National Reactor Innovation Center

NRIC GAP Assessment Update

Summary of Gaps and NRIC’s Role in Addressing them

04/02/2025

This presentation represents the results of the Gap Assessment but does not reflect DOE policy decisions.

MIS-25-83686

Summary and Key Takeaways

- Initial Gap Assessment in 2020
- Current update, engaged:
  - 19 Reactor Developers,
  - 13 DOE-NE National Technical Directors,
  - 7 National Laboratory Representatives,
  - 2 Industry Organizations.
- Synthesized feedback into 10 Gap Categories with 18 capability needs.
- Critical current needs are:
  - Additional test facility capacity to efficiently demonstrate reactors.
  - Advanced construction technologies.
  - Pilot-scale fuel fabrication capability.

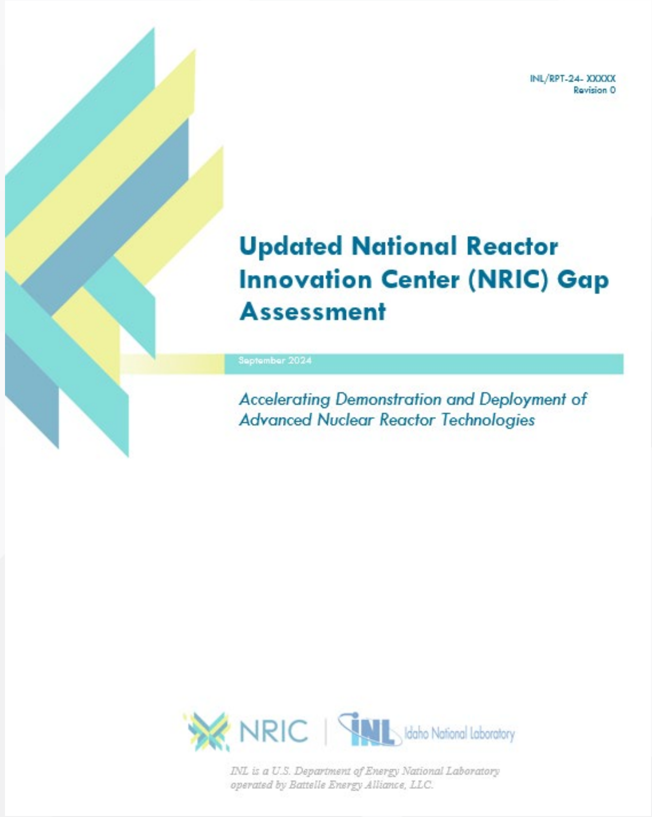
Initial Gap Assessment Performed in 2020

- Identified needed national laboratory capabilities.
- Collected data from industry and stakeholders.
  - 37 industry reactor concepts were considered.
  - Capability needs were compiled into 20 areas.
- Major outcomes:
  - Test beds (NRIC-DOME, LOTUS).
  - Experimental infrastructure.

#	Fundamental Problem
1	DOE Sites for Temporary Reactor Demonstrations
2	DOE Sites for Stand-Alone or Commercial Reactor Demonstrations
3	Feedstock special nuclear material (HALEU, Pu, U233) for Fuel Fabrication
4	Work with SNM and Radiological Material
5	Experimental Fuel Fabrication Facilities
6	Fuel Development and Qualification
7	Characterization of Fresh and Irradiated Molten-Salt Fuels
8	Nuclear Data for Fast Reactors
9	Components and Component Test Facilities (CTFs)
10	Configuration Management (CM) Processes
11	Modeling & Simulation (M&S)
12	Transportation of Advanced Reactor Fuels
13	DOE Authorization of Industry Reactor Demonstrations
14	Transition from DOE Authorization to Nuclear Regulatory Commission License
15	NRC Licensing for Advanced Reactors
16	Integrated Energy Systems (IES) Testing Capabilities
17	Office Space at MFC for Industry Collaboration
18	Decontamination & Disposition (D&D) of Reactors and Used Fuel
19	Cost and Schedule for Work at National Labs
20	Trust in DOE and the National Labs

Why Update the Gap Assessment Now?

- Significant changes occurred In the last 5 years:
    - NRIC implemented programs to address initially identified gaps.
    - Advanced Reactor Demonstration Program (ARDP) was initiated resulting in refinements of the gaps.
    - Significant increase in nuclear startup companies.
- Achieve NRIC's mission to bridge the gaps:
    - NRIC is an agile, learning and connected organization.
    - Continuous evaluation of capabilities and needs.
- The Gap Assessment Update:
    - Assesses progress, gaps and strategies.
    - Aligns program activities with stakeholders' needs, goals, objectives, and priorities.
    - Establishes and prioritizes near-term focus areas.



Gap Assessment Update Process

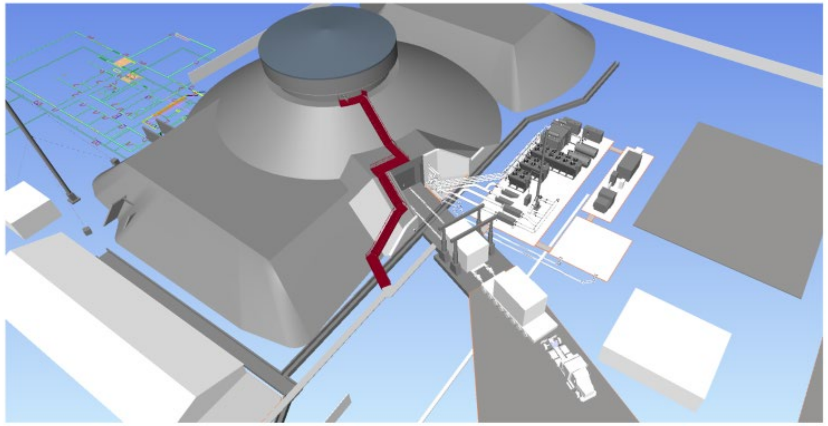
1. Reviewed the initial Gap Assessment and assessed progress
2. Updated stakeholders list
3. Conducted relevant literature reviews
4. Developed questions and interviewed stakeholders
5. Collected and analyzed feedback
6. Developed matrices by grouping gaps based on types of needs and commonalities.
7. Provided options for addressing gaps based on NRIC's capabilities (current and aspired), including National Laboratories and industry partners.

Stakeholders Who Provided Input

Stakeholder Type	Company / Organization / Program
Reactor Developer	Aalo, AlphaTech, Antares, Blue Energy, BWXT, Flibe, General Atomics, GE-Vernova, Mirion, NanoNuclear, Natura, NuScale, Oklo, Radiant, Seaborg, TerraPower, ThorCon, USNC, and Westinghouse.
National Technical Directors	Advanced Materials and Manufacturing Technologies, Advanced Reactor Regulatory Development, Advanced Reactor Safeguards and Security, Advanced Sensors and Instrumentation, DOE Office of Spent Fuel and High-Level Waste Disposition, Fast Reactors, High Temperature Gas Reactors, Integrated Energy Systems, Microreactors, Molten Salt Reactors, Nuclear Energy Advanced Modeling and Simulation, Nuclear Science User Facilities, Space Nuclear, and TRISO Fuel and Graphite Qualification Programs.
National Laboratories	ANL, INL, LANL, ORNL, PNNL, SNL, and SRNL.
Industry Organizations	EPRI, NEI.

Focus of Feedback

- What is needed?
- What is the benefit?
- What is available?
- What can DOE/NRIC do to help?



Gap Categories and Capability Needs

Gap Category	Capability Needs (Facilities, Processes, Methods, Components, Plans, Strategies)
Facilities	Reactor demonstration and testing facilities.
	Pilot-scale fuel fabrication facilities.
	Benchmark experimental facilities.
	Nuclear testing facilities (e.g., irradiation, post-irradiation examination).
	Non-nuclear testing facilities (e.g., thermal-hydraulic testing with electric surrogates).
Advanced Construction Technology / Support Technologies	Advanced construction materials development.
	Methods and technology development.
	Process improvement (e.g., project management techniques and tools, digital engineering).
Supply Chain	HALEU availability.
	Reactor components availability.
Regulatory Compliance	NRC regulatory considerations.
	DOE regulatory considerations.
Backend of the Fuel Cycle	Storage, transportation, treatment, and disposal; decommissioning of demonstration reactors.
Modeling and Simulation	Use, validation, and configuration control of tools and models.
Siting	DOE and non-DOE sites.
Communication/Collaboration	Collaboration with stakeholders and contracting with INL.
Financial and Human Capital	Funding uncertainty for near-term design / demonstration and long-term deployment as well as the need for a stable and sufficiently trained workforce.
Safeguards and Security	Strategies for HALEU fuels including remote, autonomous, and maritime application.

Gap Categories and Capability Needs

Gap Category	Capability Needs (Facilities, Processes, Methods, Components, Plans, Strategies)
Facilities	Reactor demonstration and testing facilities.
	Pilot-scale fuel fabrication facilities.
	Benchmark experimental facilities.
	Nuclear testing facilities (e.g., irradiation, post-irradiation examination).
	Non-nuclear testing facilities (e.g., thermal-hydraulic testing with electric surrogates).
Advanced Construction Technology / Support Technologies	Advanced construction materials development.
	Methods and technology development.
	Process improvement (e.g., project management techniques and tools, digital engineering).
Supply Chain	HALEU availability.
	Reactor components availability.
Regulatory Compliance	NRC regulatory considerations.
	DOE regulatory considerations.
Backend of the Fuel Cycle	Storage, transportation, treatment, and disposal; decommissioning of demonstration reactors.
Modeling and Simulation	Use, validation, and configuration control of tools and models.
Siting	DOE and non-DOE sites.
Communication/Collaboration	Collaboration with stakeholders and contracting with INL.
Financial and Human Capital	Funding uncertainty for near-term design / demonstration and long-term deployment as well as the need for a stable and sufficiently trained workforce.
Safeguards and Security	Strategies for HALEU fuels including remote, autonomous, and maritime application.

Facilities – Reactor Demonstration

What is needed?	The ability to rapidly test and demonstrate advanced nuclear technologies in a cost-effective and timely manner.
What is the benefit?	Focus on reactor design, not demonstration facility siting and associated design and regulatory burden.
What is available?	NRIC-DOME and LOTUS. These facilities have size and capacity limitations, are restricted to DOE authorized reactors, and allow for one reactor demonstration with facility turnaround time of at least one year (there are 80+ reactor developers). External fueling, defueling, and storage facilities are needed to support rapid sequencing of testing.
What can DOE/ NRIC do to help?	Establish a built-for-purpose flexible facility for testing several reactors concurrently with the ability to easily / rapidly expand facility capabilities to meet the ambitious demonstration and deployment objectives of reactor developers.

Advanced Construction

What is needed?	• Improvements in nuclear-grade construction materials (e.g., rebar, concrete) • Technology development (e.g., robot placement of rebar, automated weld inspection, advanced seismic isolation, automated refueling, remote operations, digital twin technology). • Process improvements in project management techniques and tools (e.g., Building Information Modeling).
What is the benefit?	Faster and more cost-effective construction of reactors.
What is available?	Established developers are leading improvements in nuclear-grade construction materials and construction methods (e.g., 3D printed concrete).
What can DOE/ NRIC do to help?	• Conduct workshops with experts and stakeholders to develop plans for specific materials, methods, technologies, and processes. • Collaborate with Technical Work Groups, National Laboratories, and industry organizations to optimize current capabilities prioritizing needs based on attainable demonstration timelines. • Fund initiatives to test and demonstrate advanced construction technologies.

Facilities – Fuel Fabrication

What is needed?	• Pilot-scale fuel fabrication capability for various fuel types (e.g., TRISO, salt fuels, metallic fuels). • Fuel design support - cross-cutting need to address considerations related to reactor operation, storage, transportation, and disposal.
What is the benefit?	• Cost-effective fuel fabrication to support reactor demonstrations in a timely manner. • Leverage specialized technical expertise at National Laboratories.
What is available?	• Minimal existing fuel fabrication capacity within the DOE complex. Low Enriched Fuel Fabrication Facility (LEFFF) at LANL has a small capacity taken by a vendor. Another vendor is repurposing facilities at MFC. • Several private reactor developers with current (or near-term) TRISO fuel fabrication capability.
What can DOE/ NRIC do to help?	• Establish a pilot-scale fuel fabrication facility capable of producing several fuel types with initial emphasis on salt fuels. • Continue to work with National Laboratories and private companies to develop strategies to optimize TRISO manufacturing capacity to support emerging developers prioritizing needs based on attainable demonstration timelines. • Establish a front-end engineering design program for advanced reactors fuels.

Regulatory Compliance – NRC

What is needed?	Improved efficiency in the application of the current NRC regulatory framework for advanced reactor technologies.
What is the benefit?	Avoid costly delays in the licensing effort due to inapplicable requirements and lack of guidance specific to non-LWR reactors.
What is available?	• The ADVANCE Act of 2024 requires the NRC to take actions in the areas of licensing of new reactors and fuels, including enhancing the regulatory framework and taking initiatives to make reviews of license applications more efficient, timely and predictable. • The proposed 10 CFR 53 rule was published for public comment on 10/31/2024. The NRC anticipates issuance in 2027.
What can DOE/ NRIC do to help?	Support the development of Topical Reports covering the following: • Risk-informed approaches to meeting safety requirements. • Qualification approaches for unique fuels/variants per NUREG-2246. • Qualification approaches of reactor components, sensors, instrumentation, coolants, structural materials, and energy storage.

Regulatory Compliance – DOE

What is needed?	Improved clarity regarding the expectations of the format and content of key nuclear safety design basis documents (DOE-STD-1189) and documented safety analyses for DOE reactor facilities (DOE-STD-1237).
What is the benefit?	Avoid costly delays due to inefficient development of key safety basis documents.
What is available?	INL is developing some templates and tools to improve the development process of nuclear safety design basis documents.
What can DOE/ NRIC do to help?	• Develop a roadmap that provides clear easy-to-follow expectations for development of safety basis documents along with agency roles and responsibilities identifying specific requirements, interactions and potential issues. • Continue development of templates and digital tools to streamline the development of nuclear safety design basis documents.

Recommendations

- Select areas of highest need to bridge the gap between R&D and commercial deployment.
  - Additional facility capacity to efficiently test and demonstrate reactors.
    - Establish built-for-purpose, flexible test beds with expanded capabilities relative to NRIC-DOME and LOTUS.
  - Address aspects of advanced construction technologies development and demonstration.
  - Establish a fuel design and fabrication program.
    - Fuel fabrication facility.
    - Design and testing support for advanced reactors fuels.
    - Work with TRISO manufacturers to support emerging developers.
- Gap Assessment Report submitted to DOE-HQ on 1/9/2025.
- Work with DOE and stakeholder to develop strategies to address each of the identified gaps.
- Incorporate continuous feedback from stakeholders and update strategies accordingly.

Questions?

NRIC National Reactor Innovation Center

Backend of the Fuel Cycle

What is needed?	• Technical and regulatory support for transporting fueled microreactor modules.
	• Future storage, transportation, and disposal needs.
	  • Identify specific data needs to be retained (e.g., RW-859).
	  • Identify downstream impacts of fuel designs and advanced reactor operations.

What is the benefit?	Minimize downstream challenges associated backend of the fuel cycle based on experience gained from LEU SNF management.
What is available?	• Existing storage and transportation systems from several private vendors. • No disposal path.

What can DOE/ NRIC do to help?	• Develop recommendations based on DOE's experience in shipping fuels and reactor cores to support microreactor developers.
	  • An opportunity to demonstrate transportation capability in collaboration with NE Office of Spent Fuel and HLW Disposition using the ATLAS railcar design.
	• Continue engagement with NE Office of Spent Fuel and HLW Disposition to ensure advanced reactor designs consider backend of the fuel cycle challenges.
	  • No viable approach to dispose of sodium-bonded fuel.
	  • The need for fission gas management for salt fuels.

Facilities – Nuclear Test Facilities

What is needed?	• Irradiation capabilities to support design and qualification of nuclear fuels and component. • Facilities with large hot cells capable of several reactor-specific needs (e.g., handling entire vessels, full assemblies).
What is the benefit?	Qualify fuels and reactor components under simulated reactor conditions and validate computational methods.
What is available?	• Several irradiation facilities (e.g., ATR) that are over subscribed. • Several hot cells with capacity limitations.
What can DOE/ NRIC do to help?	• Establish a fast-spectrum high-capacity test reactor (similar to the VTR design) to provide the needed irradiation testing capacity. • Establish nuclear facilities within the DOE complex to provide the necessary capacity for PIE and reactor-specific needs. • Work with National Laboratories, universities, and international organizations to develop a strategy to optimize current irradiation and PIE testing capabilities.

Facilities – Non-Nuclear Test Facilities

What is needed?	Non-nuclear testing capability with electric surrogates.
What is the benefit?	Test thermal-hydraulic systems, validate computational methods and qualify reactor components under simulated reactor conditions.
What is available?	There are various focused capabilities at National Laboratories (e.g., ANL's Mechanisms Engineering Test Loop facility).
What can DOE/ NRIC do to help?	• Work with National Laboratories, universities and private companies to develop a strategy to optimize current testing capabilities prioritizing needs based on demonstration timelines. • Establish a non-nuclear facility with electric surrogates capable of handling water, gas (helium), molten metal, and salt. • Establish a process to facilitate the needed coordination and collaboration.

Facilities – Benchmark Experiment Facilities

What is needed?	Nuclear data with advanced reactors fuels to validate neutronics and kinetics computation methods.
What is the benefit?	Validate computational methods to support safety analyses and meet regulatory requirements.
What is available?	*Five Year Execution Plan – for the Mission and Vision of the United States Department of Energy Nuclear Criticality Safety Program* OCTOBER 1, 2024 (REV. 1) FY 2025 through FY 2029.
What can DOE/ NRIC do to help?	Engage with LANL in the benchmark planning effort and develop a strategy for conducting the needed experiments utilizing facilities within the DOE complex as well as international facilities.

Supply Chain – HALEU Fuel

What is needed?	HALEU feedstock to support near-term reactor demonstrations and identification of long-term resources for deployment.
What is the benefit?	Support reactor demonstrations in a timely and cost-effective manner.
What is available?	The Inflation Reduction Act invests $700 million in HALEU Availability Program activities to acquire HALEU through purchase agreements with domestic industry partners and produce limited initial amounts of material from DOE-owned assets.
What can DOE/ NRIC do to help?	Study SRNL initiative to repurpose aluminum-based fuels stored at L-Basin as feedstock for HALEU. Current plan is to dispose of the enriched uranium in vitrified HLW glass as part of the ABD project. Timely action may be necessary prior to irreversible vitrification.

Supply Chain – Reactor Components

What is needed?	• Reactor components with the requisite qualification and QA pedigree • Alternatives to NQA-1 suppliers or expanded use of Commercial Grade Dedication. • Reactor-specific needs (e.g., specific salt compositions).
What is the benefit?	Avoid delays in reactor demonstrations and ensure the availability of methods and processes to qualify reactor components that can also be scaled up to support deployment.
What is available?	Independent activities led by private industry and National Laboratories.
What can DOE/ NRIC do to help?	Develop a plan for identifying alternatives to NQA-1 suppliers and standing up a Commercial Grade Dedication effort. • Overlaps with several of the facility gaps including the need for irradiation facilities, hot cells, and non-nuclear test facilities. • Overlaps with the advanced construction gap, specifically for development of construction components.

Siting

What is needed?	• Improved clarity in siting requirements and processes on DOE land. • General siting needs including a comprehensive national seismic database, and a Seismic Isolation Standardization program.
What is the benefit?	Avoid costly delays due to potential issues raised by DOE and EPA late in the process.
What is available?	Siting Tool for Advanced Nuclear Development (STAND).
What can DOE/ NRIC do to help?	• Enhance STAND with additional technical and economic data to assist reactor developers when making siting decisions. • Develop a roadmap to address siting considerations on DOE land, including agency roles and responsibilities and key requirements (potential overlap with DOE Regulatory Compliance).

Modeling and Simulation

What is needed?	• Easy-to-use validated advanced neutronic, kinetic, and thermal-hydraulic modeling and simulation tools with required QA and configuration control. • Misc. specific needs - radionuclide diffusion and transport in a submerged steel structures, aircraft Impact modeling in Maritime Environments.
What is the benefit?	Reduce computational cost on reactor developers to support design and regulatory activities.
What is available?	Advanced, multidimensional, and coupled multi-physics codes are funded and managed through NEAMS. Virtual Test Bed (VTB) serves as a platform to create simulations of advanced reactors.
What can DOE/ NRIC do to help?	• Facilitate the development of validation data considering demonstration and deployment priorities. • Overlaps with the facilities gap, including demonstration, benchmark, nuclear, and non-nuclear test facilities. • Include framework models (e.g., requirements models, product breakdown structure models, and models to support gaps in human and financial capital).

Communication and Collaboration

What is needed?	This is a cross-cutting gap since communication and collaboration is an aspect of all needs and opportunities identified in the Gap Assessment.
What is the benefit?	Optimize resources, identify areas with maximum return on investment, reduce duplication of effort, facilitate strategic connections.
What is available?	Several isolated efforts (e.g., National Technical Programs, Working Groups) and collaboration between some laboratories and developers.
What can DOE/ NRIC do to help?	Many suggestions were provided; the following are examples: • Maintain a process to facilitate the needed coordination. • Re-engage with advanced reactors technology Working Groups. • Help industry engage with DOD, utilities, and maritime. • Improve coordination between the National Laboratories and private industry, including dedicated liaisons. • Provide technical expertise, safety assessments, and environmental impact analyses for non-DOE sites. • Benchmark INL procurement and contracting process against other National Laboratories.

Financial and Human Capital

What is needed?	• Near-term funding to support design and demonstration. • Availability of trained and experienced workforce for demonstration projects and commercial deployment.
What is the benefit?	• Enhance the likelihood of success across a broader range of reactor demonstrations. • Provide a training path for the needed workforce.
What is available?	• Front-End Engineering and Experiment Design (FEEED) process. • DOE's $100M investment in nuclear safety training and workforce development programs. • The ADVANCE Act, signed into law in July 2024, includes provisions for NRC fee caps for advanced reactor applicants, and a new nuclear workforce training program.
What can DOE/ NRIC do to help?	Explore additional award opportunities through the FEEED Process based on the other gaps identified in the Gap Assessment.

Safeguards and Security

What is needed?	Guidance on safeguards and security requirements for advanced reactors and fuels that is integrated into all aspects of the design/build process as well as during transportation and operations.
What is the benefit?	Ensure compliance with safeguards and security requirements based on clear expectations and guidance.
What is available?	• Advanced Reactor Safeguards and Security program at Sandia. • IAEA Guidance.
What can DOE/ NRIC do to help?	• Support the development of a 3S integration strategy. • Collaborate with programs sponsored by NNSA and IAEA.

NRIC National Reactor Innovation Center

Natrium Reactor Support Program

Program Update

Caysie Marshall, Technical Program Manager (INL)

04/02/2025

MIS-25-83604

TerraPower Natrium Demonstration Reactor Advanced Reactor Demonstration Program (ARDP)

7-year DOE cost-share ARDP with $100M of scope

Fuel-related R&D with subsequent fabrication of Lead Test Pins (LTPs)

Fuel Performance Testing

- Ongoing irradiation of AFC-4B, AFC-4D, LDC-1A experiments in Advanced Test Reactor (ATR)
- Includes two new irradiation tests: LDC-1B and LDC-B4C
- Transient irradiation experiments in the Transient Reactor Test Facility (TREAT)
- Hot cell furnace test at Hot Fuel Examination Facility (HFEF)
- Mk-IIIR Sodium Loop experiments

Post Irradiation Examination (PIE)

Technical Support

Current CRADA Funding Profile

ARDP work began with two CRADAs in 2021:

- 21CRA11: Natrium Demonstration Reactor Fuels Support
- 21CRA15: Natrium Digital Engineering Support

Additional Scope and Funding by TerraPower:

- 22CRA26; $13M – Ancillary Projects/Infrastructure to support the TREAT Sodium Loop.

In Progress:

- $40M for scope (fuels tests and PIE) supporting commercialization

INL providing support for demonstration and commercialization

Key INL Facilities

- Advanced Test Reactor
- Transient Reactor Test Facility
- Hot Fuel Examination Facility
- Irradiated Materials Characterization Laboratory
- Experimental Fuels Facility
- Fuels and Applied Science Building
- Analytical Laboratory
- High Performance Computing

Fuel Fabrication

Fuel Performance Testing

Natrium Support

Post-Irradiation Examination

Technical support

Digital Engineering

NRIC National Reactor Innovation Center

Questions?

NRIC National Reactor Innovation Center

BWXT ADVANCED TECHNOLOGIES

From Concept to Reality
Design, build and test new nuclear

Abbey J. Donahue, PE

Chief Engineer
BWXT Advanced Nuclear Reactor (BANR)
BWXT Advanced Technologies LLC

NRIC Annual Program Review
04/02/2025




BWX Technologies employs nuclear technology to solve some of the world's most important problems

OUR MISSION

- Global Security
- Clean Energy
- Nuclear Medicine
- Space Exploration
- Environmental Remediation

$2.7B
2024 Revenues

415
Reactors delivered for Naval Nuclear Power

300+
Commercial nuclear steam generators

8,700+
Employees

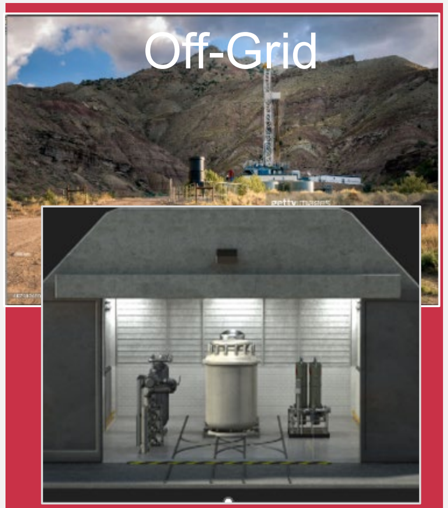
BWX Technologies, Inc.

Land
Electric & Thermal Energy

Military

- ❖ Military operations
- ❖ Reduced vulnerabilities and signature

Off-Grid

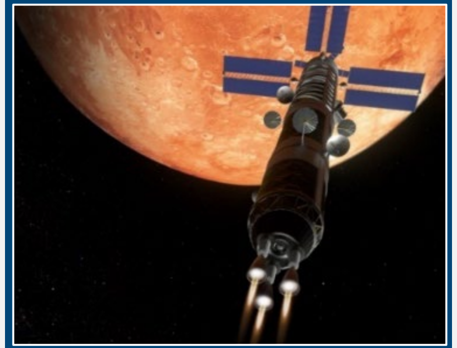


- ❖ Data centers
- ❖ Small footprint
- ❖ Mining, Oil & gas sites

Sea
Naval Nuclear Propulsion

- ❖ Naval nuclear reactors and components
- ❖ Nuclear fuel & materials

Space
Propulsion & power



- ❖ Thermal propulsion for rapid transit in the cis-lunar volume
- ❖ Deeper space exploration

Company Highlights

BWXT is one of the world's most prolific nuclear technology innovation companies and the sole manufacturer of naval nuclear reactors for U.S. submarines and aircraft carriers.

~8,700
highly skilled employees

$2.7 billion USD
in 2024 revenues

14
major manufacturing facilities totaling 4 million+ square feet

60+
years manufacturing naval nuclear components and reactors

300+
commercial nuclear steam generators manufactured

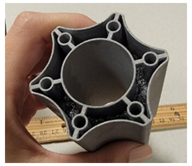
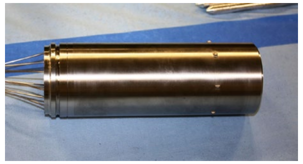
1.5 million+
Canada Deuterium Uranium (CANDU) fuel bundles provided

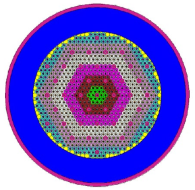
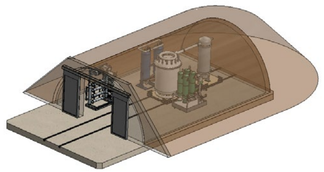
13
U.S. Department of Energy laboratories/production sites, environmental cleanup projects and NASA sites

8,000+
fuel elements delivered to U.S. national laboratories, universities and international customers

BANR Advanced Reactor Demonstration Program (ARDP) Scope



2022-2025

Fuel Development

- Reactor design and manufacturing of fuel test specimens

2025 - 2027

Demonstration

- Irradiation testing and in-process analysis of fuel integrity

2027 - 2028

Fuel Qualification

- Post irradiation examination
- Development of licensing basis

2028+

Production

- Demonstration decision
- Commercial implementation

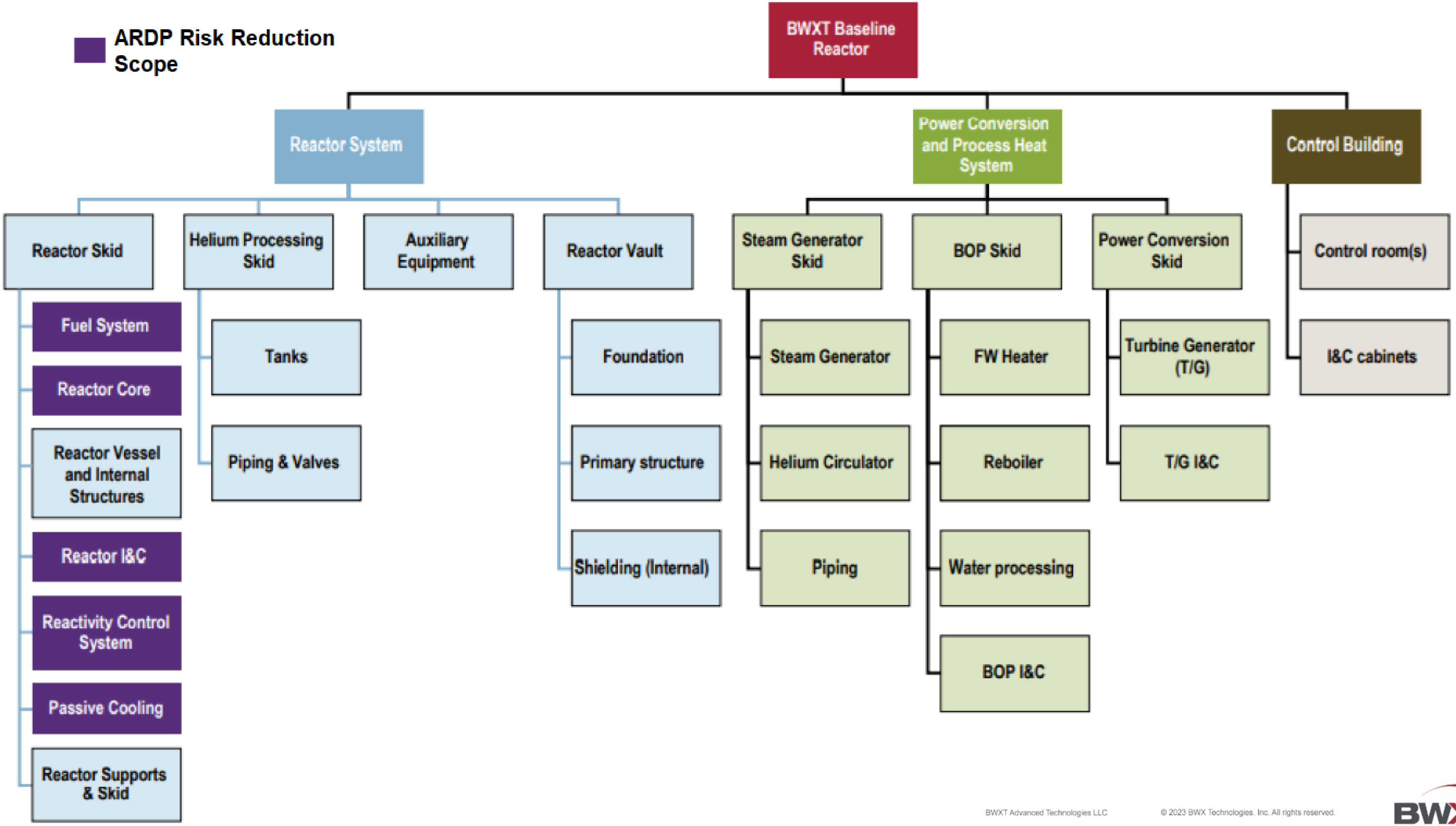
Risk Reduction Program Scope

- Mature design and manufacturing technologies, improving commercial viability
- Demonstrate advanced technology applications to reduce manufacturing costs
- Develop and demonstrate high-power density tristructural isotropic (TRISO) fuel form for microreactors
- Focus on reactor skid: fuel system, core design, reactivity control, passive cooling, I&C

Fuel-Specific Scope

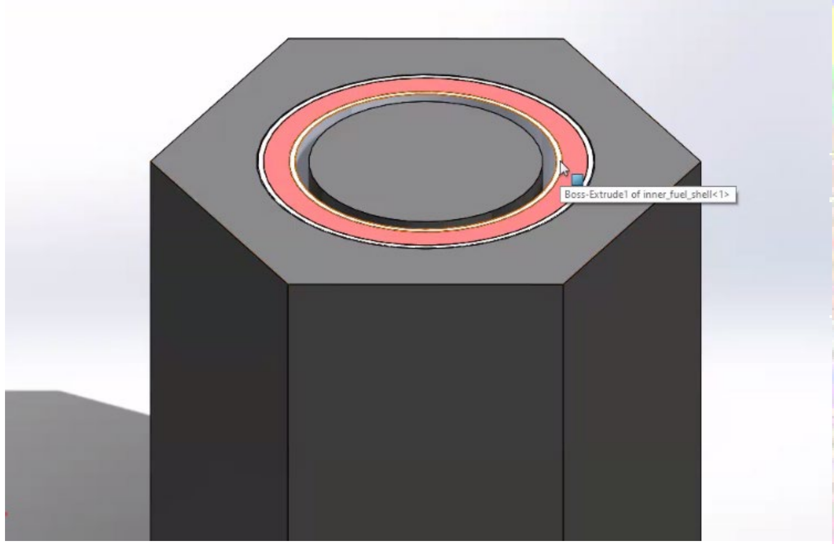
- High-Assay Low-Enriched Uranium (HALEU) fuel acquisition; TRISO fuel production
- Knowledge transfer from Idaho National Laboratory's (INL) Advanced Gas Reactor (AGR) program and Oak Ridge National Laboratory's (ORNL) TCR program
- Iterative manufacturing and testing of fuel elements, e.g. AM using CVI densification, element testing and characterization
- Irradiation (INL) and examination (ORNL) to advance UN fuel performance
- Licensing activities to advance fuel form regulatory case

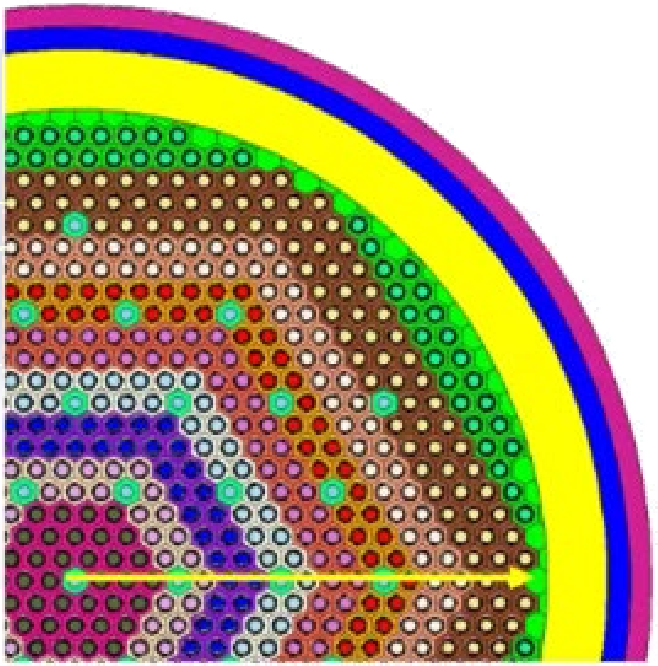
ARDP Focus

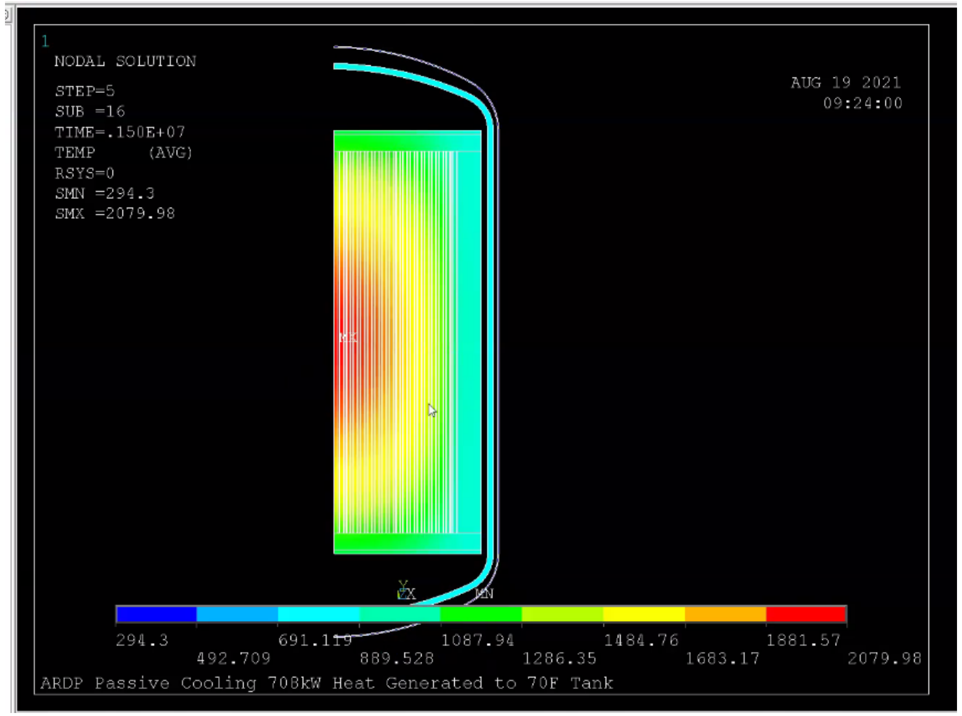


ARDP Risk Reduction Scope
BWXT Baseline Reactor
Reactor System
Power Conversion and Process Heat System
Control Building
Reactor Skid
Helium Processing Skid
Auxiliary Equipment
Reactor Vault
Steam Generator Skid
BOP Skid
Power Conversion Skid
Control room(s)
Fuel System
Reactor Core
Reactor Vessel and Internal Structures
Reactor I&C
Reactivity Control System
Passive Cooling
Reactor Supports & Skid
Tanks
Piping & Valves
Foundation
Primary structure
Shielding (Internal)
Steam Generator
Helium Circulator
Piping
FW Heater
Reboiler
Water processing
BOP I&C
Turbine Generator (T/G)
T/G I&C
I&C cabinets

BANR Fuel Development: Fuel Performance Analysis







Particle Packing of Thin Rings

55% Packing Fraction

855 µm particle diameter

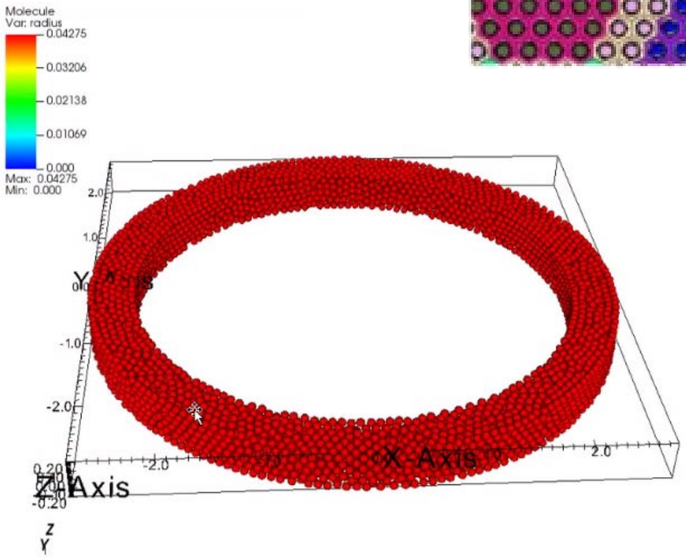
2.816 cm fuel ring outer radius

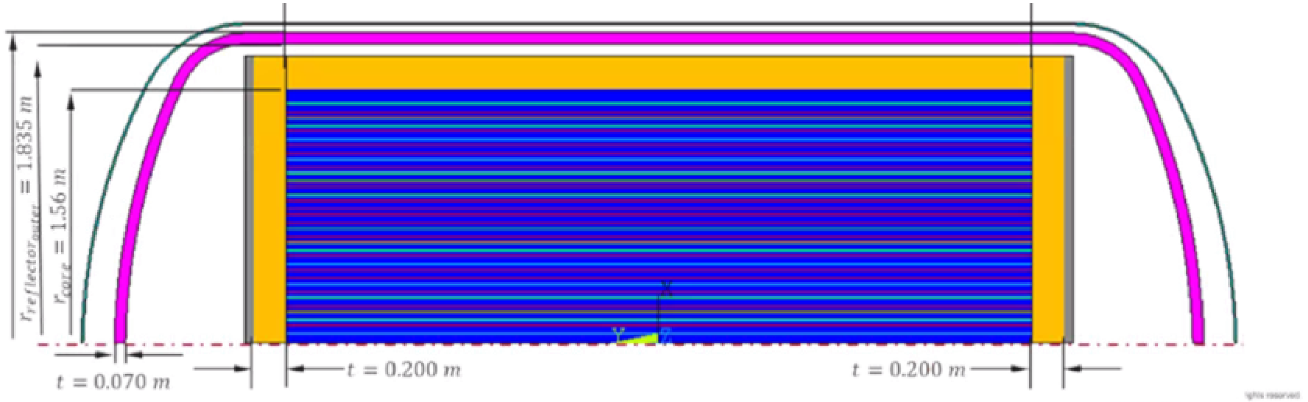
2.306 cm fuel ring inner radius

Fuel thickness = 0.513 cm (6x particle diam)

Total element thickness = 0.713 cm (0.1 cm for inner/outer walls)

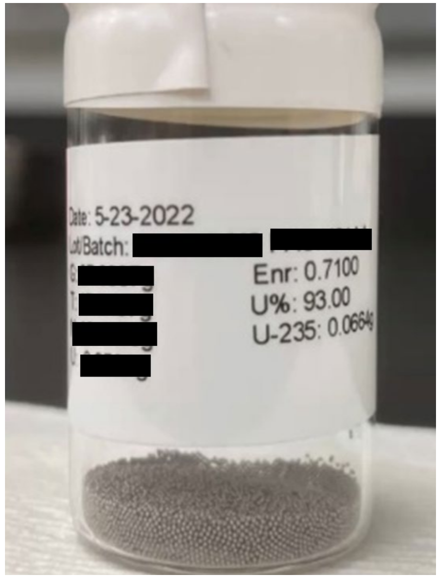
High confidence 55% PF can be achieved in annular cylinder



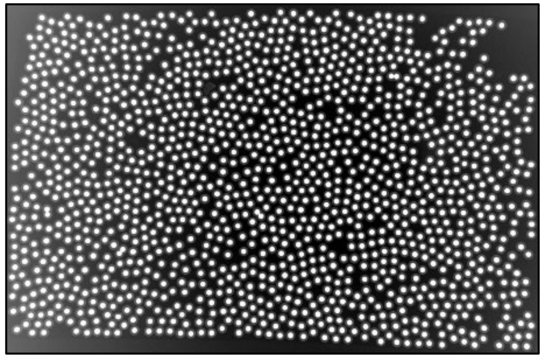


UN TRISO Fuel Development

- Particle Design Optimization 2021 – 2022
  - Significant modeling and simulation effort
    - BISON – fuel performance
    - MCNP – core analysis
    - MIXCOATL – core thermal hydraulics
  - Established particle architecture
- TRISO Fuel Fabrication 2022 - 2025
  - Process Development
    - Kernel
    - Coatings
  - Fabrication
    - First HALEU coating run generated sufficient HALEU UN TRISO particles to meet project needs by ~ 10x



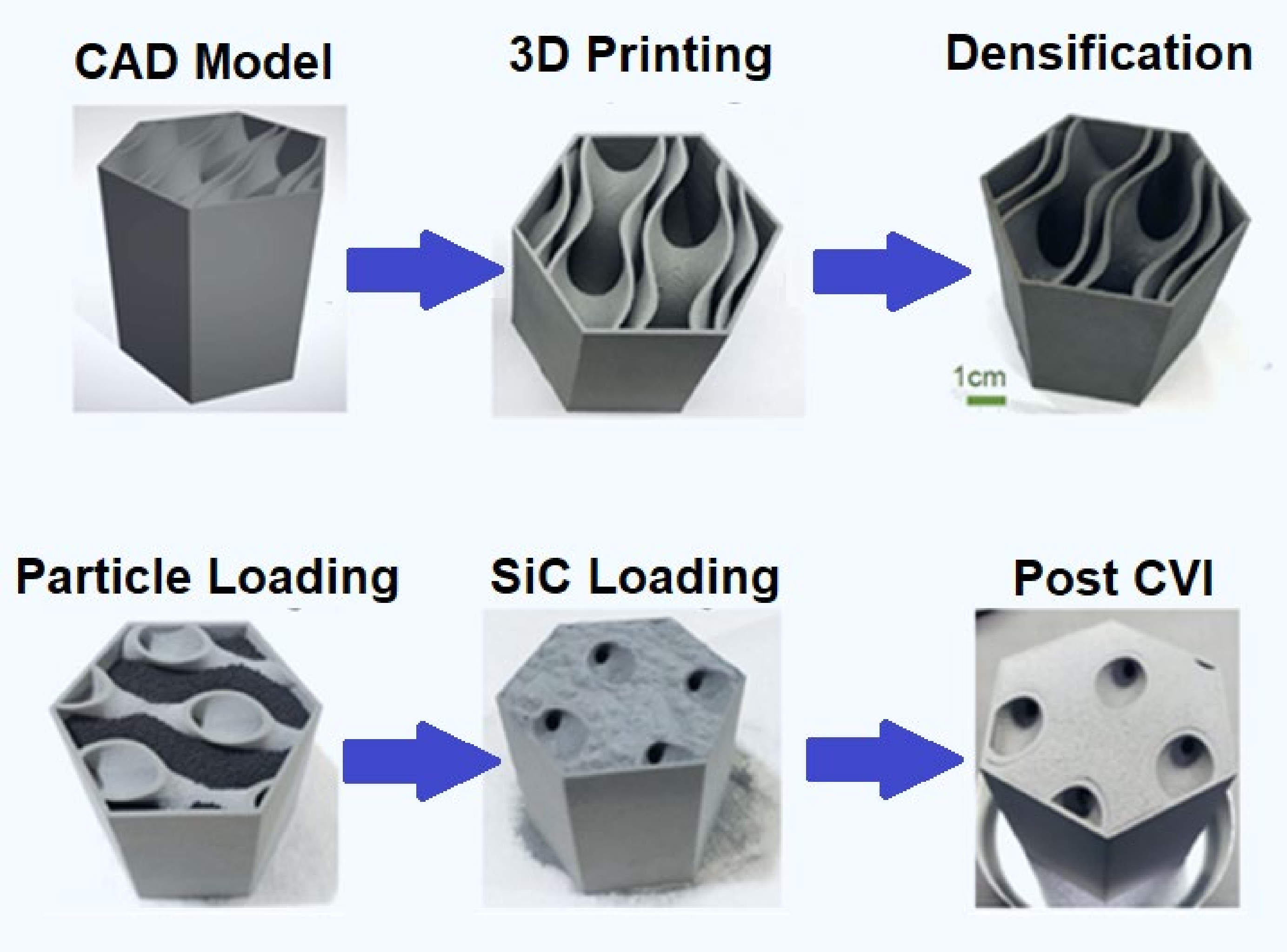
UN TRISO Kernels



Radiograph image of UN-TRISO particles

BANR Fuel Development: Fuel Element Fabrication

1. CAD Model: A fuel element geometry is created in modeling software.
2. 3D Printing: Using a 3D binder jet printer, the fuel shell is built with an industrial printhead selectively depositing a liquid binding agent onto a thin layer of powder particles. This is repeated layer by layer until the fuel element shell is complete.
3. Densification: This pre-CVI densification step provides strength to the fuel element shell so that fuel can be loaded.
4. Particle Loading: UN TRISO Particles are placed into the empty fuel element shell
5. SiC Loading: SiC powder is packed into the fuel element filling the spaces around the UN TRISO particles.
6. Post CVI: Through chemical vapor infiltration, the interior structure is densified into a SiC matrix.



TCR Fuel Element Photos from ORNL

BANR Fuel Development: Fuel Element Fabrication

- Fuel Element Shell
  - Binder Jet installed and operating
  - Fabrication process parameters developed
  - Packing studies performed

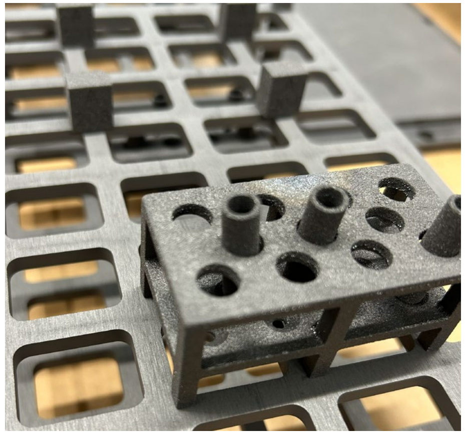
BWXT's Binder Jet

Fabrication

Packing Studies

- CVI Densification
  - BWXT furnace **operating**
  - ORNL furnace in commissioning
  - UConn early development

BWXT CVI Furnace Installed



Samples from BWXT's CVI Furnace

Acknowledgement and Thanks

U.S. DEPARTMENT OF ENERGY

NRIC National Reactor Innovation Center

INL Idaho National Laboratory

OAK RIDGE National Laboratory

NRIC National Reactor Innovation Center

BWXT BANR-1

Program Update

Caysie Marshall, Technical Program Manager (INL)

04/02/2025

MIS-25-83779

BWXT BANR-1
Advanced Reactor Demonstration Program (ARDP)

7-year DOE cost-share ARDP with $24.3M of scope at Idaho National Laboratory (INL):

- Years 1-4: Test Train Design and Fabrication
  - Currently in year 4
- Years 5-6: Irradiation
- Years 6-7: Post-Irradiation Examination (PIE)

Irradiation of uranium nitride (UN) tri-structural isotopic (TRISO) prismatic fuel in Advanced Test Reactor (ATR)

PIE to be conducted at Materials and Fuels Complex (MFC) and Oak Ridge National Laboratory (ORNL)

BWXT BANR-1 ARDP Overview

Leverage INL's learnings from Advanced Gas Reactor (AGR) programs and ORNL's fuel expertise.

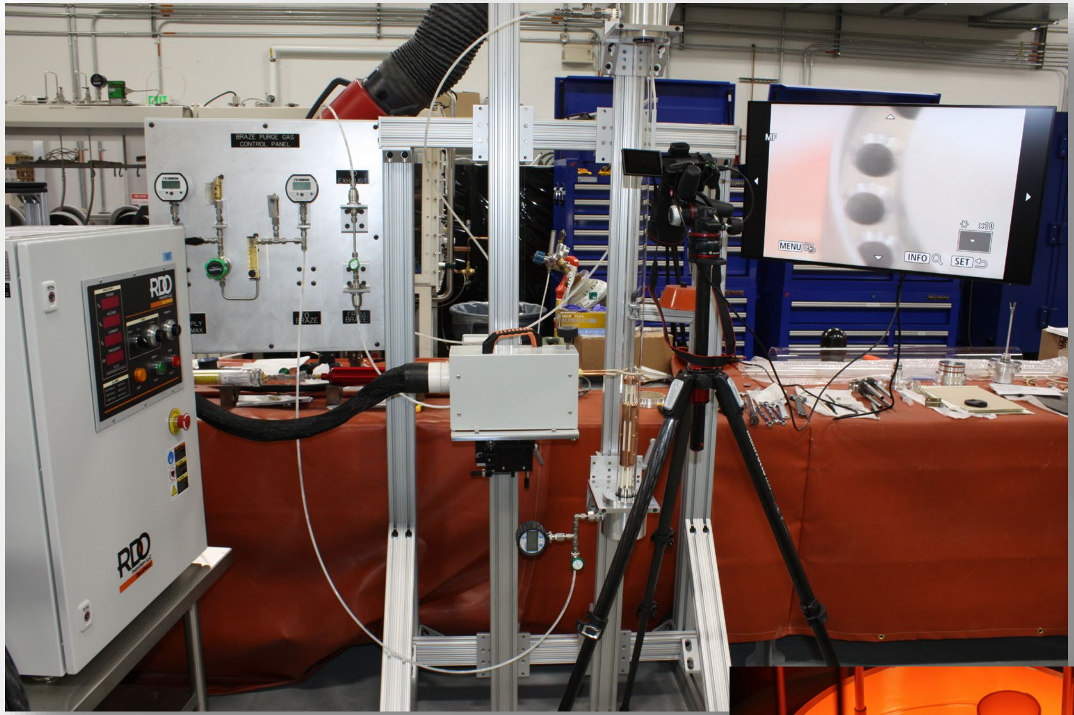
- Mechanical design
- Neutronics
- Thermal hydraulics
- Modeling and simulation
- Structural analysis
- TRISO expertise
- Irradiation

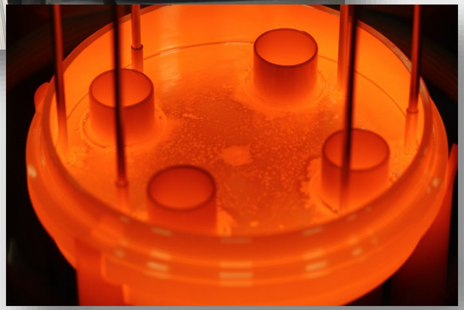
Alignment with NRIC Mission:

- Strong private-public partnerships to expedite advanced reactor commercialization.

Welding and Brazing Status

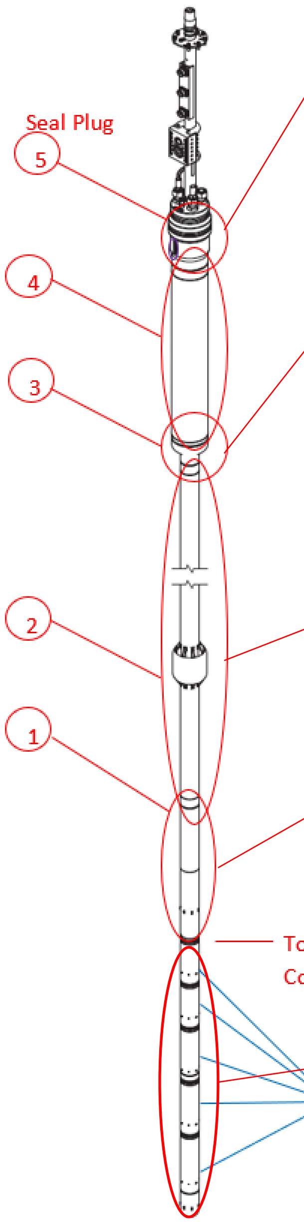
- Welding:
  - Weld procedures and welders are ready.
- Brazing:
  - Braze procedures and operator qualification is in progress (expected finish in April).
  - New brazing setup installed and used for mockups.

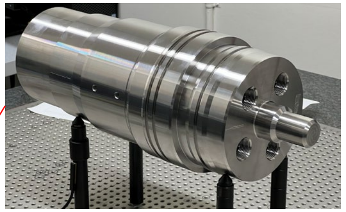




NRIC National Reactor Innovation Center

Test Train Fabrication Progress



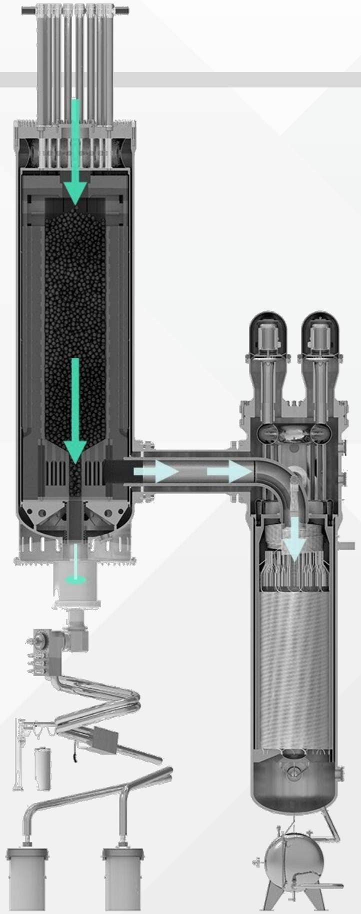


Questions?

NRIC National Reactor Innovation Center

NRIC National Reactor Innovation Center

X-energy ARDP



Heather Chichester, Program Technical Lead

04/02/2025

MIS-25-83654

X-energy Advanced Reactor Demonstration Program (ARDP)

DOE cost-share ARDP with $14.7M scope at Idaho National Laboratory (INL)

- Years 1-3: Core Modeling and Simulation, Fuel Experiment Test Train Design and Fabrication.
  - Modeling and Simulation work complete.
  - Currently in year 3 of test train design and fabrication.
- Year 4: Irradiation, PIE Planning
- Years 5-6: Post-Irradiation Examination (PIE)
  - Additional funding will be added to the program to support PIE activities.

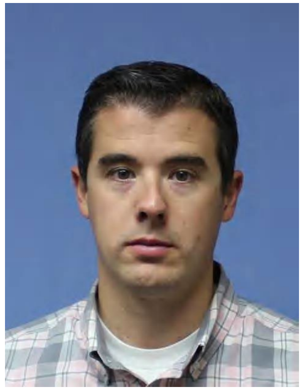
Irradiation of tri-structural isotopic (TRISO) particle fuel pebbles in Advanced Test Reactor (ATR)

PIE to be conducted at Idaho National Laboratory (INL)/Materials and Fuels Complex (MFC) and Oak Ridge National Lab (ORNL)

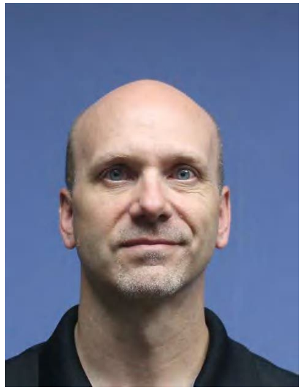
X-energy ARDP INL Team


Luke Voss
NRIC Program Manager


Heather Chichester
Program Technical Lead


Keegan Ryan
Experiment Design Engineer


John Stempien
PIE Technical Lead


Thomas Richardson
Experiment Manager


Hardik Suthar
Quality Engineer


Joe Palmer
Experiment Design Engineer


David Laug
PIE Experiment Manager

Team Members (not pictured):
Dong O. Choe
Jordan Harding
Ryan Marlow
Thomas Nance
Ryan Sandbek
Jessica Seals
Wes Smith
Philip Winston
Changhu “Tiger” Xing

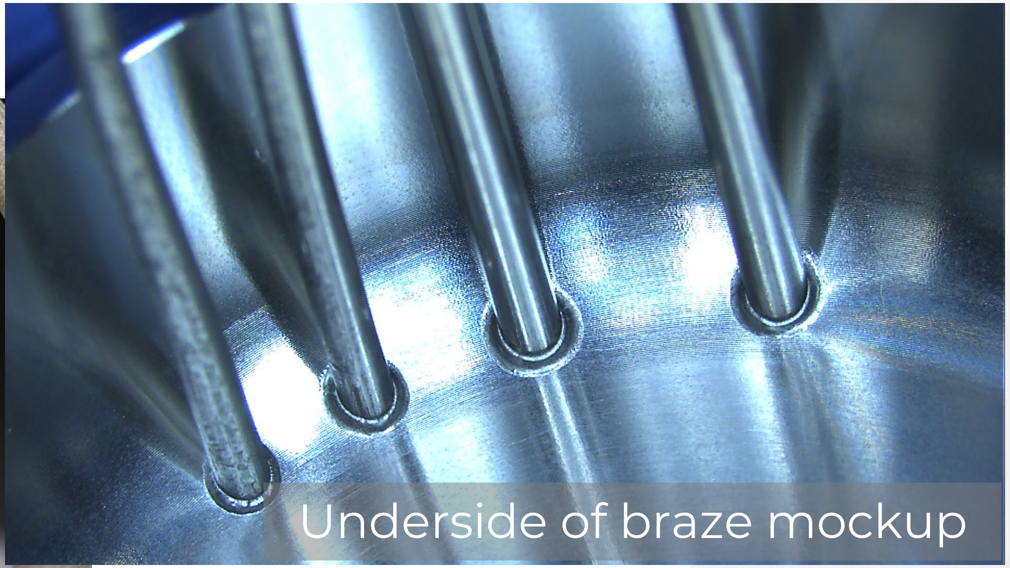
X-energy ARDP – Irradiation

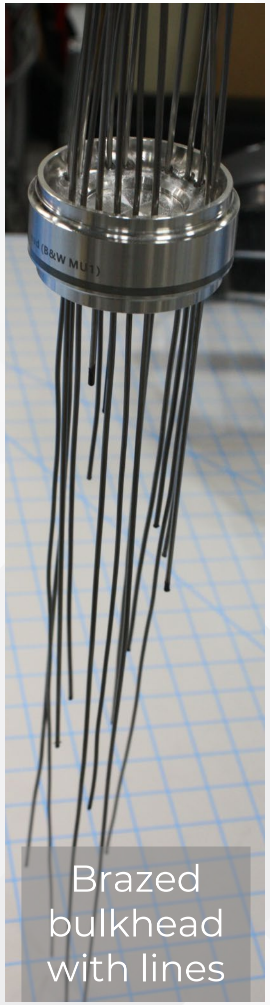
- XPeRT (X-energy Pebble Reactor Test):
  - Fueled, instrumented irradiation experiment in ATR.
  - Demonstrate performance of X-energy fuel pebbles.
  - Leverage INL expertise and lessons learned from Advanced Gas Reactor (AGR) experiments.
  - Status: Final design complete, test train fabrication in process.

XPeRT Bulkhead Brazing Mockup

- Brazing fixture fabricated
- Custom thermocouple and gas line lengths
- Multiple mockups – parameters resulted in quality braze


Bulkhead top surface

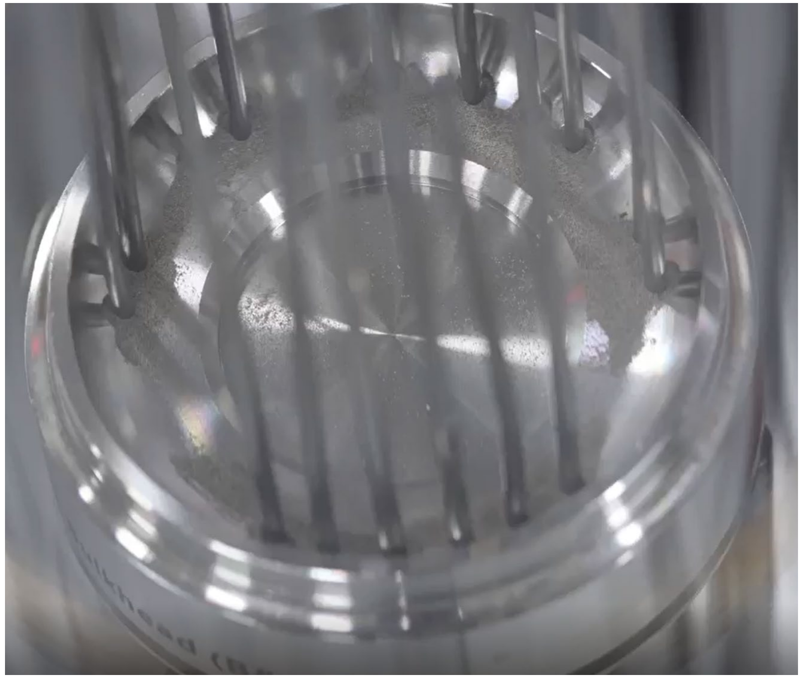

Underside of braze mockup

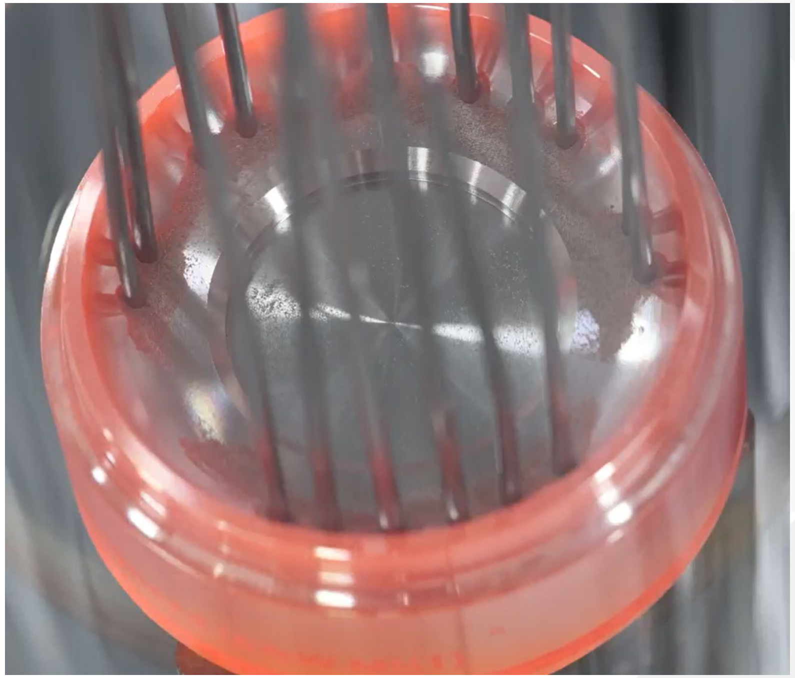

Brazed bulkhead with lines

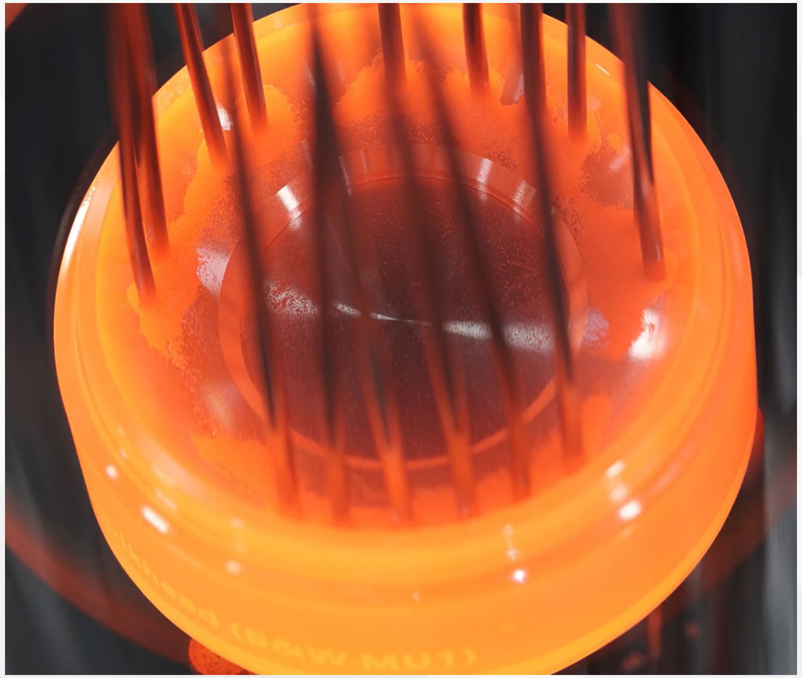

Brazing Fixture

XPeRT Bulkhead Brazing Mockup

- Bulkhead during heating

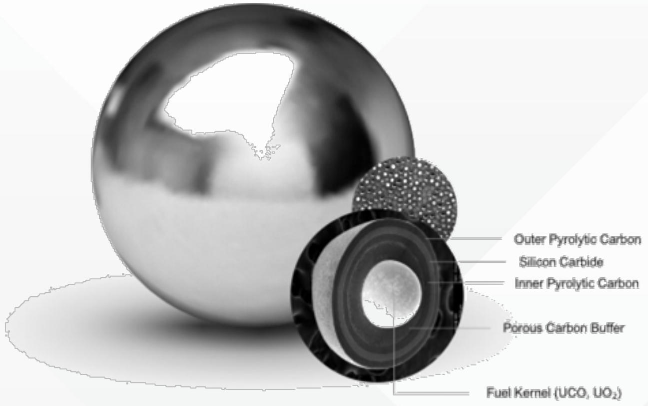






X-energy ARDP – PIE

- PIE (Post-Irradiation Examination)
  - Validate and examine fuel performance after irradiation.
  - Non-destructive and destructive tests at MFC and ORNL.
  - Furnace heating tests simulate accident scenarios.
  - Status: Developing PIE plan, determining inter-facility transfer needs, designing equipment and fixtures needed for hot cell (remote) examinations and tests.



Questions?

NRIC National Reactor Innovation Center

Clean • Safe • Secure • Affordable

XPeRT Experiment Data
Fuel Qualification Regulatory Approach

James B. Tompkins, ARDP Nuclear Fuel Lead

04/02/2025

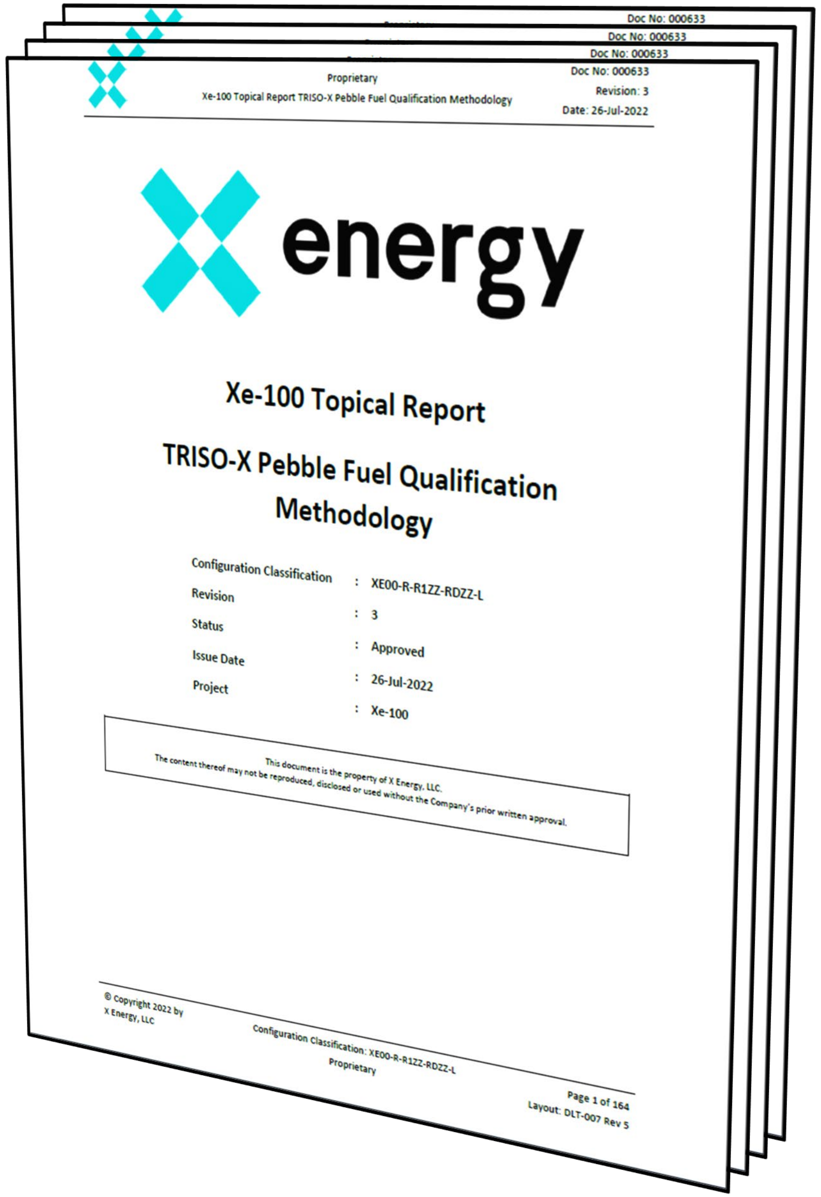
Status and Updates to X-energy Fuel Qualification Methodology

Status

- X-energy submitted Revision 3 of the “Xe-100 Topical Report: TRISO-X Pebble Fuel Qualification Methodology” to the U.S. NRC on July 29, 2022 (ML22216A179).
- U.S. NRC issued a Safety Evaluation on Revision 3 of the TR on March 9, 2023 (ML22327A201).

Planned Updates

- Recent updates to fuel qualification testing:
  - XPeRT (X-energy Pebble Reactor Test): Irradiation campaign to run TRISO-X fabricated test fuel to conditions consistent with Xe-100’s operating envelope in ATR and perform post-irradiation examinations (PIE)
  - XPLoRE (X-energy Pebble Loading Results Examination): Thermal-mechanical performance and material properties test campaign to be performed by X-energy and commercial partners.
- NUREG-2246: Fuel Qualification for Advanced Reactors
  - U.S. NRC guidance was released during the development of the first submission of the Fuel Qualification TR.
  - Next revision to the Fuel Qualification TR includes structural changes to leverage NUREG-2246 framework


Proprietary
Xe-100 Topical Report TRISO-X Pebble Fuel Qualification Methodology
Doc No: 000633
Revision: 3
Date: 26-Jul-2022

Xe-100 Topical Report

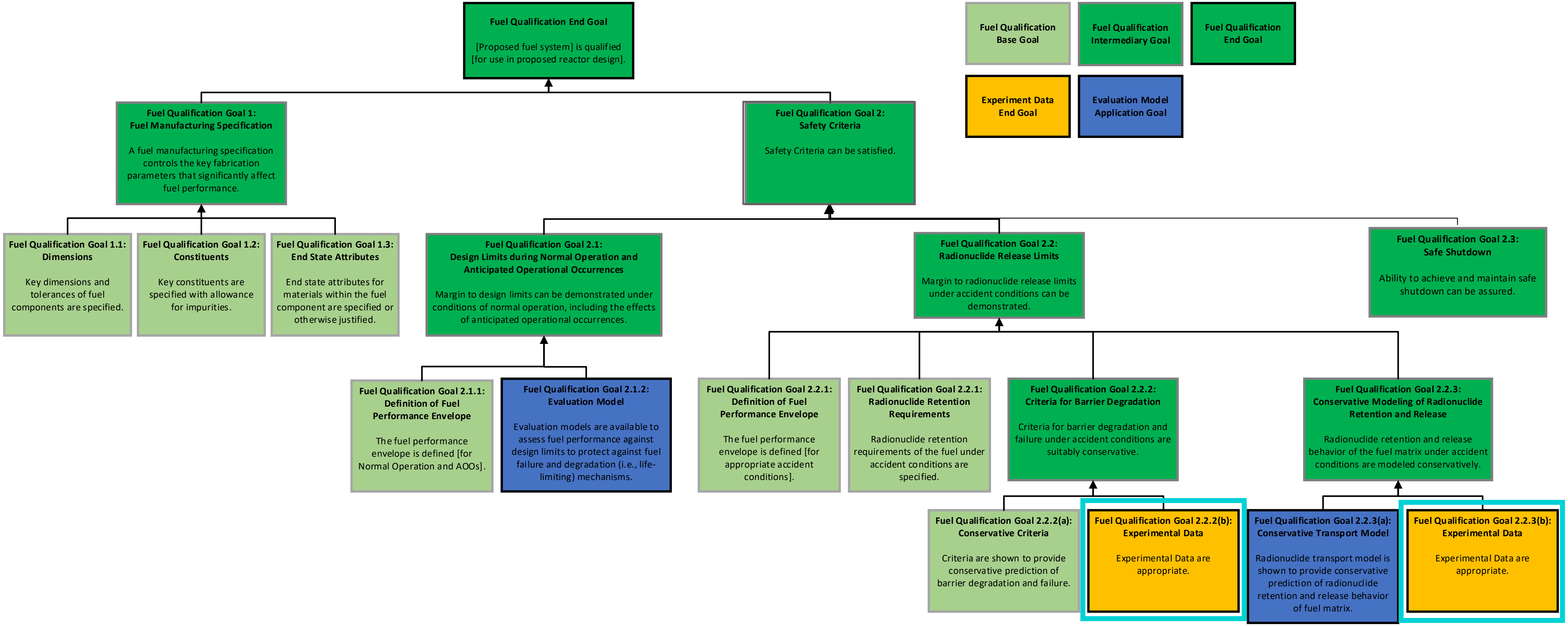
TRISO-X Pebble Fuel Qualification Methodology

Configuration Classification	: XE00-R-R1ZZ-RDZZ-L
Revision	: 3
Status	: Approved
Issue Date	: 26-Jul-2022
Project	: Xe-100

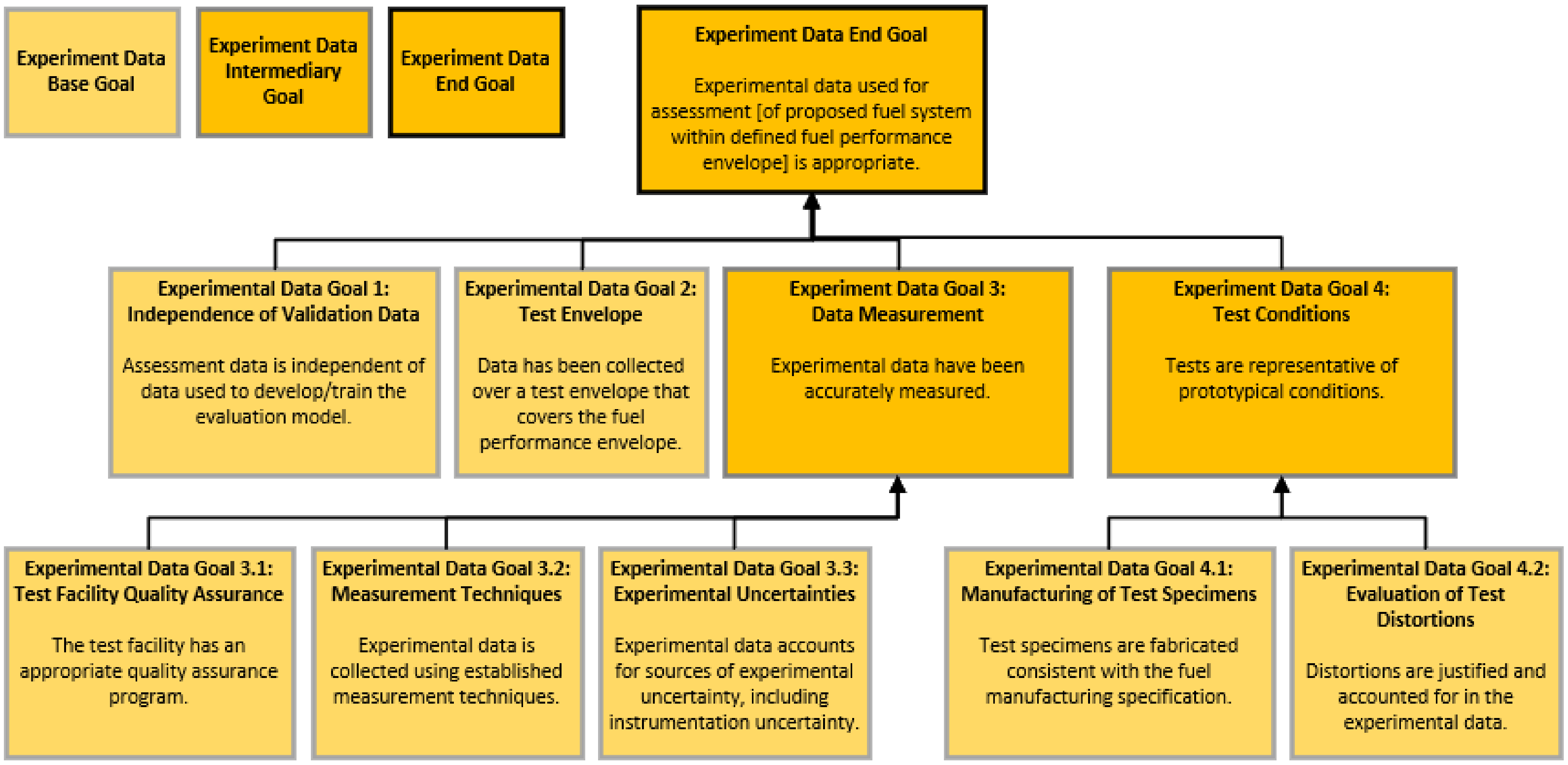
This document is the property of X Energy, LLC.
The content thereof may not be reproduced, disclosed or used without the Company's prior written approval.

© Copyright 2022 by X Energy, LLC
Configuration Classification: XE00-R-R1ZZ-RDZZ-L
Proprietary
Page 1 of 164
Layout: DLT-007 Rev 5

NUREG-2246 Fuel Qualification for Advanced Reactors Framework



NUREG-2246 Experiment Data Framework



Incorporating NUREG-2246 Experiment Data Framework in XPeRT

Base Goals

- ED Goal 1: Independence of Validation Data
  - XPeRT data not planned to develop models for safety analysis, only employed in model validation.
- ED Goal 2: Test Envelope
  - Iteration over program requirements to align with Xe-100 conditions at every stage of XPeRT design.
- ED Goal 3.1: Test Facility Quality Assurance
  - INL holds an ASME NQA-1 Certification (#NQA-125). Their quality program contains adequate controls on the implementation of programmatic elements which quality experiment data is required to have.
  - X-energy is additionally performing Commercial Grade Dedication (CGD) on the irradiation and PIE data.
- ED Goal 3.2: Measurement Techniques
  - Leveraging INL's proven track record of particle fuel testing from AGR including experimental facilities and personnel.
- ED Goal 3.3: Experimental Uncertainties
  - INL Quality Assurance Program elements provide programmatic controls.
  - Critical characteristics in XPeRT CGD dealing specifically with quantification of experimental uncertainties.
- ED Goal 4.1: Manufacturing of Test Specimens
  - TRISO-X fabricated test fuel elements
  - Consistent with Condition 1 of the EPRI UCO TRISO-Coated Particle Fuel Performance TR, X-energy is responsible for evaluation of discrepancies between tested fuel
- ED Goal 4.2: Evaluation of Test Distortions
  - Consistent with Condition 2 of the EPRI UCO TRISO-Coated Particle Fuel Performance TR, X-energy is responsible for evaluation of distortions between fuel operating conditions and experiment conditions.
  - Critical characteristics in XPeRT CGD dealing specifically with irradiation test distortions

NRIC Program Review

04/02/2025

Forward-looking statements

ABOUT THIS PRESENTATION
This presentation is provided by Oklo Inc. (“Oklo”) for informational purposes only. The information contained herein does not purport to be all inclusive and no representations or warranties, express or implied, are given in, or in respect of, this presentation. To the fullest extent permitted by law, in no circumstances will Oklo or any of its subsidiaries, interest holders, affiliates, representatives, partners, directors, officers, employees, advisers or agents be responsible or liable for any direct, indirect or consequential loss or loss of profit arising from the use of this presentation, its contents, its omissions, reliance on the information contained within it, or on opinions communicated in relation thereto or otherwise arising in connection therewith.

NO OFFER OR SOLICITATION
This presentation does not constitute an offer to sell or the solicitation of an offer to buy any securities, or a solicitation of any vote or approval, nor shall there be any sale of securities in any jurisdiction in which such offer, solicitation or sale would be unlawful prior to registration or qualification under the securities laws of any such jurisdiction. This presentation is not, and under no circumstances is to be construed as, a prospectus, an advertisement or a public offering of the securities described herein in the United States or any other jurisdiction. No offer of securities shall be made except by means of a prospectus meeting the requirements of Section 10 of the Securities Act of 1933, as amended, or exemptions therefrom.

NO REPRESENTATIONS OR WARRANTIES
This presentation is for informational purposes only and does not purport to contain all of the information that may be required to evaluate Oklo. Viewers of this presentation should make their own evaluation of Oklo and of the relevance and adequacy of the information and should make other investigations as they deem necessary. This presentation is not intended to form the basis of any investment decision by any potential investor and does not constitute investment, tax or legal advice. No representations or warranties, express or implied, are or will be given in, or in respect of, this presentation or any other written, oral or other communications transmitted or otherwise made available to any party in the course of its evaluation of an investment in Oklo, and no responsibility or liability whatsoever is accepted for the accuracy or sufficiency thereof or for any errors, omissions or misstatements, negligent or otherwise, relating thereto. To the fullest extent permitted by law, in no circumstances will Oklo or any of its subsidiaries, interest holders, affiliates, representatives, partners, directors, officers, employees, advisers or agents be responsible or liable for any direct, indirect or consequential loss or loss of profit arising from the use of this presentation, its contents, its omissions, reliance on the information contained within it, or on opinions communicated in relation thereto or otherwise arising in connection therewith. The information contained in this presentation is preliminary in nature and is subject to change, and any such changes may be material. Oklo disclaims any duty to update the information contained in this presentation.

FORWARD-LOOKING STATEMENTS
This presentation includes statements that express Oklo’s opinions, expectations, objectives, beliefs, plans, intentions, strategies, assumptions, forecasts or projections regarding future events or future results and therefore are, or may be deemed to be, “forward-looking statements.” The words *“may,” “will,” “can,” “could,” “should,” “expects,” “anticipates,” “intends,” “plans,” “believes,” “seeks,” “estimates,” ‘continue,” “might,” “possible,” “potential,” “predict,” “project,” “goal,” “would,” “commit”* or, in each case, their negative or other variations or comparable terminology, and similar expressions may identify forward-looking statements, but the absence of these words does not mean that a statement is not forward-looking. These forward-looking statements include all matters that are not historical facts. They appear in a number of places throughout this presentation and include statements regarding our intentions, beliefs or current expectations concerning, among other things, the timing, goals and benefits of nuclear fuel recycling, environmental benefits and goals of Oklo’s projects, results of operations, financial condition, liquidity, prospects, growth, strategies and the markets in which Oklo operates. Such forward-looking statements are based on information available as of the date of this presentation, and current expectations, forecasts and assumptions, and involve a number of judgments, risks and uncertainties.
As a result of a number of known and unknown risks and uncertainties, the actual results or performance of Oklo may be materially different from those expressed or implied by these forward-looking statements. The following important risk factors could affect Oklo’s future results and cause those results or other outcomes to differ materially from those expressed or implied in the forward-looking statements: risks related to the development and deployment of Oklo’s powerhouses; the risk that Oklo is pursuing an emerging market, with no commercial project operating, regulatory uncertainties; risks related to acquisitions, divestitures, or joint ventures we may engage in; the potential need for financing to construct plants; market, financial, political and legal conditions; the effects of competition; risks related to accessing HALEU and recycled fuels; risks related to our supply chain; risks related to power purchase agreements; risks related to human capital; risks related to our intellectual property; risks related to cybersecurity and data privacy; changes in applicable laws or regulations; the outcome of any government and regulatory proceedings and investigations and inquiries; the risk that the acquisition of Atomic Alchemy fails to produce the expected benefits; and those factors in the other documents filed by Oklo from time to time with the U.S. Securities and Exchange Commission.
The foregoing list of factors is not exhaustive. You should carefully consider the foregoing factors and the other risks and uncertainties of the other documents filed by Oklo from time to time with the U.S. Securities and Exchange Commission. The forward-looking statements contained in this presentation and in any document incorporated by reference are based on current expectations and beliefs concerning future developments and their potential effects on Oklo. There can be no assurance that future developments affecting Oklo will be those that Oklo has anticipated. Oklo undertakes no obligation to update or revise any forward-looking statements, whether as a result of new information, future events or otherwise, except as may be required under applicable securities laws.

INDUSTRY AND MARKET DATA
In this presentation, Oklo relies on and refers to certain information and statistics regarding the markets and industries in which Oklo competes. Such information and statistics are based on Oklo’s management’s estimates and/or obtained from third party sources, including reports by market research firms and company filings. While Oklo believes such third party information is reliable, there can be no assurance as to the accuracy or completeness of the indicated information. Oklo has not independently verified the accuracy or completeness of the information provided by the third-party sources.

Overview

- About Oklo
- Aurora at Idaho National Laboratory
- Fuel for the Aurora at Idaho National Laboratory
- Aurora Fuel Fabrication Facility
- Recycling
- NRIC Program Feedback

Overview

- About Oklo
- Aurora at Idaho National Laboratory
- Fuel for the Aurora at Idaho National Laboratory
- Aurora Fuel Fabrication Facility
- Recycling
- NRIC Program Feedback

About Oklo

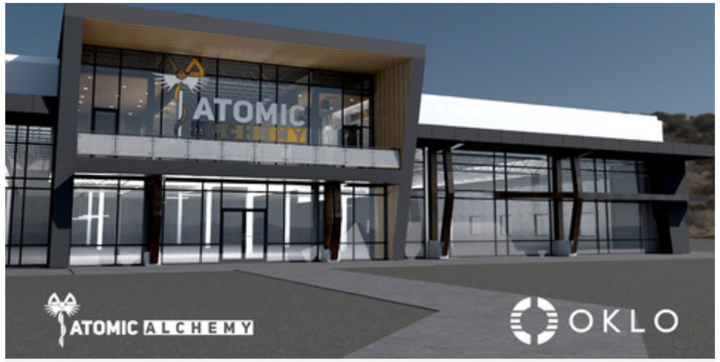
Oklo Goes Public Via SPAC Merger

By Aaron Sorenson May 9, 2024

Source

Oklo plans to acquire radioisotope firm Atomic Alchemy for $25 million in shares

Mon, Nov 18, 2024, 10:00AM | Nuclear News



Atomic Alchemy's radioisotope production facility (Image: Hillside Architecture)

Source

ADVANCED REACTORS

Oklo and Switch partner on nuclear

Mon, Jan 6, 2025, 7:31AM | Nuclear News

Advanced nuclear company Oklo and data center developer Switch closed out 2024 by announcing a new partnership to deploy 12 GW of advanced nuclear power under a master power agreement.

Source

Overview

- About Oklo
- Aurora at Idaho National Laboratory
- Fuel for the Aurora at Idaho National Laboratory
- Aurora Fuel Fabrication Facility
- Recycling
- NRIC Program Feedback

Aurora at Idaho National Laboratory

INL Powerhouse licensing milestones achieved

- ✓ Engaged with the NRC in a Pre-Application Readiness Assessment to streamline licensing for the Aurora powerhouse.
- ✓ Submitted the Licensed Operator Topical Report to enable fleet-based licensing for lower costs, faster deployment, and greater efficiency.
- INL asset aligns with our expanded 75 MWe reactor design.
- Essential milestones for both our initial and future reactor asset deployments.
- A strategic approach focused on optimizing design efficiency and meeting customer needs.

Aurora at Idaho National Laboratory

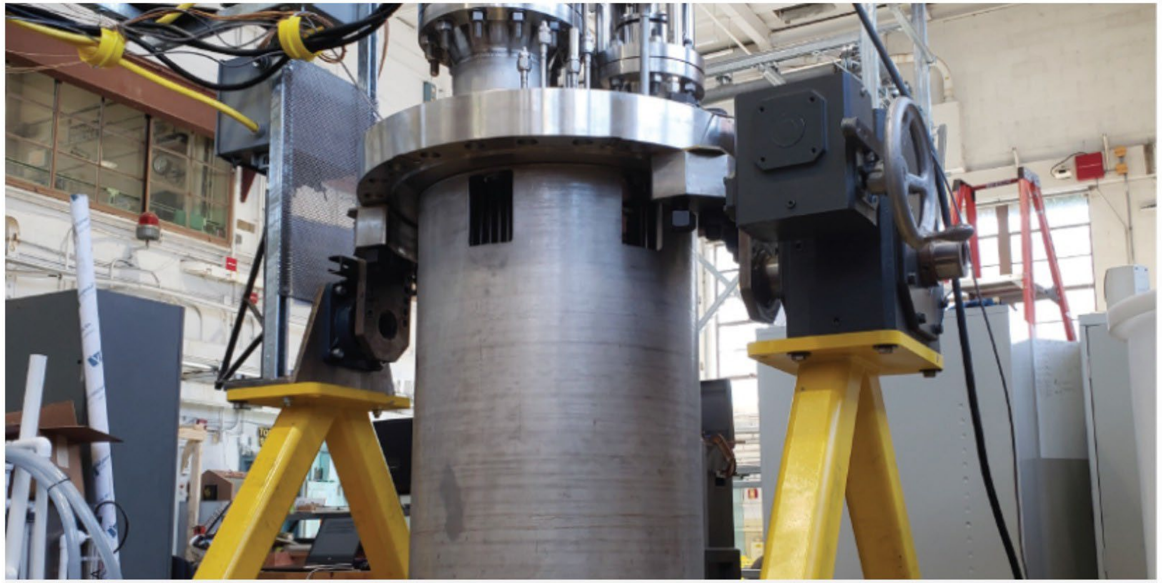
- Proximity to the Materials & Fuels Complex (MFC) provides a unique opportunity for performing irradiation experiments & post irradiation examination

  - Qualification of advanced fuels
  - Testing of new materials
  - Irradiation testing for others

RESEARCH & APPLICATIONS

GAIN awards include plan to integrate fast reactor test vehicle in Oklo's Aurora

Thu, Mar 21, 2024, 10:00AM | Nuclear News



The primary system of THETA at Argonne's Mechanisms Engineering Test Loop Facility, where Oklo is conducting sodium thermal-hydraulic testing with support from a GAIN award announced in 2021. (Image: Argonne National Laboratory)

Link

Overview

- About Oklo
- Aurora at Idaho National Laboratory
- Fuel for the Aurora at Idaho National Laboratory
- Aurora Fuel Fabrication Facility
- Recycling
- NRIC Program Feedback

Fuel for the Aurora at INL

- Oklo was selected for access to 5 metric tons of metal HALEU produced from recovered EBR-II driver fuel
  - Competitive process launched by INL in 2019

- HALEU reguli produced will become feedstock for Oklo's fuel fabrication

HALEU Reguli Produced from Recovered EBR-II Driver Fuel

Source: INL/EXT-19-53191

Overview

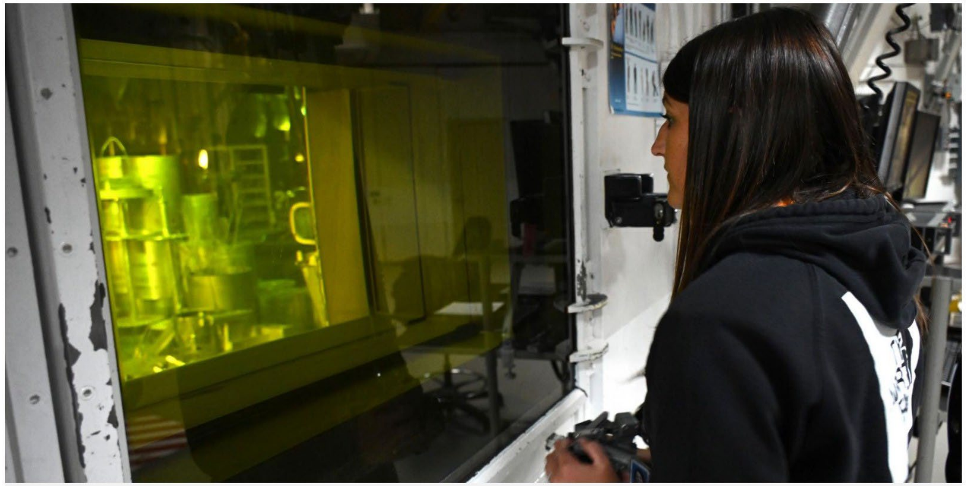
- About Oklo
- Aurora at Idaho National Laboratory
- Fuel for the Aurora at Idaho National Laboratory
- Aurora Fuel Fabrication Facility
- Recycling
- NRIC Program Feedback

Aurora Fuel Fabrication Facility

- Safety Design Strategy (SDS) approved by DOE in December 2023
- Conceptual Safety Design Report (CSDR) approved by DOE-ID in September 2024
- Facility clean up kicked off
- Preliminary design activities on going
    - Projected Preliminary Documented Safety Analysis (PDSA) expected to be submitted in 2025

DOE approves conceptual safety design report for Oklo fuel fabrication facility

Wed, Oct 16, 2024, 9:59AM | Nuclear News



At INL's Fuel Conditioning Facility, spent nuclear fuel material is being recycled into fuel for Oklo's commercial Aurora Powerhouse deployment at INL. (Photo: INL)

Source

Aurora Fuel Fabrication Facility (formerly MFC-798)

Recap

- ✓ Site
- ✓ Fuel
- ✓ Fuel Fabrication

Overview

- About Oklo
- Aurora at Idaho National Laboratory
- Fuel for the Aurora at Idaho National Laboratory
- Aurora Fuel Fabrication Facility
- Recycling
- NRIC Program Feedback

Recycling

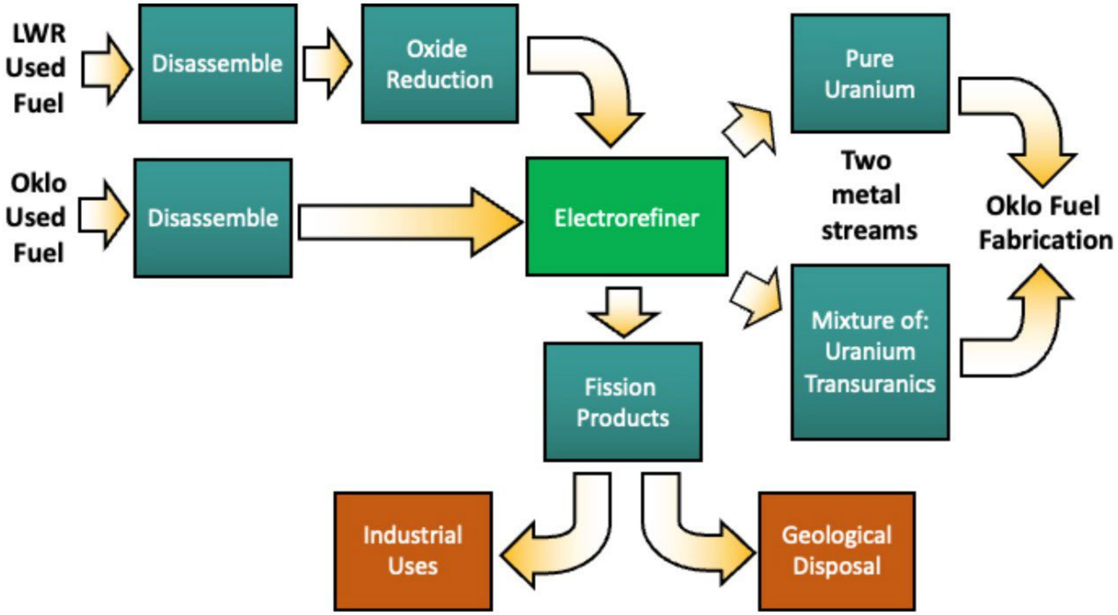
- Oklo is investing in developing commercial-scale recycling of existing used nuclear fuel waste to potentially reduce fuel costs
- Oklo is collaborating with the U.S. Department of Energy on commercializing of recycling through four DOE cost-share awards totaling more than $17M
- Completed end-to-end demonstration of advanced fuel recycling

Oklo completes end-to-end demonstration of advanced fuel recycling

Thu, Jul 18, 2024, 5:10AM | Radwaste Solutions

Engineers in Argonne's Chemical and Fuel Cycle Technologies Division. (Photo: Argonne National Laboratory)

Link



Overview

- About Oklo
- Aurora at Idaho National Laboratory
- Fuel for the Aurora at Idaho National Laboratory
- Aurora Fuel Fabrication Facility
- Recycling
- NRIC Program Feedback

NRIC Program Feedback

- Developers rely on capabilities across the DOE complex
  - Continue supporting activities outside of INL (e.g., METL)

Former Secretary Granholm at the METL facility

[Source](#)

Laboratories Currently Working with Oklo

NRIC Program Feedback (cont.)

- Be a driver of continuous improvement at both INL and other National Laboratories
- Improved stewardship of taxpayer funding
- Continue advocating for industry and raising the expectations across the lab
- Suggestions for consideration
  - Identify and deliberately share lessons learned from one project to another
  - Identify best practices from other National Laboratories
  - Before embarking upon a new activity with an industry partner – brainstorm across INL divisions to try and identify the potential issues that might arise during the project
  - Expand NRIC reach beyond INL (e.g., METL)

Risk Factors

Unless the context otherwise requires, the terms “we,” “us,” “our” and similar designations refer to Oklo Inc.

1. Our business plan requires substantial investment. If there are significant redemptions in connection with the proposed business combination, we may need to make significant adjustments to our business plan or seek additional capital. Depending on our available capital resources, we may need to delay or discontinue expected near-term expenditures, which could materially impact our business prospects, financial condition, results of operations and cash flows by limiting our ability to pursue some of our other strategic objectives and/or reducing the resources available to further develop our design, sales and manufacturing efforts.
2. In order to fulfill our business plan, we will require additional funding in addition to any funding resulting from the proposed business combination. Such funding may be dilutive to our investors and no assurances can be provided as to the availability or terms of any such funding. Any such funding and the associated terms will be highly dependent upon market conditions and the progress of our business at the time we seek such funding.
3. Our projected corporate expenditures and our ability to achieve profitability are subject to numerous risks and uncertainties, including uncertainties related to the impact of inflation, evolving regulatory requirements, raw material and nuclear fuel availability, global conflicts, global supply chain challenges and component manufacturing and testing uncertainties, local and domestic energy policies, international energy policies, international trade policies, government contracting and procurement rules, among other factors. Accordingly, it is possible that our overall expenditures could be higher than the levels we currently estimate, and any increases could have a material adverse effect on our business prospects, financial condition, results of operations and cash flows.
4. We may experience a disproportionately larger impact from inflation and rising costs. Although the impact of material cost, labor, or other inflationary or economically driven factors will impact the entire nuclear and energy transition industry (including renewable sources of electricity, like solar and wind), the relative impact will not be the same across the industry, and the particular effects within the industry will depend on a number of factors, including material use, technology, design, structure of supply agreements, project management and other factors, which could result in significant changes to the competitiveness of our technology and our ability to sell our powerhouses, which could have a material adverse effect on our business prospects, financial condition, results of operations and cash flows.
5. We are an early-stage company with a history of financial losses (e.g., negative cash flows), and we expect to incur significant expenses and continuing financial losses at least until our powerhouses become commercially viable, which may never occur.
6. If we fail to manage our growth effectively, we may be unable to execute our business plan which could have a material adverse effect on our business prospects, financial condition, results of operations and cash flows.
7. We have not yet sold any powerhouses or entered into any binding contract with any customer to deliver electricity or heat and there is no guarantee that we will be able to do so in the future. This limited commercial operating history makes it difficult to evaluate our prospects and the risks and challenges we may encounter.
8. Our business plan includes the use of investment tax credits, production tax credits or other forms of government funding to finance the commercial development of our powerhouses, and there is no guarantee that our projects will qualify for these credits or that government funding will be available in the future.
9. The amount of time and funding needed to bring our powerhouses to market may greatly exceed our projections.
10. Our construction and delivery timeline estimates for our powerhouses may increase due to a number of factors, including the degree of pre-fabrication, standardization, on-site construction, long-lead procurement, contractor performance, plant qualification testing and other site-specific considerations.
11. We do not currently employ any risk sharing structures to mitigate the risks associated with the delivery and performance of our powerhouses. Any delays or setbacks we may experience for our first commercial delivery or failure to obtain final investment decisions for future orders could have a material adverse effect on our business prospects, financial condition, results of operations and cash flows and could harm our reputation.
12. Any failure to effectively update the design, construction, and operations of our powerhouses to ensure cost competitiveness could reduce the marketability of our powerhouses and adversely impact our expected deployment schedules.
13. Our business plan and our ability to achieve profitability relies on the concurrent development of two configurations of our powerhouses (15 MWe and 50 MWe), and makes certain assumptions with respect to learnings, efficiencies and regulatory approvals as a result of this concurrent development approach which may not be accurate or correct. Any adverse change to these assumptions may have a material adverse effect on our business prospects, financial condition, results of operations and cash flows.
14. Our business plan and our ability to achieve profitability may also rely on the development of other configurations of our powerhouses (100 MWe, or other sizes), and makes certain assumptions with respect to learnings, efficiencies and regulatory approvals as a result of this new development approach which may not be accurate or correct. Any adverse change to these assumptions may have a material adverse effect on our business prospects, financial condition and results of operation and cash flows.
15. Our cost estimates are highly sensitive to broader economic factors, and our ability to control or manage our costs may be limited. Capital and operating costs for the deployment of a first-of-a-kind powerhouse like the Aurora are difficult to project, inherently variable and are subject to significant change based on a variety of factors including site specific factors, customer off-take requirements, regulatory oversight, operating agreements, supply chain availability, supply chain availability effects on reactor and power plant performance, inflation and other factors.
16. Opportunities for cost reductions with subsequent deployments are similarly uncertain. To the extent cost reductions are not achieved within the expected timeframe or magnitude, the Aurora may not be cost competitive with alternative technologies, which may have a material adverse effect on our business prospects, financial condition, results of operations and cash flows and could harm our reputation.
17. The amount of time and funding needed to bring our nuclear fuel to market at scale may significantly exceed our expectations. Any material change to our assumptions or expectations with respect to our timeline and funding needs, or any material overruns or other unexpected increase in costs or delays, which may have a material adverse effect on our business prospects, financial condition, results of operations and cash flows and could harm our reputation.
18. The market for advanced fission power is not yet established and may not achieve the growth potential we expect or may grow more slowly than expected and may be superseded or rendered obsolete by new technology or the novel application of existing technology.
19. The market for recycled nuclear fuel in the United States is not yet established and may not achieve the growth potential we expect or may grow more slowly than expected as a result our investment in recycling may be misplaced.
20. We and our customers operate in a politically sensitive environment, and the public perception of fission energy can affect our customers and us.
21. Our technology requires regulatory approvals, and policies around the handling and use of radioactive materials that affect regulatory requirements, processes and the ability to regulate these technologies may change and make regulatory approvals not attainable, adversely affecting our business.
22. Our business plan involves contracting with the government and government-affiliated entities, and any changes or delays to contracting procedures, rules and regulations could lengthen our timeframes to construct and operate our plants, which could materially and adversely affect our business.
23. The occurrence of adverse events, cancellations of significant projects, delays in project timelines, adjustments in cost structures, and other negative developments announced by competitors could have an impact on our operations, financial performance, and future prospects.
24. Incidents involving nuclear energy facilities in the United States or globally, including accidents, terrorist acts or other high profile events involving radioactive materials, could materially and adversely affect the public perception of the safety of nuclear energy, our customers and the markets in which we operate, and such adverse effects could potentially decrease demand for nuclear energy, increase regulatory requirements and costs or result in liability or claims that could materially and adversely affect our business.
25. While we believe our cost estimates are reasonable, they may increase significantly through design maturity, when accounting for supply chain availability, fabrication costs, as we progress through the regulatory process, or as a result of other factors, including unexpected cost increases that particularly effect our powerhouses.
26. Building a new fuel fabrication facility is challenging as a result of many factors, including regulatory and construction complexity, and may take longer or cost more than we expect.
27. We have not sought nor received third-party cost estimates at this time but expect to do so in the future. Such third-party cost estimates may be significantly higher than our current estimates, which may affect the marketability of our powerhouses and our expectations with respect to our business plan and future profitability
28. There is limited precedent for independent developer construction and operation, or use of power purchase agreements, other behind-the-meter or off-grid business models relating to deployment of fission power plants.
29. There is limited operating experience for metal-fueled fast reactors of this type, configuration and scale, compared to that of the existing fleet of large light water reactors. This may result in greater than expected construction cost, deployment timelines, maintenance requirements, differing power output and greater operating expense.
30. Operating a nuclear power plant in a remote environment or in an industrial application has additional risks and costs compared to conventional electric power and heat applications. Such deployments may require additional costs including costs associated with the licensing process, configuration control of the plant, minimum operating staff, training, security infrastructure, radiation protection, government reporting, and nuclear insurance, all of which may be cost prohibitive or reduce the competitiveness of technology.
31. Competition from existing or new competitors or technologies could cause us to experience downward pressure on prices, fewer customer orders, reduced margins, the inability to take advantage of new business opportunities, and the loss of market share.
32. Successful commercialization of new, or further enhancements to existing, alternative carbon-free energy generation technologies, such as adding carbon capture and sequestration/storage mechanisms to fossil fuel power plants, wind, solar, or fusion, may prove to be more cost effective or appealing to the global energy markets and therefore may adversely affect the market demand for, and our ability to, successfully commercialize our targeted powerhouses.
33. The cost of electricity and heat generated from our powerhouses may not be cost competitive with electricity and/or heat generated from other sources, and there is no guarantee that we will be able to charge a premium relative to other energy sources, which could materially and adversely affect our business prospects, financial condition, results of operations and cash flows.
34. Changes in the availability and cost of oil, natural gas and other forms of energy are subject to volatile market conditions that could adversely affect our business prospects, financial condition, results of operations and cash flows.
35. We rely on a limited number of suppliers for certain materials and supplied components, some of which are highly specialized and are being designed for first-of-a-kind or sole use in our power plants. We and our third party vendors may not be able to obtain sufficient materials or supplied components to meet our manufacturing and operating needs or obtain such materials on favorable terms. Additionally, certain components may only be available from international suppliers.
36. Our business operations rely heavily on securing agreements with suppliers for essential materials and components which will be used to construct our powerhouses, fuel fabrication facilities, and recycling facilities.
37. Customers may rescind or back out of non-binding agreements due to various reasons which could adversely affect our revenue streams, project timelines, and overall financial performance.
38. The operations of our planned fuel facility in Idaho, planned power plants in Idaho and Ohio, and any future facilities, will be highly regulated by the U.S. federal and state-level governmental authorities, including the U.S. Nuclear Regulatory Commission ("NRC") and regulatory bodies in other jurisdictions in which we may establish operations. Our operations and business plans could be significantly impacted by changes in government policies and priorities.
39. Our business is subject to stringent U.S. export control laws and regulations. Unfavorable changes in these laws and regulations or U.S. government licensing policies, our failure to secure timely U.S. government authorizations under these laws and regulations, or our failure to comply with these laws and regulations could have a material adverse effect on our ability to expand globally and thereby affect our business prospects, financial condition, results of operations and cash flows.
40. Changes in governmental agency budgets as well as staffing shortages at national laboratories and other governmental agencies may lengthen our estimated timelines for regulatory approval and construction.
41. We are pursuing an application for a novel design with the NRC, which will require NRC approval of our safety system design among other approvals and may result in additional analysis and design changes, including potential redesigns of certain systems, and could lead to increased costs and delays with respect to regulatory approvals.
42. We have not yet submitted our updated combined operating license application to the NRC and no powerhouse in the Aurora product family has yet been approved or licensed for use at any site by the NRC or any other regulatory agency, and approval or licensing of these designs and the timing of such approval or licensing, if any, is not guaranteed.
43. The existing NRC framework has not been applied to license a nuclear fuel recycling facility for commercial use, and there is no guarantee that the NRC will support the development of our proposed nuclear fuel recycling facility on the timeline we anticipate or at all.
44. Our fuel fabrication facilities will be highly regulated by the U.S. government, potentially including both the NRC and the U.S. Department of Energy and approval or licensing of these facilities is not guaranteed.
45. The design of the Aurora powerhouses has not been approved in any country, and approvals must be obtained on a country-by-country basis before the powerhouses can be deployed. Approvals may be delayed or denied or may require modification to our design, which could have a material adverse effect on our business prospects, financial condition, results of operations and cash flows.
46. Our operations involve the use, transportation and disposal of toxic, hazardous and/or radioactive materials and could result in liability without regard to fault or negligence.
47. Our powerhouses, like many advanced fission reactors, are expected to rely, in part, on high assay low enriched uranium ("HALEU") which is not currently available at scale. Access to a domestic supply of HALEU may require significant government assistance, regulatory approval, and additional third-party development and investment to ensure availability. If we are unable to access HALEU, or our access is delayed, our ability to manufacture fuel and to produce electricity and/or heat will be adversely affected, which could have a material adverse effect on our business prospects, financial condition, results of operations and cash flows.
48. We must obtain governmental licenses to possess and use radioactive materials, including isotopes of uranium, in our fuel facility operations. Failure to obtain or maintain, or delays in obtaining, such licenses could impact our ability to generate electricity and/or heat for our customers and have a material adverse effect on our business prospects, financial condition, results of operations and cash flows.
49. We must obtain regulatory approvals for the use of various materials in our powerhouse designs. This includes long lead time irradiation testing and analysis, which may require redesign or use of alternative suppliers if results are unsatisfactory.
50. We may require certain materials and components which are only produced in limited quantity and may be predominantly produced outside of the United States. Cultivating supply chain manufacturing capacity for key materials and components depends on supply chain partners and may require cooperation from the United States or other governments and may result in shortages and delays if not accomplished within assumed timelines or costs.
51. Unresolved spent nuclear fuel storage and disposal policy issues and associated costs could have a significant negative impact on our plans to recycle spent fuel as a potential fuel source for our powerhouses. Additionally, U.S. policy related to storage and disposal of used fuel from our power plant and/or negative customer perception of risks relating to these policies could have a significant negative impact on our business prospects, financial condition, results of operations and cash flows.
52. The nature of our business requires us to interact with various governmental entities, making us subject to the policies, priorities, regulations, mandates and funding levels of such governmental entities and we may be negatively or positively impacted by any change thereto.
53. Prospective future customers may also require that we comply with their own unique requirements relating to their compliance with policies, priorities, regulations, controls and mandates, including provision of data and related assurance for environmental, social, and governance related standards or goals.
54. Power purchase agreements are a key component to our anticipated business model for sales of power, and customers may be able to void all or part of these contracts under certain circumstances. We may need to find substitute customer power and/or heat offtake, or may need to cancel licensing work related to particular customers and sites as a result of changes in customer demand or contracts with customers.
55. Power purchase agreements may include penalties for not delivering sufficient electric and/or heat energy on schedule, which may result in liabilities and reductions in cash flow.
56. We could incur substantial costs as a result of violations of, or liabilities under, environmental laws.
57. Changes in tax laws could adversely affect our business prospects and financial results.
58. The U.S. government's budget deficit and the national debt, as well as any inability of the U.S. government to complete its budget or appropriations process for any government fiscal year could have an adverse impact on our business prospects, financial condition, results of operations and cash flows.
59. We rely on intellectual property law and confidentiality agreements to protect our intellectual property. We may also rely on intellectual property we license from third parties. Our failure to protect our intellectual property rights, our infringement of third-party intellectual property or our inability to obtain or renew licenses to use intellectual property of third parties, could adversely affect our business.
60. Uncertain global macro-economic and political conditions could materially adversely affect our business prospects, financial condition, results of operations and cash flows.
61. We depend on key executives and management to execute our business plan and conduct our operations. A departure of key personnel could have a material adverse effect on our business.
62. Our business plan requires us to attract and retain qualified personnel including personnel with highly technical expertise. Our failure to successfully recruit and retain experienced and qualified personnel could have a material adverse effect on our business.
63. Reduction in energy demand or changes in climate-related policies may change market conditions, reducing our product's competitiveness and affecting company performance.
64. There is substantial doubt about our ability to continue as a going concern, and we may require additional future funding whether or not the proposed business combination is consummated.
65. Beginning in January 2022, there has been a precipitous drop in the market values of growth-oriented companies like ours, particularly companies that entered into business combination agreements with Special Purpose Acquisition Companies (“SPACs”). In recent months, inflationary pressures, increases in interest rates and other adverse economic and market forces have contributed to these drops in market value. As a result, our securities are subject to potential downward pressures, which may result in high redemptions of the cash available from the trust fund. If there are substantial redemptions, there will be a lower float of our common stock outstanding, which may cause further volatility in the price of our securities and adversely impact our ability to secure financing following the closing of the proposed business combination.
66. Securities of companies formed through SPAC mergers such as the proposed transaction may experience a material decline in price relative to the share price of the SPAC prior to the merger.