Market-driven Optimization of the XENITH Microreactor

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Pathway: Advanced Reactor Development

Abstract

Scope. X Energy, LLC (X-energy) proposes to mature a transportable microreactor design that maximizes near-term manufacturability and cost-competitiveness for commercial markets. The X-Energy Next-generation Integrated Transportable High-temperature (XENITH[1]) Microreactor Plant features a 20 megawatt-thermal (MWth) high-temperature heat source, powered by X-energy's inherently safe proprietary tristructural isotropic (TRISO) fuel, TRISO-X. The project's primary focus is to *complete preliminary design of this innovative Nuclear Reactor System*, which can drive power conversion systems to commercially generate emission free electricity, district heat, and high-temperature process heat for industrial applications. The presented project completes key steps in the *design* of a Microreactor and the associated Shielding, Heat Transfer, Power Conversion, and Deployment & Transport systems.

Background. Over the past 5 years, X-energy has engaged in the development of several compact, high performance, TRISO-fueled special purpose reactors including a $65M investment in the design of a rapidly deployable nuclear power plant for the U.S. Department of Defense (DoD) Strategic Capabilities Office (SCO). In each of these efforts, X-energy extended the high temperature gas-cooled reactor (HTGR) technology platform with high performance materials, compact power transport and conversion systems, and novel engineering to enable operational flexibility, portability, reliability, and ruggedness for transport. Through these projects, X-energy has built a specialized best-in-class engineering team, an integrated modeling and simulation suite, and a quality process that supports agile nuclear design prototyping.

Impact. In 2022, X-energy conducted a market survey of applications, customers, and stakeholders to identify technical and economic requirements of small, standalone power generating plants for remote communities and mining operations, campus combined heat and power (CHP), critical infrastructure resiliency deployments, disaster relief, and maritime power in the continental U.S., Alaska, and Canada. Based on this input, our ~5 megawatt-electric (MWe) XENITH, deployed individually or in bundles for higher power, competes well in these applications against current and proposed sources of power as measured by the Levelized Cost of Electricity, providing sustained emission free power that replaces diesel alternatives.

Objective. X-energy and their partner team will accelerate the market readiness of the XENITH microreactor system toward a first-of-a-kind (FOAK) system featuring an innovative reactor design and proven technologies for balance of plant systems. The primary goal is to complete preliminary design of a versatile microreactor System, demonstrating performance and safety of form, fit, and function using X-energy's multiphysics design and analysis suite. Additionally, we will leverage our partners' capabilities to deliver conceptual designs of a compact high-temperature heat exchanger (Bosal) and a

[1] Trademark pending

high-performance helium circulator (Calnetix). Aided by INL expertise, we will exploit ASME-codified high temperature materials and weldments. ORNL, with their state-of-the-art tools and methods, will assist in the design of sophisticated shielding systems that enable safe operation and transport. These are all key components of the baseline plant architecture that enable the concepts of operations and deployment that we envision for the plant.

X-energy will perform design trade-offs to converge on optimal solutions through two Design and Analysis Cycles (DAC), interspersed with two Requirements Analysis Cycles (RACs). To ensure that the design is realizable for near-term deployment, we mature the cost model and supply chain assessments in parallel with design activities. The ongoing synergy of technical and economic analysis will ensure successful achievement of the shared goal of X-energy and the DOE: accelerating commercialization of transportable reactors, their enabling technologies, and a US-centric supply chain.

List of Deliverables: Within this project scope, the following are the major deliverables proposed.

- Customer Design Review – DAC #1 slide deck
- Customer Design Review – DAC #2 slide deck
- System Design Requirements Document
- Reactor System Design Description
- Plant System Design Description
- Cost and Supply Chain Report
- Monthly Progress Reports

Methods to Be Employed. X-energy employs a comprehensive Systems Engineering approach to design that includes: requirements, conceptual architecture, sizing, design and confirmatory analysis. X-energy's microreactor team has the necessary skillsets, experience, and tools for an agile but quality oriented, NQA-1 compliant, design process. For the XENITH cost evaluation assessment, we use a detailed, hardware system-based Work Breakdown Structure. We perform cost assessments with inputs from potential suppliers and internal cost estimates, using parametric optimization, to evaluate changes in the FOAK and Nth-of-a-kind (NOAK) system costs.

Potential Impact of the Project. The XENITH project provides a direct, focused path to U.S.-centric microreactor industry competitiveness, consistent with the objectives of *Pathway 2: lead directly to advances in the innovation and competitiveness of a broad set of domestic nuclear reactor designs and technologies*. The project enables microreactor technology to become competitive and replace the fossil-fired plants serving similarly small applications. By building upon on the well-established HTGR platform, turbomachinery developed for, and adapted from, similarly demanding applications, and integrating insights gained from our recent microreactor design efforts, the benefits of XENITH include:

- Getting to market in the next 3-5 years and establishing advanced microreactors as a near-term option for zero-emission power and heat for off-grid, grid resiliency, and special purpose energy markets;
- Enabling innovations that enhance the economic competitiveness of inherently safe, modular HTGRs;
- Paving the way for the licensing of transportable nuclear reactors; and
- Further leveraging DOE's +$800M investment in the development of uranium carbide uranium oxide (UCO) TRISO fuel, graphite, and high-temperature alloys, enabling high performance and safety in a small package.

Major Participants. **X-energy** leads the reactor design and analysis, and overall plant architecture, and deployment concept. **Bosal** and **Calnetix** provide the conceptual designs of the compact, high-temperature intermediate heat exchanger and circulator, respectively. **INL**, who led the ASME BPVC Section 3 Division 5 high temperature materials qualification campaign, provides guidance on integration of these materials into this system, specifically regarding joining and weldment issues. Finally, **ORNL** applies their SCALE Code System to assess radiation shielding designs for these compact systems.