release frequency or the radiological consequence, or alternatively move the PEP EPZ boundary further outward until the dose consequences meet the established criterion dose levels.

The results of the protective measures evaluation also explore the characteristics of LBEs, including timing, initiating events, and radionuclide release specifics, to understand the need for protective measures and their effectiveness. Population distribution around the site is also factored into this evaluation to determine whether affected areas beyond the SB have a significant population presence. If protective measures are deemed necessary, the analysis will assist in optimizing these actions and informing procedures within the emergency response plan, ensuring that all PEP EPZ events are adequately addressed.

6.6 PEP EPZ Determination

Based on the event evaluation, dose assessment, and protective measures evaluation, there are three potential outcomes for the PEP EPZ determination. These outcomes align with the requirements in §50.33(g)(2)(i) and §50.160.

- No PEP EPZ: This outcome occurs if the event evaluation and dose assessment do not derive a distance where doses exceed the established criteria. In such cases, no further PEP EPZ is needed, indicating that protective measures for the public beyond the facility structures are unnecessary.

- PEP EPZ at Site Boundary (SB): This outcome is realized when doses greater than the established criteria are projected, but only within the SB. It also applies when doses exceeding the criteria are projected beyond the SB; however, the evaluation determines that predetermined, prompt protective measures are not necessary. In both scenarios, the licensee is responsible for implementing onsite protective measures under the requirements of §50.160(b)(1)(iii)(B).
- PEP EPZ Beyond Site Boundary: This outcome occurs when doses exceeding the established criteria are projected to occur beyond the SB, and a determination is made that predetermined, prompt protective measures are necessary. In this scenario, the PEP EPZ is set at the derived distance beyond the SB, and the licensee must comply with additional requirements, including offsite radiological emergency planning under §50.160(b)(1)(iv)(B). The derived distance must also meet the requirements of §50.160(b)(3).

The outcomes of the PEP EPZ determination establish the applicable regulatory requirements under §50.160. If the PEP EPZ extends beyond the SB, the applicant must provide additional information to satisfy requirements related to offsite organizations and emergency planning capabilities. If the PEP EPZ is at the SB, only the requirements related to defining the PEP EPZ (§50.160(b)(3)) must be satisfied. All outcomes, including those with no PEP EPZ established, must also comply with general emergency planning requirements as outlined in §50.160(a), (b)(1)(i)-(iv)(A), (b)(2), (b)(4), and (c).

7. Conclusions

The Xe-100 PEP EPZ sizing methodology, as described in this report, establishes a comprehensive framework for determining the size of the emergency planning zone based on site-specific analyses of radiological dose consequences. Using a risk-informed, performance-based approach, the methodology integrates probabilistic risk assessments, source term analyses, and emergency response considerations to holistically evaluate potential radiological impacts on the public.

The assessment process ensures compliance with regulatory dose limits and establishes appropriate emergency planning capabilities. If required, modifications to the plant design or adjustments to the PEP EPZ boundary are considered to meet established criteria. This approach emphasizes the importance of maintaining safety while optimizing the emergency planning zone, providing assurance that appropriate protective actions are in place to safeguard public health in the event of radiological incidents.

The Xe-100 PEP EPZ determination methodology ultimately represents a balanced and effective strategy for emergency preparedness, ensuring that the EPZ size is technically justified and tailored to the unique characteristics of the reactor while maintaining compliance with regulatory requirements. X-energy is requesting NRC review and approval of the Xe-100 PEP EPZ sizing methodology to support future PEP EPZ sizing analysis required by 10 CFR 50.33(g)(2).

8. Cross References and References

8.1 Cross References and References

Document Title Cross References: X-energy documents that <u>may</u> impact the content of this document. References: X-energy or other documents that <u>will not</u> impact the content of this document	**Document No.**	**Rev./ Date of Issuance**	**Cross Reference/ Reference**
[1] Performance-Based Emergency Preparedness for Small Modular Reactors, Non-Light-Water Reactors, and Non-Power Production or Utilization Facilities	RG 1.242	0	Reference
[2] An Approach for Risk-Informed Performance-Based Emergency Planning	NEI 24-05	July 2024	Reference
[3] Planning Basis for the Development of State and Local Government Radiological Emergency Response Plans in Support of Light Water Nuclear Power Plant	NUREG-0396	December 1978	Reference
[4] Xe-100 Radiological Consequence Analysis – Preliminary Scoping Report	006870	3	Cross Reference
[5] Xe-100 Licensing Topical Report Mechanistic Source Term Approach	000632	2	Cross Reference
[6] Final Rule: Emergency Preparedness for Small Modular Reactors and Other New Technologies	SECY-22-0001	Jan 2022	Reference
[7] Xe-100 Probabilistic Risk Assessment: Risk Integration – Preliminary Scoping	002200	October 2024	Cross Reference
[8] PAG Manual: Protective Action Guides and Planning Guidance for Radiological Incidents	EPA-400/R-17/001	January 2017	Reference
[9] Guidance on the Treatment of Uncertainties Associated with PRAs in Risk-Informed Decision Making	NUREG-1855	1	Reference
[10] Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors	RG 1.233	June 2020	Reference
[11] Risk-Informed Performance-Based Technology Inclusive Guidance for Non-Light Water Reactor Licensing Basis Development	NEI 18-04	Aug. 2019	Reference
[12] Acceptability of Probabilistic Risk Assessment Results for Advanced Non-Light Water Reactor Risk-Informed Activities	RG 1.247	March 2022	Reference
[13] Probabilistic Risk Assessment Standard for Advanced Non-Light Water Reactor Nuclear Power Plants	ASME ANS RA-S-1.4-2021	2021	Reference
[14] Selection of a Seismic Scenario for an EPZ Boundary Determination	ML24187A096	May 2024	Reference
[15] Interim Staff Guidance – Emergency Planning for Nuclear Power Plants	NSIR/DPR-ISG-01	November 2011	Reference

Document Title Cross References: X-energy documents that may impact the content of this document. References: X-energy or other documents that will not impact the content of this document	**Document No.**	**Rev./ Date of Issuance**	**Cross Reference/ Reference**
[16] Xe-100 Licensing Topical Report Transient and Safety Analysis Methodology	007834	1	Cross Reference
[17] Xe-100 Licensing Topical Report, Atmospheric Dispersion and Dose Calculation Methodology	007116	2	Cross Reference
[18] Contents of Applications; Technical Information	10 CFR 52.47	March 24, 2021	Reference
[19] Preparation of Environmental Reports for Nuclear Power Stations	RG 4.2	3	Reference
[20] Methodology for Establishing the Technical Basis for Plume Exposure Emergency Planning Zones at NuScale Small Modular Reactor Plant Sites	TR-0915-17772-NP	3	Reference
[21] Emergency Planning for Research Reactors	ANSI/ANS-15.16-2015	February 2015	Reference