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

X Energy, LLC (X-energy) Responses to "NRC Staff's Preliminary Questions on the NRC Assessment of the X Energy, LLC Xe-100 Principal Design Criteria Licensing Topical Report"

References:

1) Letter from T. Chapman to U.S. Nuclear Regulatory Commission dated 13 July 2022, “Submission of X Energy, LLC (X-energy) Xe-100 Principal Design Criteria Licensing Topical Report” (ML22195A260)

2) Email from NRC to X-energy dated 17 November 2022, “U.S. NRC Preliminary Questions regarding X Energy LLC Topical Report: "Xe-100 Principal Design Criteria Licensing Topical Report" (ML22322A176)

On November 30, 2022, the NRC held a public observation meeting with X-energy to discuss preliminary questions the staff developed during their review of Reference 1. During the course of the meeting, X-energy provided a response to each of the staff’s clarification questions but identified the need to respond more thoroughly. The purpose of this letter is to provide those written responses to the preliminary questions provided in Reference 2. These responses are intended to support the NRC staff’s preparations for a planned audit on X-energy’s approach to developing the principal design criteria for the Xe-100 reactor.

This letter contains no commitments. If you have any questions or require additional information, please contact Ingrid Nordby at inordby@x-energy.com.

Sincerely,

DocuSigned by:
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Enclosure:

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NRC STAFF'S PRELIMINARY QUESTIONS ON THE NRC ASSESSMENT OF THE X ENERGY, LLC XE-100 PRINCIPAL DESIGN CRITERIA LICENSING TOPICAL REPORT

This topical report (TR) describes the development of the principal design criteria (PDCs) for the X Energy LLC (X-energy) Xe-100 pebble-bed, high-temperature gas-cooled reactor (HTGR). X-energy states that the PDCs described in the TR were developed using the guidance in Regulatory Guide (RG) 1.232, "Guidance for Developing Principal Design Criteria for Advanced (Non-Light Water) Reactors," Nuclear Energy Institute (NEI) 21-07, "Technology Inclusive Guidance for Non-Light Water Reactor Safety Analysis Report: Content for Applicants Using the NEI 18-04 Methodology," Revision 1, and Xe-100-specific probabilistic risk assessment (PRA) safety functions and design features. X-energy requested review and approval of these PDCs by the U.S. Nuclear Regulatory Commission (NRC) for use by future applicants for permits, licenses, certifications, and/or approvals under applicable regulations under Title 10 of the Code of Federal Regulations (10 CFR) governing the development of PDCs.

The NRC staff has prepared the following questions for discussion at an upcoming public meeting:

Questions:

1. The NRC staff recognizes that the Xe-100 design has not been finalized at the time of this TR review. Thus, X-energy's implementation of the risk-informed and performance-based process in NEI 18-04 (called the Licensing Modernization Project (LMP)) is in progress including the development of the PRA for the Xe-100 design. The TR uses the terminologies (e.g., PRA safety function (PSF), Required Function Design Criterion (RFDC), and Complementary Design Criterion (CDC)) associated with NEI 18-04 and NEI 21-07. However, as the Xe-100 design progresses and the LMP process continues to be implemented, it is possible that the LMP yields results that are different from those assumed in this TR. For example, the PRA may identify new or different PSFs that form the basis for new or different CDC(s). **How are LMP terminologies in the TR used in relationship to the preliminary design and the future implementation of the LMP?**

X-energy Response:

LMP terminology used in this TR is consistent with the terminology used in relation to other documentation regarding the Xe-100 design and associated analyses. As an example, X-energy has sought to incorporate the term "safety-significant" in place of "important to safety" as the LMP methodology has an established process for determining such significance, whereas important to safety has significant precedent based on light water reactor safety cases. The review of MHTGR-DC and initial input from the NRC on Revision 1 of this TR provide confidence in the Xe-100 approach to developing PDC that implements LMP processes and terminology. Further confidence will be gained upon NRC endorsement of NEI 21-07 that we anticipate will include any further clarification on the use of LMP-based terminology in the development of PDC. A future revision of this PDC TR is expected and will fully incorporate insights

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from NEI 18-04 activities (i.e., RSF/RFDC/PDF/CDC) and the maturing safety analysis and PRA modelling and is expected to produce a set of PDC unlikely to change significantly following submittal of the PSAR.

2. The TR maintains the use of the terminology "anticipated operational occurrence [AOO]" for various PDCs (e.g., PDCs 25, 26, 29, and so on) the same as RG 1.232. The NRC staff notes that the definition of AOO used in the LMP (see NEI 18-04) is different from the definition in 10 CFR Part 50 Appendix A. **What definition of AOO is intended in the TR?**

X-energy Response:
The NEI 18-04 definition of AOO is used and intended in this TR. The definitions of other LBEs (i.e., DBE, BDBE, DBA) also use the NEI 18-04 definitions. The PDC TR will be updated to clearly state the source and definition of any key terms, especially those developed from NEI 18-04.

3. The TR uses 'postulated accident' for PDCs 31, 34, 61, 64, 70, and 71. It is not consistent with NEI 18-04 terminology for licensing basis events (LBEs). **Why don't these PDCs use NEI 18-04 terminology?**

X-energy Response:
The phrase "postulated accident" will be replaced in all Xe-100 PDC given that it is not a defined term in NEI 18-04. Because the phrase "postulated accident" is not completely analogous to the NEI 18-04 definition of DBA, each replacement of the phrase "postulated accident" in PDC 31, 34, 61, 64, 70, and 71 will be carefully considered.

4. Tables 1 - 4: It is not clear to the NRC staff whether X-energy is requesting NRC staff review and approval of the information in these tables. For example, for Tables 1 and 2, is X-energy requesting the NRC staff review and approval of the acceptability of RSFs and PSFs and their relationship to PDC in the tables? Since the Xe-100 design is conceptual or preliminary at the time of this TR review and thus the implementation of the LMP process (including the probabilistic risk assessment) in NEI 18-04 may not have been sufficiently completed, it is not clear how the RSFs and PSFs in Tables 1 and 2 are final. **What are expectations for NRC staff review of Tables 1-4?**

X-energy Response:
X-energy understands that Tables 1 through 4 of the TR are not needed for the staff to make a safety evaluation of the proposed PDC. The tables assist the reader in understanding different categories of PDC in the context of X-energy's NEI 18-04 implementation (e.g., those PDC that accommodate RSFs/PSFs, support normal operations, considered special treatments), however they do not substantiate the PDC themselves.

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5. Table 6, PDC 1: The phrase "throughout the life" was changed to "for an appropriate period of time" to account for the application of quality assurance special treatments to NSRST [Non-Safety-Related with Special Treatment] SSCs [structures, systems, and components]." The NRC staff understand that this is consistent with NEI 21-07, and while NEI 21-07 is under NRC review, it has not been endorsed. **As such, what other justification can be provided for this change?**

X-energy Response:
X-energy expects NRC to endorse NEI 21-07 without exception in forthcoming regulatory guidance. NRC input on this design criteria will be considered in a future revision of the TR as needed.

6. Table 6, PDC 5: The proposed PDC states that "…shall not be shared among nuclear power units unless it can be shown that such sharing will not significantly impair their ability to perform their required safety functions [RSFs]…" X-energy proposed to replace 'safety functions' used in RG 1.232, Appendix C, Criterion 5 (MHTGR-DC 5) with RSFs. According to RG 1.233, safety-significant SSCs (i.e., Safety-related (SR) and NSRST SSCs) perform both RSFs and risk-significant functions or functions that are necessary for defense-in-depth (DID) adequacy. Accordingly, the use of RSFs in PDC 5 appears to cover only a portion of safety-significant functions. **Why does this PDC use RSFs instead of safety-significant functions?**

X-energy Response:
PDC 5 would not be an RFDC or a CDC under the LMP process. X-energy expects to meet the intent of the phrase "sharing will not significantly impair their ability to perform their required safety functions" leveraging PDC 6, "Monitoring, Inspection, and Testing," which focuses in on special treatments (e.g., "Maintenance Program that assures targets for SSC availability and effectiveness of maintenance to meet SSC reliability targets" [NEI 18-04]).

If RSFs are deemed necessary and sufficient for an orderly shutdown of all units, then X-energy considers limiting the scope of PDC 5 to just RSFs meeting the intent of the PDC. In addition, cooldown was removed from the PDC because the RSFs provide adequate heat removal, reactivity control, and radionuclide retention indefinitely without the need for the unit to cooldown, which MHTGR-DC 26 rationale (4) affirms is not necessarily an RSF (i.e., credited as performed by safety-related SSCs) for this technology.

7. Table 6, PDC 6: X-energy proposes a single, generic PDC (i.e., PDC 6) for RG 1.232, Appendix C, Criteria (MHTGR-DCs) 18, 32, 36, 37, 45, and 46 associated with monitoring, testing, and inspection. The following expressions used in MHTGR-DCs 18, 32, 36, 37, 45, and 46 are not used in proposed PDC 6:

- "structural and leaktight integrity" (MHTGR-DCs 32, 37, and 46)
- "appropriate material surveillance program" (MHTGR-DC 32)
- "integrity and capability of the system" (MHTGR-DCs 36 and 45)
- "for reactor shutdown" (MHTGR-DC 46)

What is the justification for omitting these expressions?

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X-energy Response:

PDC 6 would not be an RFDC or CDC under the LMP process. X-energy is considering using the NEI 18-04 methodology as the basis for removing PDC 6 given that all of the design criteria would be covered as capability targets or special treatments In Chapter 6 and 7 of PSAR based on the structure in NEI 21-07.

"Structural and leaktight integrity" - The PDCs for "structural integrity" are 45, 70, and 71 (currently accommodating Xe-100 RFDC 1.1.4 and 1.2.4), and PDC 6 covers "monitoring, periodic inspection and/or testing to ensure functional capability" in line with PDCs 45, 70, and 71. Leaktightness is not a direct capability requirement for any Xe-100 PDC. PDC s14 and 15, CDC 16, PDCs 30 and 31, and CDC 34 provide criteria related to helium pressure boundary integrity. All of the above PDCs will have defined capability targets (including acceptable helium leakage for CDC 16 and 34 for specific LBEs and normal operations), but some leakage is acceptable as modelled for the Xe-100 and based on past HTGR technology precedent. PDC 6 covers "monitoring, periodic inspection and/or testing to ensure functional capability" in line with PDCs 14 and 15, CDC 16, PDCs 30 and 31, and CDC 34.

"Appropriate material surveillance program" - The specific special treatments to support the HPB PDC, including PDC 31, will be specified in future submittals and will demonstrate and provide confidence that the reliability and capability targets for the HPB PDCs will be met. The current expectation is that a material surveillance program will be part of those special treatments and the wording of PDC 6 is broad enough to include such a material surveillance program, which is expected to be covered under "periodic inspection and/or testing."

"Integrity and capability of the system" - PDC 6 includes the term "functional capability." Capability targets for PDC 34 and 44 will be defined in future submittals. Given that functional capability is already covered in the PDC that accommodate RFDC/CDC, there is no need to repeat the language in PDC 6.

"For reactor shutdown" - Given that shutdown capability is already covered in the PDC that accommodate RFDC/CDC, there is no need to repeat the language in PDC 6.

8. Table 6, PDC 6: As describe above, PDC 6 is a single PDC for monitoring, testing, and inspection of selected MHTGR-DCs. However, several other proposed PDC also contain testing and inspection requirements similar to those associated with PDC 6. For example:

- Table 6, PDC 21: "The protection system shall be designed to permit periodic testing of its functioning when the reactor is in operation, including a capability to test channels independently to determine failures and losses of redundancy that may have occurred."
- Table 6, PDC 61: "These systems shall be designed (1) with a capability to permit appropriate periodic inspection and testing of components that are required to perform safety-significant functions… (4) with a residual heat removal capability having reliability and testability that reflects the safety-significance of decay heat and other residual heat removal…"
- Table 6, PDC 72: "The reactor building shall be designed to permit (1) appropriate periodic inspection of all important structural areas and the depressurization pathway, and (2) an appropriate surveillance program."

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Why is PDC 6 only used to capture monitoring, testing, and inspections from some of the relevant MHTGR-DCs?

X-energy Response:
X-energy seeks to create PDC 6 language that is inclusive of all the monitoring, inspection and testing criteria described in the set of MHTGR-DC. As a design criteria, it is a recognized design principal that SSCs be monitorable, inspectable, and testable. These functions are implemented in an NEI 18-04-based safety case via the selection of special treatments to align monitoring, testing, and inspection capabilities with the appropriate plant programs and operational controls (e.g., Technical Specifications) based on the safety-significance of the functions the SSCs provide. For Revision 1 of the PDC TR:

- PDC 21: The need to test channels independently is already captured as a special treatment for RPS, so there seemed to be no harm in keeping PDC 21 based on the MHTGR-DC endorsed by the NRC in RG 1.232. Regardless of the exact PDC language, the intent of PDC 21 will be met with testing requirements on RPS. With NRC agreement, X-energy could remove PDC 21 and reference that the intent of PDC 21 will be captured by PDC 6 in a future revision to the TR.
- PDC 61: Included requirements for cooling capability and confinement and/or filtering above in addition to the testing requirements. With NRC agreement, items (1) and (4) can be removed from PDC 61 in a future revision of the TR with the basis that they are covered by PDC 6. PDC 61 would then contain the content of items 2, 3 and 5 of the MHTGR-DC.
- PDC 72: Oversight by X-energy. With NRC agreement, X-energy will remove PDC 72 based on the fact that the criteria is sufficiently covered by PDC 6.

9. Table 6, PDC 12 omits the language "or can be readily detected and suppressed." This change appears to be more restrictive, especially considering the stage of the design. **Why was this language omitted?**

X-energy Response:
X-energy intends to modify the PDC 12 language to better align with the RSFs given that inherent reactivity control is a design feature of the Xe-100 based on geometry and material selections, and based on past HTGR operational precedent and, that our current analyses will suppress power oscillations. In future revisions to this TR, X-energy may revise this language to the original RG 1.232 language if analyses show that detection and suppression are required.

10. Table 6, PDC 14 adds the phrase "that may cause changes in core geometry." Based on the level of design information available, it is not clear to the NRC staff that core geometry is the only function of the pressure boundary. Provided RSFs 1.14 and 1.24 are consistent with this, but RSFs 1.31 and 1.32 may not only require geometry to be maintained. **Why was this terminology added to constrain the PDC?**

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X-energy Response:
The HPB is designed to meet RSF 1.3 and PSF 4. The current PDC 14 language in the TR reflects only RSF 1.3. X-energy will revise this TR to add a CDC to PDC 14 that will meet PSF 4.1 and PSF 4.2.

11. Table 6, PDC 19 restricts the scope of the design criteria to AOOs and design basis events (DBEs); while this is consistent with the described function of the operators and control room for safety functions of the facility, exposure to the operators is also included in the scope of the PDC. **What events will operators be protected against radiation exposures in excess of 5 rem total effective dose equivalent (TEDE)?**

X-energy Response:
The Xe-100 operators will be protected against AOOs and DBEs such that they will not receive a TEDE dose in excess of 5 rem. X-energy will consider how to best structure PDC 19 to differentiate between the function that the operators provide for the safe operation of the plant and the goal of protecting the operators from exposures to AOOs and DBEs (i.e., occupational hazards).

12. Table 6, PDC 20 states that "The protection system shall be designed… and (2) to sense conditions to initiate the operation of systems and components that are to perform required safety-significant functions." The NRC staff interprets "required safety-significant functions" to be RSFs in RG 1.233.

RG 1.232, Appendix C, Criterion 20 (MHTGR-DC 20) states that "The protection system shall be designed … and (2) to sense accident conditions and to initiate the operation of systems and components important to safety." The expression 'systems and components important to safety' in MHTGR-DC 20 is not limited to those performing RSFs, i.e., SR SSCs according to RG 1.233. **Why is this PDC limited to SSCs performing RSFs?**

X-energy Response:
Currently the Xe-100 reactor protection system (RPS) only performs RSFs (i.e., control reactivity, control water/steam ingress), as such, Part (2) of the PDC is only focused on RSFs. Part (1) focuses on meeting SARRDL for AOOs which ensures that the protection system maintains the Xe-100 within its normal operating envelope.

X-energy will consider combining Parts (1) and (2) because the differentiation of "initiate automatically the operation of" and "to initiate the operation of" may not be warranted for the Xe-100 design. If the function in Part (2) needs to be expanded to include "safety-significant functions," X-energy will consider other systems beyond RPS that could perform these functions.

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13. Table 6, PDC 20: The first instance of Xe-100 PDC 6 uses the expression 'required safety-significant functions' but the red-line strikeout replaces this with 'required safety functions.' **Why is this inconsistent?**

X-energy Response:
As described in the response to Question 12, currently the Xe-100 reactor protection system (RPS) only performs RSFs (control reactivity, control water/steam ingress). X-energy notes that the final wording and the red-line strikeout are not consistent and this editorial error will be corrected in the next revision to the TR by modifying "safety-significant" to read "safety."

X-energy notes that there is a minor editorial error in Question 13. The question states "…first instance of Xe-100 PDC 6…" and X-energy notes that the original intention was most likely to state "…first instance of Xe-100 PDC 20…"

14. Table 6, PDC 26 omits of fuel loading from the scope of the PDC. **Why is this, given fuel loading is a continuous reactivity manipulation for the design?**

X-energy Response:
Per RG 1.232, this portion of PDC 26 is focused on bringing the plant to cold shutdown and is driven by the need to "inspect and repair a plant following an accident." While the Xe-100 fuel loading is continuous, it is an activity for normal operations.

Removing fuel pebbles does provide a means to reduce reactivity in the core; however, removing fuel (or adding a poison material, which is not planned in the Xe-100 design basis) currently is not necessary for DID adequacy.

15. Table 6, PDC 34 (and specifically, the RFDC portion) removes constraints on the role of the system. It is not clear what constitutes "effective cooling" with respect to the safety function (e.g., what SSCs are needed to be cooled and what functions does this cooling support). Further, it is not clear what role the RFDC/CDC split for this PDC is. **Why is the "safety-significant function" language in the CDC versus having this make-up part of the RFDC?**

X-energy Response:
The intent of splitting up PDC 34 into RFDC and CDC is to align with the guidance in NEI 18-04, particularly Table 5-2, Layer 2 qualitative DID guidance, "Minimize frequency of challenges to SR SSCs." To meet this criterion, our active heat removal system described in CDC 34 is being designed to be available for all AOOs as the preferred means of heat removal in such events. The passive system will be operational and available for all DBAs, DBEs, and internal hazard BDBEs, to include AOOs and normal operations. However, the design requirement (as interpreted from Table 5-2, Layer 2 qualitative DID) is for an active cooling

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system to be available for normal operations and all AOOs such that the passive cooling system is only relied upon for DBEs, DBAs, and BDBEs.

Effective cooling will be defined in more detail in future submittals with respect to safety analysis and PRA. At a high-level, effective cooling for the CDC is defined as meeting PDC 10 for the SARRDL and effective cooling for the RFDC is defined as meeting PDC 16 and the radioactivity release limits described in NEI 18-04.

To concur with the response to Question 3, "postulated accidents" will be changed to DBAs.

16. Section 4, "REFERENCES," contains several that are not used in the TR although they are described as being referenced.

X-energy Response:
X-energy will retain references 3, 6, 7, and 8 and remove references 1, 2, 4, 5, 9, and 10.

17. Section "ABREVIATIONS [sic]," (Page 6 of 80) contain abbreviations that are not used in the TR (e.g., SRDC, PSAR), although they are described as being used.

X-energy Response:
X-energy will revise "DC" to "design certification," change "HTR" to "HTGR," and remove PSAR, SAFDL, and SRDC.