U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

Advancement of High Temperature Gas Cooled Reactors for Grid-Scale Applications: Xe-100 Conceptual Design and Risk-Informed, Performance Based Licensing

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Pathway: First of a Kind Demonstration Project
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Scope of the Project. The Xe-100 Concept Finalization (XeCF) Project will accelerate deployment of advanced reactors (ARs) by enabling completion of X-energy's grid-scale High-Temperature Gas-cooled Reactor (HTGR) Conceptual Design while applying the Risk-Informed, Performance Based licensing framework. Project scope is organized around four Tasks:

- Provide project coordination, to include administration, configuration, document, subcontract, and financial management; scheduling; and project controls support to ensure deliverables and milestones are achieved.
- Perform regulatory development through NRC engagement on key topics, including: 1) Execute the risk-informed, performance-based (RIPB) framework in support of conceptual design; 2) Develop White Papers to familiarize the NRC Staff with the Xe-100 design; 3) Execute the Technology-Inclusive Concept of Application (TICAP) framework with the completed, mature Xe-100 concept design; and 4) Administer an Appen. B Quality Assurance Program.
- Define the requirements and functions that an economically competitive, licensable, low-technology risk advanced reactor must meet in order to comply with DOE AR demonstration project, electricity, and process heat customer needs.
- Complete the Xe-100 Reactor/Plant Conceptual Design, to include finalizing the Xe-100 functional baseline to demonstrate that the system can achieve the required performance and programmatic goals; and conducting design, modelling, and simulation analyses to mature all Xe-100 reactor/plant Systems, Structures, and Components (SSCs). At completion, conduct an external Basic/Final Design Readiness Review.

Objectives of the Project. The Project enables X-energy to complete the Conceptual Design phase for a grid-scale (300 MWe plant based on four, 75 MWe modules) application of the HTGR technology. Concurrently, we engage with the NRC to address key technical topics through 1) incorporation of the RIPB/TICAP licensing methodology and 2) presentation/ delivery of Xe-100 design-specific white papers. By accomplishing these objectives, X-energy will proceed into Basic/Final Design phase, leading to submission of a Design Certification license application to the NRC in the early 2020s. It also ensures a predictable non-LWR licensing process by familiarizing the NRC staff with specifics of HTGR design/analysis methods and by exercising RIPB licensing evaluation techniques against a specific non-LWR design.

Description. X-energy has invested significant effort and resources over the past 10 years (including ~$47 million of private funding) to develop a Generation IV AR Pebble Bed HTGR. We have assessed domestic and international electricity and process heat market needs, available technologies and technology readiness, risks, and level of effort required to bring an AR to market in the U.S. The completion of our XeCF Project provides the foundation for efficient and effective commercial demonstration of the Xe-100 HTGR by the mid-to-late 2020s. This Project matures our design, improves economic projections, and enables us to deliver a U.S.-based AR solution increases competitiveness of the domestic nuclear industry.

List of Major Deliverables and Tasks (presented in chronological order):

Deliverable	Date
Monthly Progress Reports	Monthly
Quarterly Project Summary Reports	Quarterly
Functional Architectural Summary Report	4/30/20
Physical Architecture Summary Report	6/26/20
Plant Design Requirements Document (PDRD) Summary Report	6/30/20
Integrated System Performance Summary Report	10/30/20
Performance Verification Analysis Summary Report	10/31/20
Major SSCs Performance Verification Analysis Summary Report	11/30/20
Risk-Informed, Performance Based Framework Summary Report	12/15/20
Regulatory White Paper and Engagement Assessment Summary Report	12/31/20

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Methods to Be Employed. X-energy employs a comprehensive Systems Engineering approach to establish the Xe-100 design process. Our approach defines clear completion gates and success criteria throughout the Conceptual Design phase that leads to a more mature, measurable design at Project completion. X-energy also exercises the RIPB process described by the Licensing Modernization Program (LMP), TICAP, and in NEI 18-04 and DG-1353, which forms the basis of our iterative design development process, drawing upon X-energy's HTGR LMP demonstration – completed in 2018. Use of the RIPB process improves the Xe-100 design regulatory certainty and provides the opportunity to leverage this intrinsically safe reactor design to optimize demonstration costs and subsequently enhance economic confidence.

Potential Impact of the Project. Our XeCF Project addresses the iFOA goals: to establish innovative, domestic nuclear industry-driven designs and technologies (our Xe-100) to improve the overall economic outlook for nuclear power in the U.S. ***This Project builds confidence consistent with the DOE AR Demonstration Project requirements, as well as for future private investment that will be essential to complete a FOAK demonstration.*** In the long-term, the Project enables ARs to compete domestically and compete for international nuclear export opportunities. The benefits of our Project are:

- Advances the Xe-100 HTGR design through the Concept Design phase and into the Basic/Final Design phase – a reactor that addresses niche markets where long-term nuclear co-generation energy (electricity and process heat) is a necessity
- Adds further clarity to aspects of the NRC's non-lightwater reactor RIPB regulatory approach, benefitting all U.S. ARs
- Provides a forum for familiarizing NRC staff with key aspects of HTGR design through white papers and presentations

The outcomes of the XeCF Project are towards U.S. competitiveness, improved timelines, and regulatory certainty:

U.S. Competitiveness:

- Improves the maturity of a U.S.-based Generation IV AR design that is technologically superior compared to international competitors. This increases the probability of deploying and capturing future electricity/process heat nuclear projects (example potential customers include: The Kingdom of Jordan, Poland, U.S. domestic mineral mining/mineral processors, and two Canadian electrical utility operators – all considering AR deployment before 2030).
- Leverages DOE's +$250M investment in the development of UCO TRISO fuel by advancing an AR that uses this fuel form. This increases Xe-100 licensing basis maturity and improves the maturity of commensurate construction cost and schedule estimates. This brings with it added confidence in the economic performance projections (Levelized Cost of Energy [LCOE], overnight costs, and capital costs) that could be used to evaluate technologies for potential future DOE AR demonstration projects.

Improving Timelines:

- Enables DOE to achieve their targeted mid-to-late 2020s AR demonstrations by furthering innovative HTGR designs, maturing FOAK AR design certification and regulatory elements, and addressing fundamental NRC technology-inclusive licensing issues that will benefit all AR projects.
- Completes the Xe-100 conceptual design by late 2020—critical to ensuring a mid-to-late 2020s demonstration for the Xe-100 by enabling more detailed and meaningful pre-application engagement with the NRC faster than private funding alone will allow.

Resolving Regulatory Issues:

- The RIPB framework improves the regulatory certainty of X-energy's Xe-100 design and enables us to leverage its intrinsically safe design and passive safety features to optimize license development, NRC license application review time/cost, design and construction costs, and subsequently enhance confidence in deployment and operations costs for other non-LWR HTGRs.
- Provides licensing pathway clarity that will benefit not only X-energy, but all ARs entering more mature phases of design, development, and regulatory interaction.

Major Participants. The X-energy Team is comprised of: X Energy LLC (X-energy), Southern Nuclear Company, Burns&McDonnell, and the Idaho National Laboratory. Additional subcontracted engineering services are provided by Aerotherm and MPR Associates.