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

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Department of Energy Acknowledgement and Disclaimer

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Agenda & Objectives

Agenda:

- Introductions
  - Presentation
    - Overview of Xe-100
    - EPZ Guidance Background
    - Overall Plume Exposure Pathway (PEP) Emergency Planning Zone (EPZ) Methodology
  - Conclusions and Next Steps
  - Questions and Answers
- Closing Comments

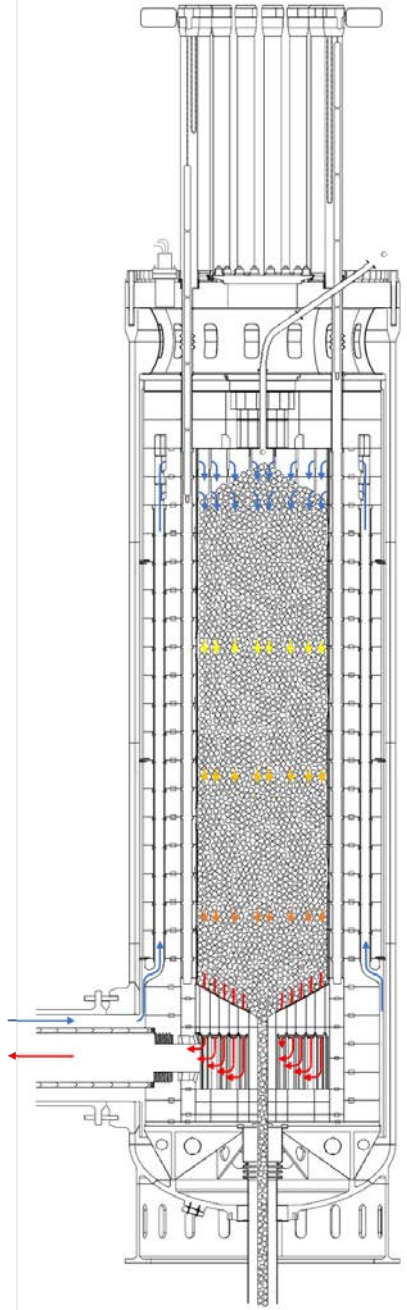
Objectives:

- Provide an overview of the X-energy Licensing Topical Report "Plume Exposure Pathway Emergency Planning Zone Sizing Methodology "
  - The LTR will be used to support future PEP EPZ sizing analysis required by 10 CFR 50.33(g)(2)
- Discuss:
  - EPZ Guidance and Rulemaking and how methodology conforms
  - Methods and inputs used to define PEP EPZ size

Xe-100 Overview

X-energy is developing the Xe-100, a 200 MWt, 80 MWe high-temperature gas-cooled reactor (HTGR). The reactor core is a pebble bed design.

- The Xe-100 will be used to produce high-temperature steam for:
  - Electricity
  - Industrial processes
- Core
  - Approximately 220,000 spherical pebbles
- Fuel:
  - Each pebble contains approximately 19,000 TRISO fuel particles
  - U-235 enrichment up to 15.5 weight percent
  - Fuel is in UCO form
- Coolant: Helium
  - Nominal core inlet/outlet temperatures: 260/750°C



EPZ Guidance Background

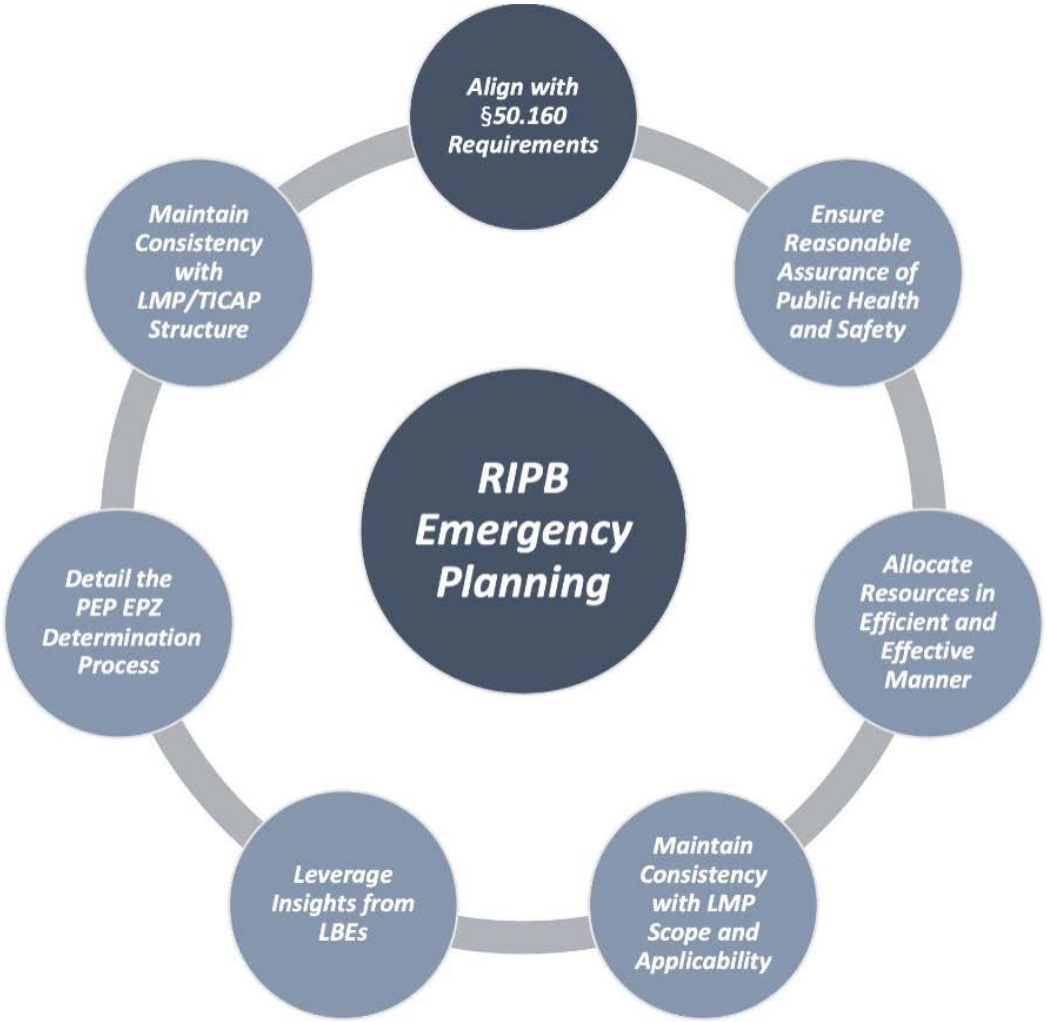
- Historically, LWR fleet has used large uniform emergency planning zones (EPZs)
  - Plume exposure pathway EPZ: 10 miles
  - Ingestion exposure pathway EPZ: 50 miles
- NRC Rulemaking for Emergency preparedness for small modular reactors (SMRs) and other new technologies (2023) aim to develop emergency plans that are commensurate with plant risk
  - Introduced new approach under §50.160 and §50.33(g)(2)
  - Removal of the ingestion exposure pathway EPZ (addressed by describing available preventive capabilities), retains the plume exposure pathway (PEP) EPZ
    - §50.33(g)(2)(i): The plume exposure pathway EPZ is the area within which:
      - (A) Public dose, as defined in § 20.1003 of this chapter, 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

EPZ Guidance Background

- NRC has provided high-level guidance in RG 1.242 in meeting new rulemaking requirements to determine PEP EPZ
- NEI along with Argonne National Lab and industry experts has developed and submitted NEI 24-05 to NRC for endorsement, to provide detailed guidance in meeting these requirements in deriving the PEP EPZ with the use of information from the Licensing Modernization Project (LMP) based safety case
- NEI has also submitted a White Paper: “Selection of a Seismic Scenario for an EPZ Boundary Determination” to NRC for endorsement to establish reasonable seismic scenario selection criteria for EPZ considerations

EPZ Guidance Background

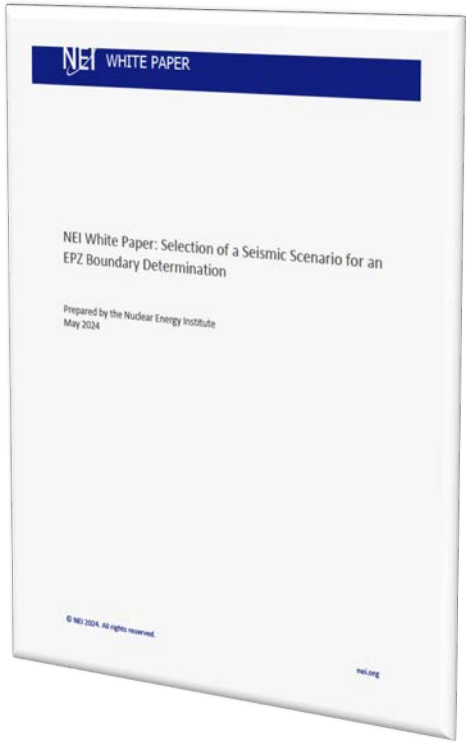
- Goal: Establish an approach that leverages the insights from technology-inclusive RIPB design and licensing methods to develop an EP strategy that provides reasonable assurance of adequate protection of the public health and safety while allocating resources for dose savings in an efficient and effective manner
- Develop an approach for deriving the plume exposure pathway EPZ and associated emergency plan elements (actions, resources, etc.) which integrates information from the LMP-based safety case



NEI 24-05, R0

EPZ Guidance Background

- “Selection of a Seismic Scenario for an EPZ Boundary Determination”, May 2024
- The key insight and conclusion utilized by X-energy from this white paper are:
  - It is reasonable to conclude that the 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) with design response spectra, whichever is lower**



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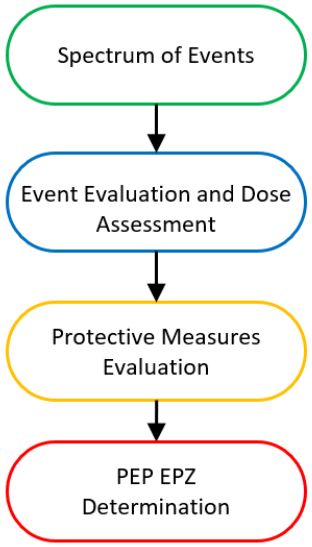
Overall PEP EPZ Methodology

- The X-energy PEP EPZ sizing methodology outlined in the LTR aims to align with the discussed guidance documents to provide strong foundation for the methodology
    - Aligned with new SMR/ONT § 50.160 approach to alleviate need for exemptions
- Will utilize the Licensing Basis Events (LBEs) and their insights (frequency, consequence, timing, etc.) from the LMP approach to establish the credible spectrum of events to inform the PEP EPZ sizing analysis
    - Integration with LMP/TICAP structure maintains consistency in DID and RIPB safety case
    - Using results from Probabilistic Risk Assessment (PRA), Mechanistic Source Term, and Atmospheric Dispersion and Dose Consequence Analyses to inform PEP EPZ analysis
- X-energy's goal is to use the PEP EPZ methodology for future Xe-100 sites

Overall PEP EPZ Methodology

- The developed methodology follows the same structure as developed in NEI 24-05, with following enhancements:
  - Usage of additional criteria for consequence and timing based preliminary screening, and
  - NEI Seismic White Paper informed Seismic Hazards method for Alternative Hazards Method as described in NEI 24-05
  - Differences in Dose Aggregation assumptions



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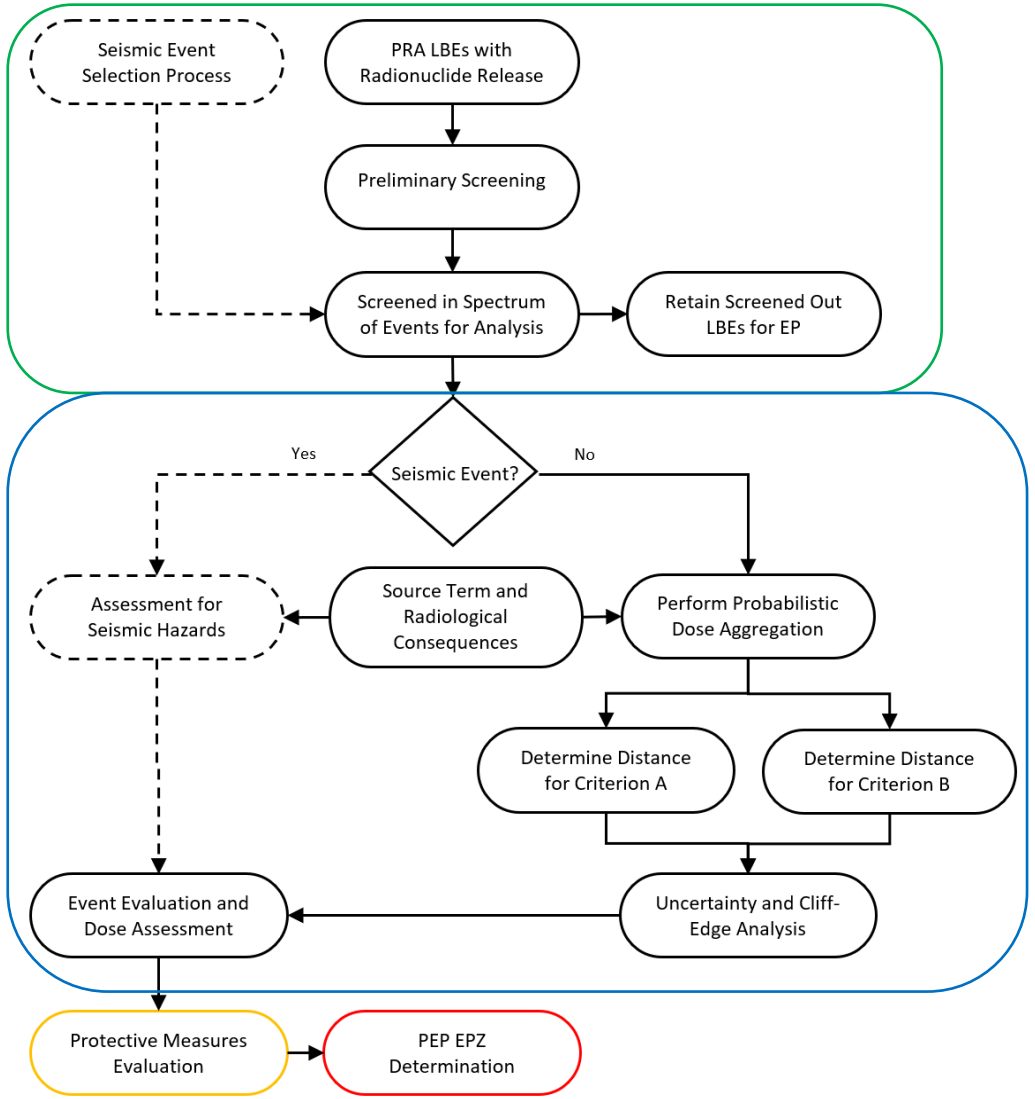
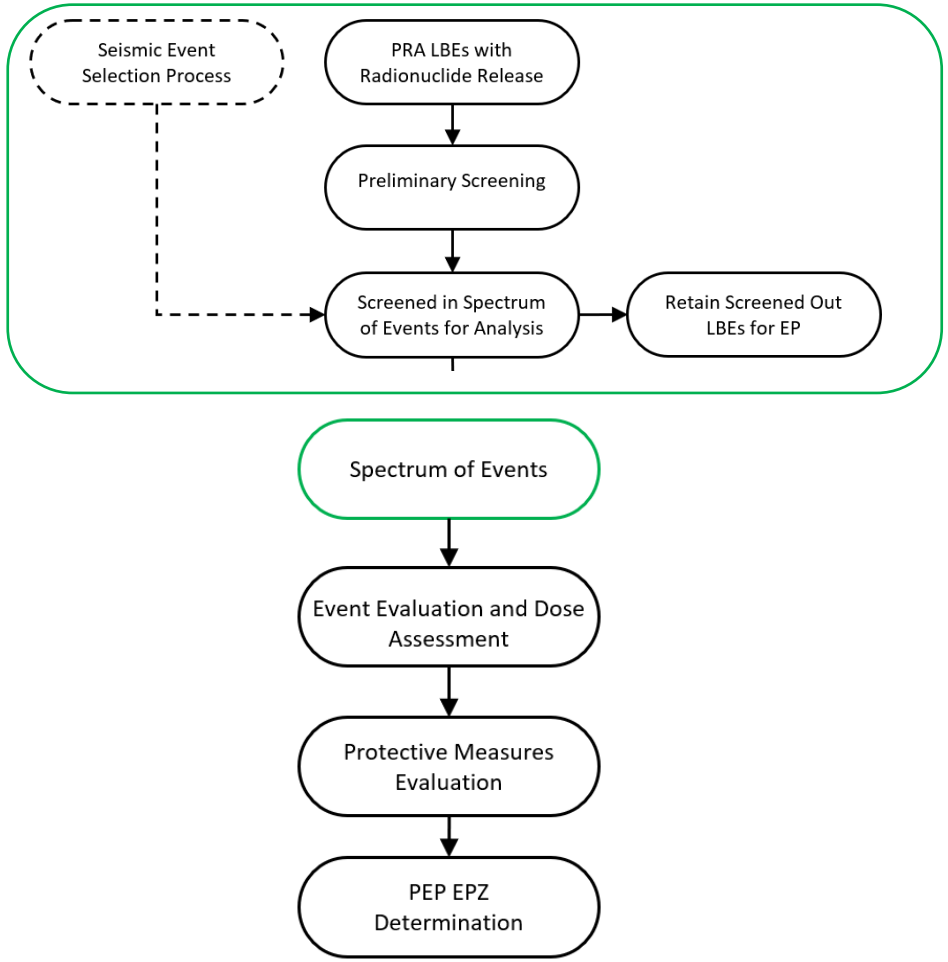


Spectrum of Events

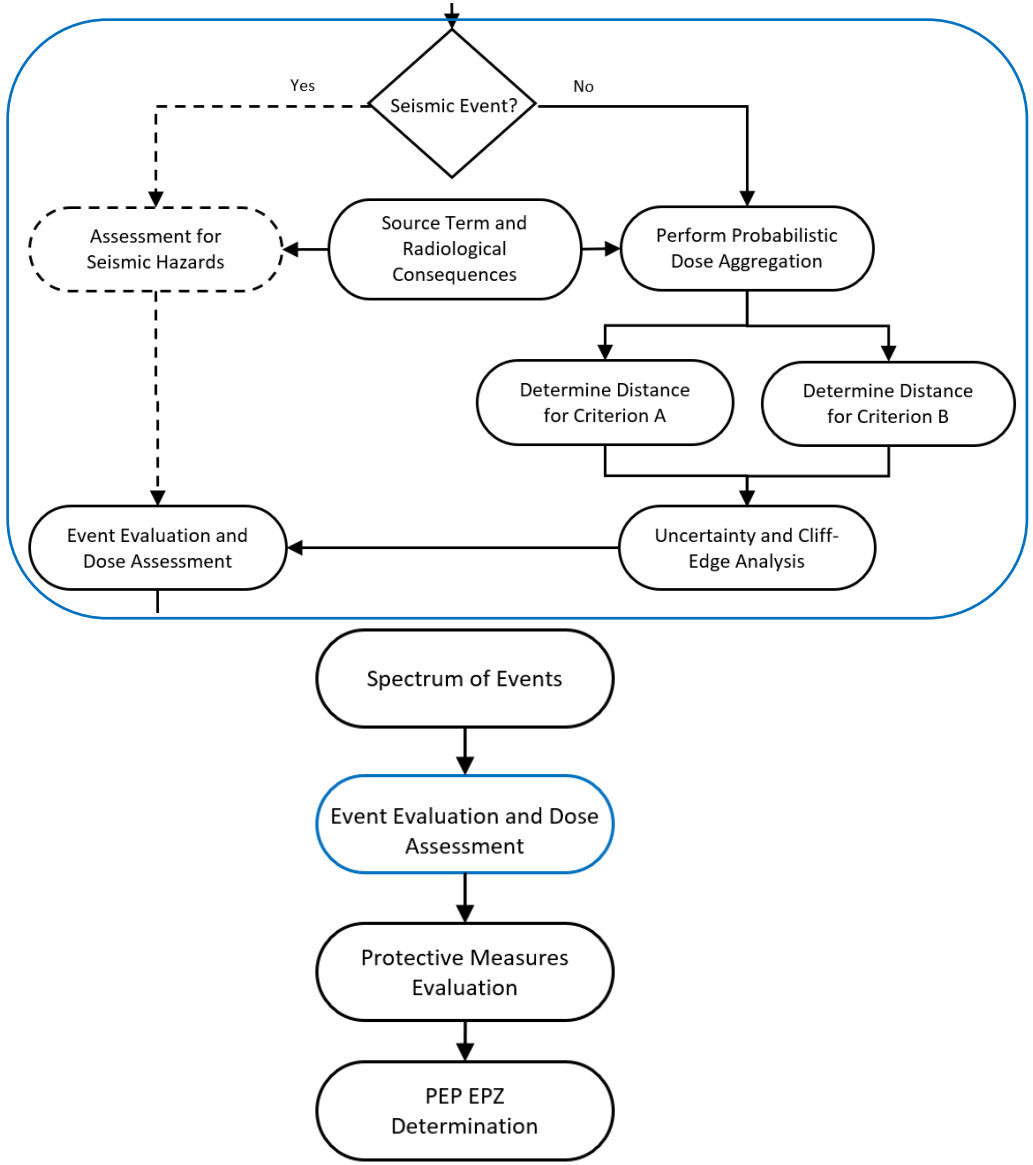
- The process starts with those LBEs (AOOs, DBEs, and BDBEs) with radionuclide release.
  - Based on information from PRA following RG 1.233 (NEI 18-04) and RG 1.247 (ASME/ANS RA-S-1.4-2021)
- Preliminary screening is possible dependent on:
  - Dose size (very small releases)
  - Timing (if sufficient data is available):
    - Time from accident initiation to radionuclide release (including recognition of need for actions, which may not occur at time zero)
    - Time from radionuclide release to when protective actions are necessary
- The preliminary screening reduces the effort necessary for subsequent analyses
- For seismic initiators, use NEI Seismic Event Selection Whitepaper as basis for inclusion into spectrum of events



NEI 24-05, R0

Event Evaluation and Dose Assessment

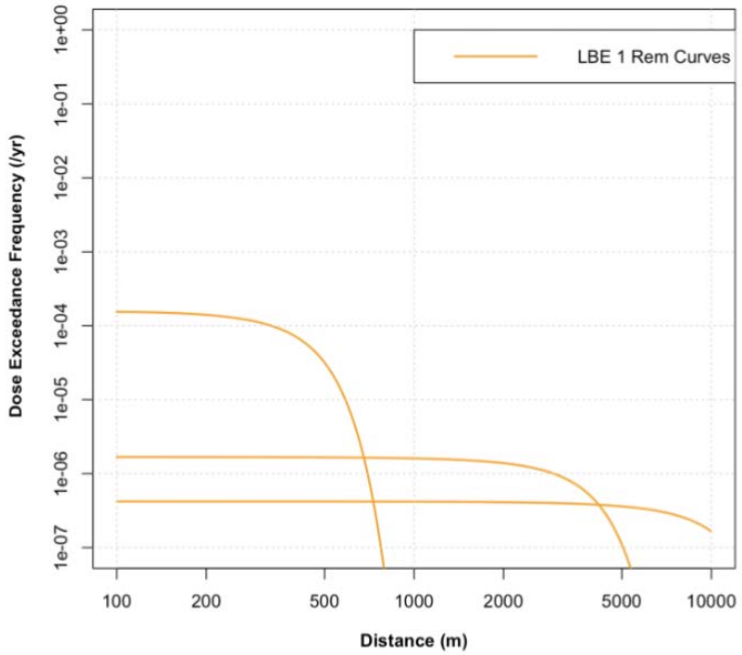
- For those non-seismic LBEs with radionuclide release, either:
  - A probabilistic dose aggregation is performed and dose-versus-distance curves are created for 1 rem and 200 rem
  - Demonstrate at pre-determined distance criteria for 1 rem and 200 rem are met
- Aligns with Appendix A of RG 1.242 and the historic approach utilized in NUREG-0396
- Analyses are performed utilizing cumulative dose-vs-distance curves (a plant-holistic perspective)
- Separate dose-vs-distance evaluation for selected seismic events

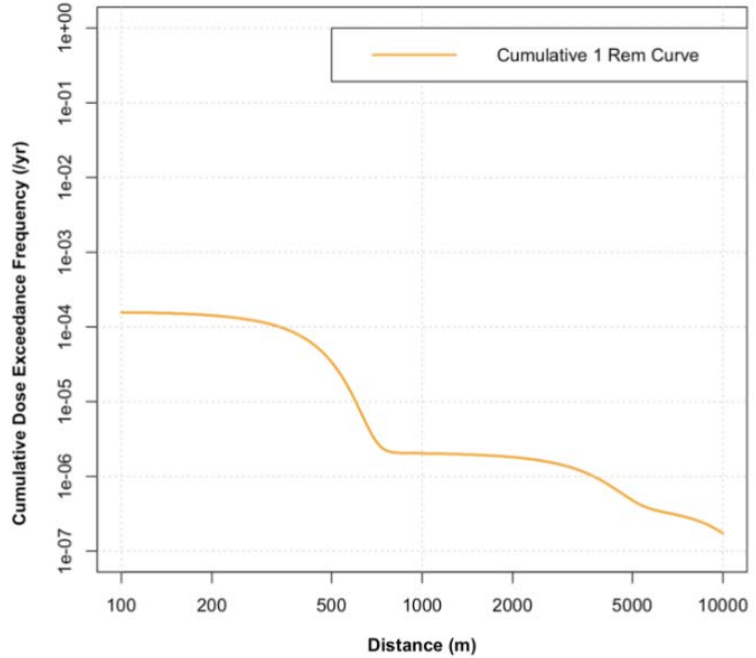


NEI 24-05, R0

Event Evaluation and Dose Assessment

- For probabilistic dose-vs-distance curves
  - Mean values of LBE frequency and 96-hour dose are used
  - Using Mechanistic Source Term Approach and Atmospheric Dispersion and Dose Calculation Methodology to develop dose exceedance @ 1 rem and 200 rem vs distance

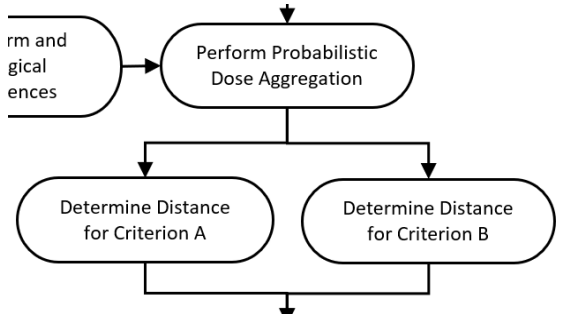


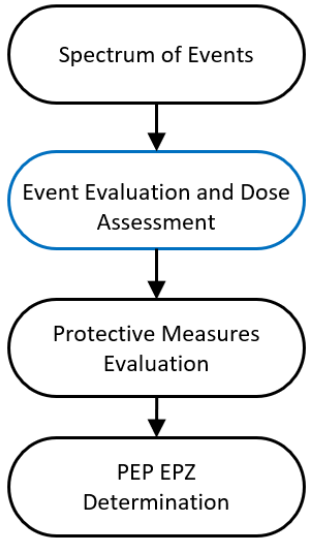


NEI 24-05, R0

Event Evaluation and Dose Assessment

- Two criteria are identified in NEI 24-05 for comparison with the dose aggregation curve, based on NUREG-0396:
  - The criteria guide decision-making, they are not strict quantitative thresholds
- Criterion A:
  - 1 rem at 1E-5 per plant year cumulative freq.
  - Aligns with 50.33(g)(2)(i)(A/B) (1 rem TEDE over 96 hours, protective measures not expected to be needed past distance, EPA PAGs) and consistency with historic criteria (NUREG-0396)
- Criterion B:
  - 200 rem at 1E-6 per plant year cumulative freq.
  - Consistency with historic criteria (NUREG-0396)
  - Provides additional confidence regarding the need for predetermined, prompt actions for low frequency, potentially high consequence events





NEI 24-05, R0

Event Evaluation and Dose Assessment

In NUREG-0396, probabilistic dose aggregation curves based on WASH-1400 were used to partially derive the 10-mile plume exposure EPZ

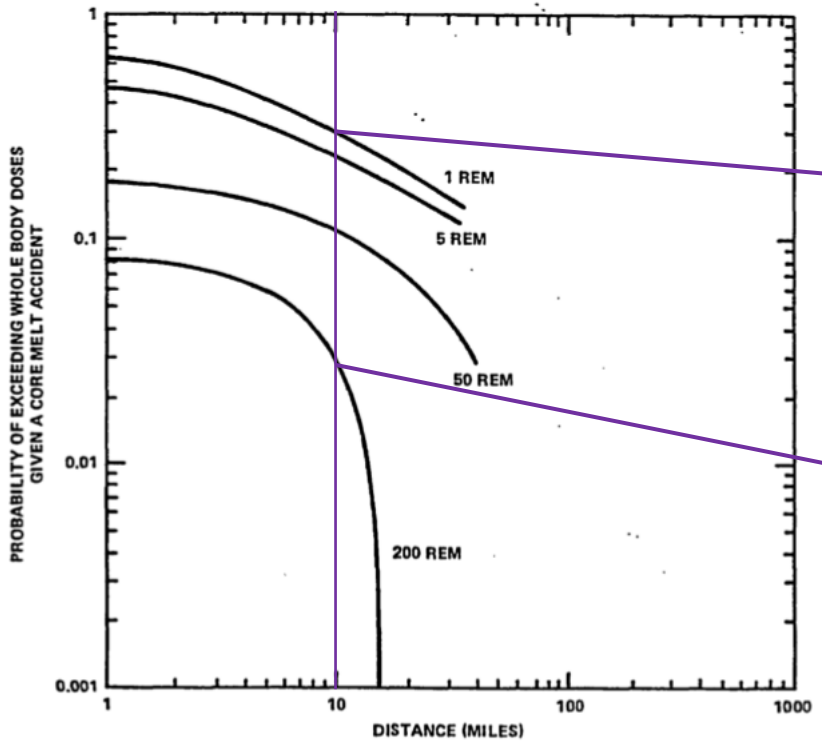


Figure I-11. Conditional Probability of Exceeding Whole Body Dose Versus Distance. Probabilities are Conditional on a Core Melt Accident (5×10^{-5}).

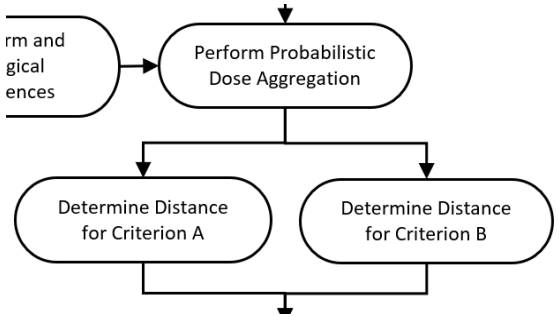
NUREG-0396

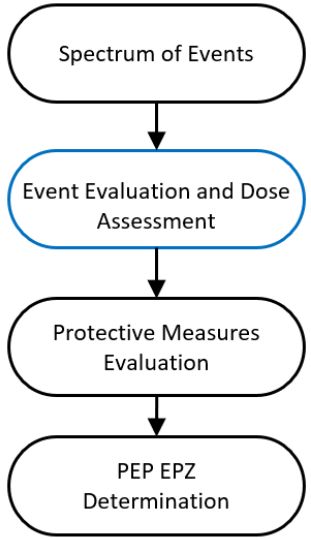
- **1 rem:**

$$5 \times 10^{-5} \left(\frac{1}{\text{yr}}\right) \times 0.3 = 1.5 \times 10^{-5} \left(\frac{1}{\text{yr}}\right)$$

- **200 rem:**

$$5 \times 10^{-5} \left(\frac{1}{\text{yr}}\right) \times 0.03 = 1.5 \times 10^{-6} \left(\frac{1}{\text{yr}}\right)$$





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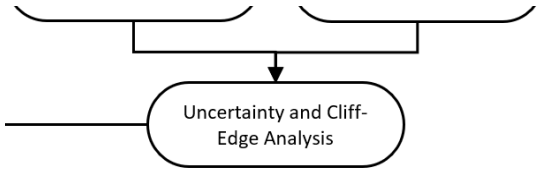
Event Evaluation and Dose Assessment

- Following the assessment, an uncertainty analysis and cliff-edge evaluation is performed
  - Respective PRA/Source Term/Dose Calc uncertainties discussed in other LTRs
  - Bounding analysis and supplemental 5 rem curve
- Aligns with Appendix B of RG 1.242
- Identify cliff edges:
  - Small change in metric causes significantly different result



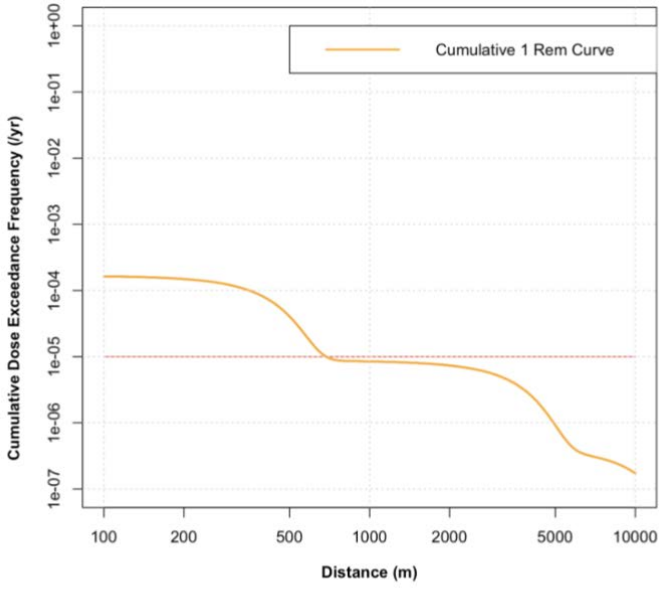
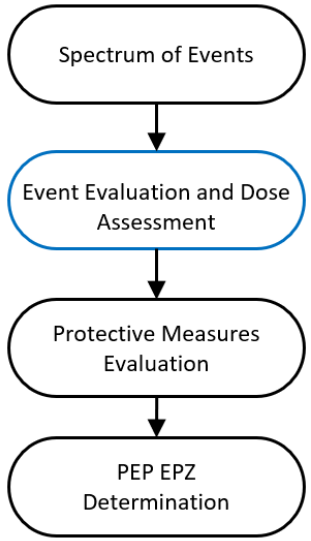


Figure 4.6: Example of Potential Cliff-Edge Effect

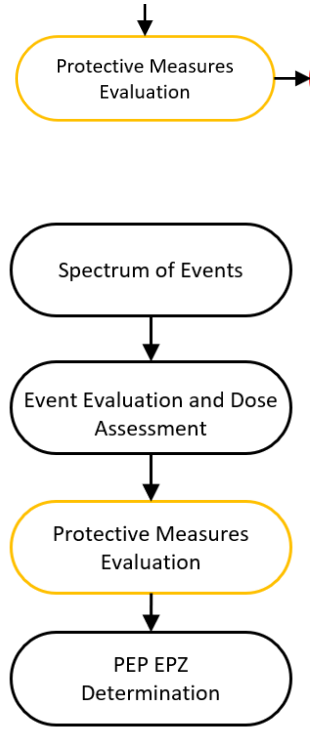
NEI 24-05, R0



NEI 24-05, R0

Protective Measures Evaluation

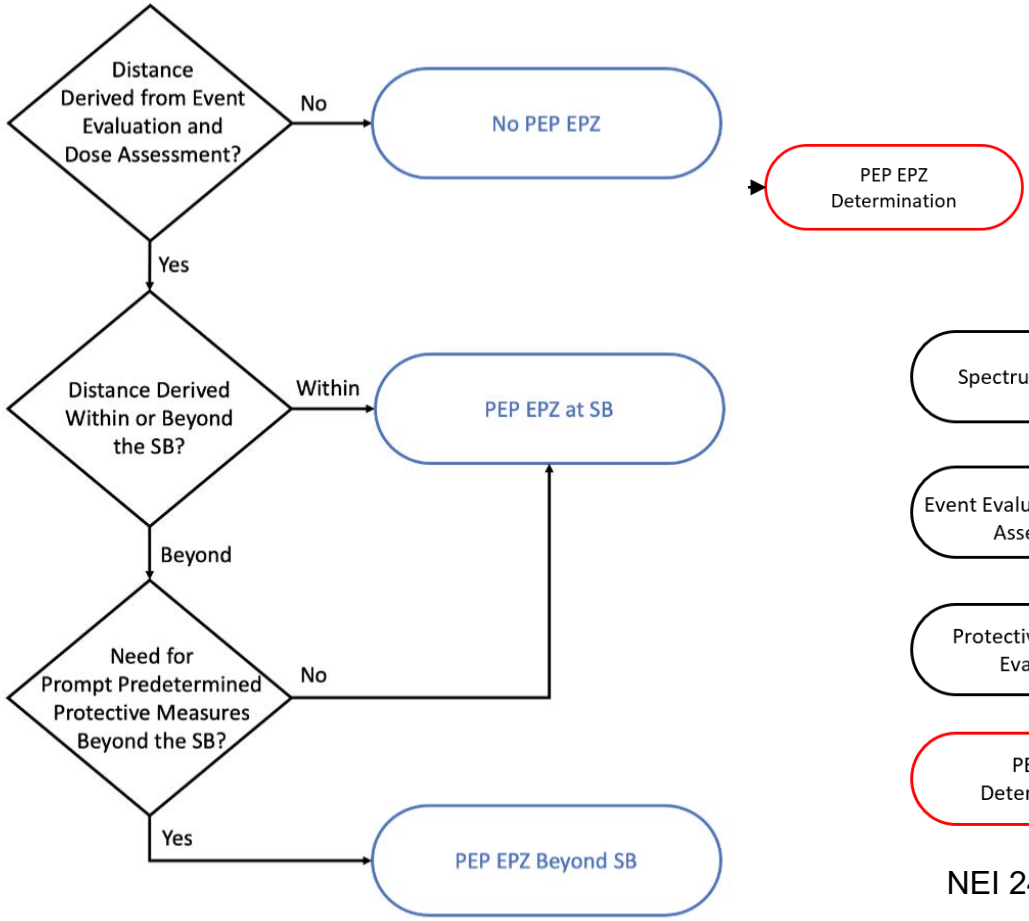
- If a distance is derived beyond the SB, then a protective measures evaluation is performed to determine the need for prompt, predetermined protective measures
- Analysis of LBE Characteristics:
  - Examine event timing, timing for ad hoc actions, initiating events, and specifics of radionuclide release
  - Assess the need for and effectiveness of protective measures
    - Evaluate capabilities of local organizations
    - Sensitivity studies with and without actions
- Site Characteristics Assessment:
  - Evaluate population distribution around site boundary
  - Co-located facilities
- Findings of this analysis are reviewed by the Integrated Decision-Making Process Panel (IDPP) to assess Defense-In-Depth (DID) adequacy when considering uncertainties, model limitations, etc.



NEI 24-05, R0

PEP EPZ Determination

- Three possible outcomes:
- No PEP EPZ:
  - No distance exceeds dose criteria; no protective measures are needed beyond facility structures
- PEP EPZ at Site Boundary (SB):
  - Doses exceed criteria but only within the SB, or exceed beyond SB but do not require predetermined protective measures. Licensee implements onsite measures per §50.160(b)(1)(iii)(B)
- PEP EPZ Beyond SB:
  - Doses exceed criteria beyond the SB and require prompt protective measures. PEP EPZ extends beyond SB, requiring offsite radiological emergency planning under §50.160(b)(1)(iv)(B) and compliance with §50.160(b)(3)



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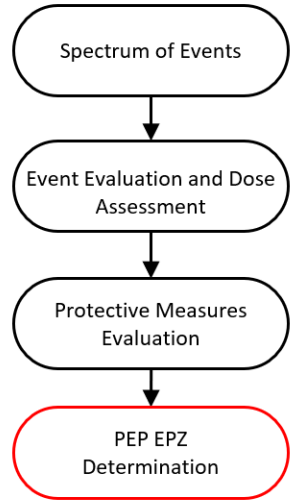

NEI 24-05, R0

Conclusion | Next Steps

X-Energy:

- To submit methodology LTR and coordinate with the NRC staff for review and approval
- Perform technical analysis as outlined by methodology to establish PEP EPZ size

NRC:

- 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).