

Master Plan For Responsible Advanced Nuclear Development in New York:

Research and Development Study

NEW YORK STATE

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Notice

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Table of Contents

Notice ..... **i**

List of Figures ..... **vi**

List of Tables ..... **vi**

Summary **S-1**

1. Introduction **1**

1.1 Study Approach 2

2. Advanced Reactor R&D Landscape **5**

2.1 Commercial Readiness of Advanced Nuclear Technologies 5

2.1.1 Gen III+ and Gen IV Distinctions 5

2.1.2 Supply Chain Challenges 7

2.1.3 Workforce Challenges 8

2.2 Federal and State Nuclear Research & Development Landscape 9

2.2.1 Federal Programs Funding Nuclear R&D 9

2.2.2 Nuclear R&D at National Laboratories 12

2.2.3 Nuclear R&D at the State Level 15

2.2.4 Comparison of Federal and State Roles 19

3. Manufacturing and Project Delivery **21**

3.1 Background Information 21

3.1.1 What R&D Effort Entails in Practice 21

3.1.2 Requirements for Manufacturing 21

3.1.3 Priority, Readiness, and Timeline Considerations 22

3.2 Key R&D Topics 22

3.2.1 Streamline Qualification Pathways to Expand the Nuclear-Qualified Supplier Base (M1) 22

3.2.2 Reduce the Cost and Complexity of NQA-1 Programs (M2) 24

3.2.3 Address Capital-Investment Barriers for Forging and Specialized Component Production (M3) 24

3.2.4 Advanced Modularization, Factory Fabrication, and Automated Assembly (M4) 25

3.2.5 Improve Nondestructive Evaluation and Inspection Techniques (M5) 26

3.2.6 Mitigate Liability Barriers for Commercial Suppliers (M6) 27

3.2.7 Improve Constructability and Modernizing Project-Delivery Models (M7) 27

3.2.8 Strengthening the Construction and Manufacturing Workforce (M8) 28

3.3 New York State Strengths Assessment....28
3.4 Potential Role for New York State....30
4. Materials and Components....32
4.1 Background Information....32
4.1.1 Code Qualification Timelines and Regulatory Constraints....32
4.1.2 Global Supply Chain Volatility and Post-COVID-19 Constraints....32
4.1.3 Limited U.S. Infrastructure for Gen IV Testing in Relevant Environments....33
4.1.4 Data Gaps for Novel Materials and Coolants....33
4.1.5 Different Challenges for Gen III+ and Gen IV Reactors....33
4.2 Key R&D Topics....34
4.2.1 Qualification of Advanced High-Temperature Alloys and Coatings (C1)....34
4.2.2 Coolant Compatibility and Corrosion Performance in Sodium, Helium, and Molten Salts (C2)....35
4.2.3 Irradiation Testing and Lifetime Data for Graphite, Concrete, and Structural Alloys (C3)....35
4.2.4 Advanced Manufacturing for Primary Components (C4)....36
4.2.5 Developing Test Standards and Validated Methods for Advanced Manufacturing (C5)....37
4.2.6 Securing Supply Chains for Critical Reactor Materials (Graphite, Lithium-7, Helium, Metal Powders) (C6)....38
4.2.7 Qualification of High-Temperature Passive Safety Systems and Specialized Components (C7)....39
4.2.8 Radiation-Hardened Sensors and High-Temperature Instrumentation (C8)....39
4.3 New York Strengths Assessment....40
4.4 Potential Role for New York State....41
5. Fuel and Fuel Cycle....44
5.1 Background Information....44
5.1.1 Front-end Capacity Gaps Are Uneven (LEU versus HALEU)....45
5.1.2 Fuel Qualification Timelines Are a Pacing Bottleneck....46
5.1.3 Nonstandard Fuels Risk Fragmentation without Coordination....46
5.1.4 Fuel Needs Differ by Reactor Class....47
5.1.5 Spent Nuclear Fuel Reprocessing....47
5.2 Key R&D Topics....48
5.2.1 Establish a Reliable HALEU Supply Chain (F1)....48

5.2.2 Scale TRISO Fuel Fabrication and Qualification for HTGRs (F2) 48
5.2.3 Metallic Fast-Reactor Fuel Development, Behavior Modeling, and Commercial-Scale Production (F3) 49
5.2.4 Extending Gen III+ Fuel Lifetime through Accident-Tolerant Fuel and LEU+ Pathways (F4) 50
5.2.5 Advanced Fuel Qualification Acceleration and High-Fidelity Fuel Performance Simulation (F5) 50
5.2.6 Spent Fuel Management and Disposal Pathways for Non-Oxide Spent Fuels (F6) 51
5.2.7 Evaluate Long-Term Reprocessing Options and Safeguards (F7) 51
5.2.8 Use of Thorium as a Fuel (F8) 52
5.3 New York Strengths Assessment 53
5.4 Potential Role for New York State 54
6. Site Characterization and Preparation 56
6.1 Background Information 56
6.1.1 Data Needed for Licensing and Data Needed for Construction Readiness Diverge 56
6.1.2 State and Regional Datasets Can Substitute for Site-Specific Collection if Validated 57
6.2 Key R&D Topics 57
6.2.1 Develop Modular, Reactor-Specific Site Characterization Templates (S1) 57
6.2.2 Advance Predictive Modeling Tools for Environmental and Geotechnical Impacts (S2) 58
6.2.3 Streamline Data Requirements for Emergency Planning Zone Determinations (S3) 58
6.2.4 Develop Approaches to Integrate Nuclear Reactors at Existing (Nonnuclear) Brownfield Sites (S4) 59
6.2.5 Improve Early-Phase Environmental Baselining (S5) 60
6.2.6 Standardize Site Geotechnical and Subsurface Investigation Protocols (S6) 61
6.3 New York Strengths Assessment 61
6.4 Potential Role for New York State 63
7. Testing and Validation Infrastructure 65
7.1 Background Information 65
7.2 Key Testing and Validation Infrastructure Gaps 67
7.2.1 Expand Access to High-Temperature, Coolant-Specific Test Loops for Gen IV Reactors 67

7.2.2 Increase Irradiation Testing Capacity for Fuels and Structural Materials 68
7.2.3 Increase Irradiation Testing Capacity for Materials and Coatings 69
7.2.4 Scale Post-Irradiation Examination Capacity 69
7.2.5 Establish Integrated Component-Scale Testbeds 70
7.2.6 Create Shared Test Infrastructure for Multiunit Control Room Demonstrations 71
7.3 New York State Strengths Assessment 71
7.4 Options for Closing the Infrastructure Gap 74
7.5 Potential Role for New York State 75
8. Fusion Energy R&D 76
8.1 Background Information 76
8.2 Key R&D Topics 78
8.2.1 System Integration and Net Plant Performance (N1) 79
8.2.2 Tritium Fuel Cycle and Fuel Self-Sufficiency (N2) 79
8.2.3 Materials Performance in Fusion Environments (N3) 79
8.2.4 Energy Capture, Blanket Systems, and Power Conversion (N4) 80
8.2.5 Plant Reliability, Maintainability, and Operations (N5) 80
8.2.6 Long-Duration Plasma Stability and Confinement (N6) 81
8.2.7 Plasma-Facing Components and Divertor Operations (N7) 81
8.2.8 Fuel Target Fabrication and Injection (N8) 81
8.2.9 Optics and Component Survivability (N9) 81
8.2.10 Repetitive Driver and Pulsed-System Performance (N10) 82
8.2.11 Synchronized Magnetization, Compression, and Control (N11) 82
8.2.12 High-Temperature Superconducting Wire and Magnet Systems (N12) 83
8.3 New York State Strengths Assessment 83
8.4 Potential Role for New York State 85
9. Findings and Conclusions 87
9.1 Working with New York State's Research Institutions 87
9.2 Fission R&D Findings 89
9.3 Fission R&D Prioritization 91
9.4 Fusion Energy R&D Findings 94
9.5 Conclusions 94
Acronyms and Abbreviations 96
Appendix A. Methodology Details A-1

Appendix B. R&D Investments by Reactor Technology B-1
Appendix C. Nuclear R&D Funding Detail C-1
Appendix D. State and University R&D Catalog D-1
Appendix E. New York R&D Capabilities E-1
Endnotes EN-1

List of Figures

Figure 1. Advanced nuclear technology pathways 6
Figure 2. Map of Current U.S. Nuclear R&D Landscape 18
Figure 3. TRISO Fuel Form 44
Figure 4. Nuclear Fuel Cycle from Mining to Disposal 46
Figure 5. DOE Fusion Science and Technology Roadmap 78
Figure 6. Summary of R&D Priorities 92

List of Tables

Table 1. Example R&D Topics for Select Advanced Reactor Technologies 7
Table 2. Supply Chain and Workforce Gaps and Associated R&D Topics by Reactor Class 9
Table 3. Key DOE NE Budget Line Items: Nuclear R&D Funding 10
Table 4. R&D Activity Taxonomy (Federal) 14
Table 5. State-level Nuclear R&D Approaches 16
Table 6. New York Institutional Strengths—Manufacturing and Project Delivery R&D Topics 30
Table 7. Assessment Summary of Manufacturing and Project-Delivery R&D Topics 31
Table 8. New York Institutional Strengths—Materials and Components R&D Topics. 41
Table 9. Materials and Components: Summary Assessment of R&D Needs, Risk to Deployment, and Potential Role for New York State 43
Table 10. New York Institutional Strengths—Fuel and Fuel Cycle R&D Topics. 54
Table 11. Fuel and Fuel Cycle: Summary Assessment of R&D Needs, Risk to Deployment, and Potential Role for New York State 55
Table 12. New York Institutional Strengths: Site Characterization and Preparation R&D Topics. 63
Table 13. Site Characterization and Preparation: Summary Assessment of R&D Needs, Risk to Deployment, and Potential Role for New York State 64

Table 14. Testing and Validation Infrastructure Located in New York State with Capabilities Relevant to the Nuclear Industry 72
Table 15. Crosswalk of Testing and Validation Infrastructure Gaps to Dependent R&D Topics and New York State Capabilities 73
Table 16. Overview of Fuel Components for a Fusion Machine 76
Table 17. Select New York State-Based University Fusion Research Programs 83
Table 18. Summary of New York State's Existing R&D Ecosystem 88
Table 19. Summary of the Priority for Deployment for Each R&D Area, and Options for New York State with Cost Ranges 93

Summary

As part of the "Master Plan for Responsible Advanced Nuclear Development in New York" (Master Plan), this study focuses on the research and development (R&D) needs for advanced nuclear technologies, and the role New York State (NYS) can play in addressing them. It identifies the R&D needs of advanced nuclear and New York State's existing R&D capabilities and finds the overlaps and opportunities between them.

The study examines R&D both in respect of nuclear fission and fusion energy technologies.

New York State's nuclear R&D capabilities can serve markets beyond the State's goal of adding 5 gigawatt-electric (GWe) of new nuclear generating capacity. Hosting R&D activities can provide material benefits for New York State, including new jobs and economic activity. It can accelerate the adoption of nuclear technologies and their many benefits regardless of whether those reactor technologies are adopted in New York State. Many R&D results are also generalizable, providing benefits across different technologies.

Nuclear power has existed at a commercial scale in the U.S. since 1957 and research into advancements and efficiencies has been ongoing for decades. New York State has played a strong role in industry developments and is home to the country's oldest operating nuclear plant, Nine Mile Point Clean Energy Center (Nine Mile Point) Unit 1, which began operating in 1969. This established industry experience provides a solid foundation for the advanced reactor technologies being considered for deployment. For Generation III+ (Gen III+) light water reactors, the technology is well established. Deployment risk is often centered on logistical and execution factors, including constructability, supplier qualification, supply-chain constraints, workforce availability, and project-delivery models. These factors also apply to Generation IV reactors, but they also introduce novel coolants, fuel forms, and advanced materials that can operate at higher temperatures, higher pressures, and faster neutron spectra. Ongoing research R&D focuses on expanding performance, improving cost competitiveness, mitigating deployment risk, and validate and qualify the advancements necessary for new reactor designs. Innovation is essential to overcoming the technical factors constraining the commercial deployment of next-generation advanced nuclear technologies.

In the U.S., federal funding and national laboratories lead nuclear research, which shapes the opportunity for State investment. National laboratories, and some State educational institutions, focus on the most capital-intensive research activities and host much of the testing and

irradiation infrastructure required for R&D. Most of which focuses on developing new materials, components, and processes, as well as reprocessing and recycling of spent fuel and waste. This research can be capital intensive because testing and demonstration facilities must meet a range of requirements to ensure a safe environment for researchers, and some facilities may require licensing, constructing and operating a reactor. It also creates shared national constraints that states must strategically complement rather than duplicate.

State-level R&D efforts typically focus on applied research, demonstration, and deployment readiness, including manufacturing innovation, siting and permitting analysis, workforce development, supply-chain strengthening, and site preparation for future demonstrations. States leverage proximity to national laboratories and their academic institutions to complement federal infrastructure to host technology testbeds and research reactors, which can provide a competitive advantage in research related to materials, spent fuel, and waste. In New York State, Brookhaven National Laboratory (BNL) conducts important research on nuclear material performance and model simulation, creating opportunities for cooperation; it operates side-by-side with highly regarded New York organizations such as Rensselaer Polytechnic Institute (RPI), which conducts nation-leading research and nuclear reactor training.

This report identifies key R&D needs across four broad categories and assesses the NYS opportunity within each:

- Manufacturing and Project Delivery
- Materials and Components
- Fuel, Fuel Cycle, and Spent Nuclear Fuel
- Site Characterization and Preparation

In addition, the report evaluates cross-cutting needs in Testing and Validation Infrastructure, which can help advance R&D in each of the four categories listed above.

This study considers various types of advanced nuclear fission technologies, spanning Gen III+ Light-Water Reactors (LWRs) and Generation IV non-LWRs (Gen IV). Each R&D category was reviewed in the context of these advanced reactor technologies, including microreactors. The technologies considered differ based on coolant type and include LWRs, High Temperature Gas Reactors (HTGRs), sodium-cooled reactors, sodium-cooled fast reactors (i.e., a sodium-cooled reactor that does not use a moderator such as graphite), molten salt reactors (MSRs), and reactors cooled by other metals, such as lead.

An assessment of R&D opportunities was undertaken to evaluate New York State's R&D strengths in each topic, the potential for New York State, as a single state, to have a meaningful impact on advancing R&D on the topic, the relevance of the topic to prioritized reactor types, and finally the overall risk to deployment if the R&D topic is not addressed.

The State is home to several premier institutions that lead critical research on these topics and provide a strong foundation for further opportunities and exploration. Many educational and State institutions offer programs that address many of the R&D needs, as shown in Table S-1.

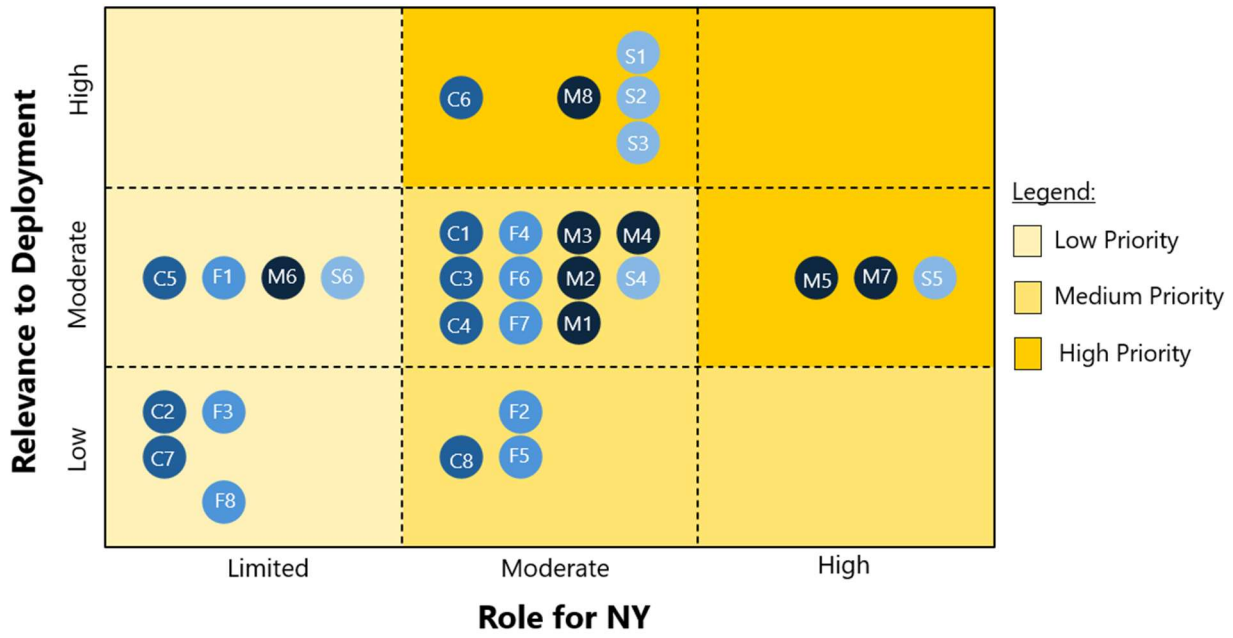
Table S-1. Summary of R&D Needs and New York State Capabilities by Category

R&D Category	R&D Need (Gen III+)	R&D Need (Gen IV)	Illustrative NYS Strengths (Example Institutions)
Manufacturing & Project Delivery	Significant	Significant	AI-assisted quality assurance, digital twins, and digital engineering (RPI, University at Buffalo); advanced and hybrid additive manufacturing (RIT, RPI); workforce programs (SUNY system)
Materials & Components	Limited	Significant	High-temperature alloys, ceramics, and composites (Stony Brook University); extreme-environment characterization (BNL); materials science (Cornell University); radiation-effects modeling (RPI)
Fuel & Fuel Cycle/ Spent Nuclear Fuel	Limited	Significant	Ceramic and metallic fuel fabrication research and nuclear data (RPI, BNL); advanced fuel performance evaluation (BNL); spent fuel R&D (Stony Brook University)
Site characterization & preparation	Significant	Significant	Environmental, geotechnical, and site modeling and digital twins (University at Buffalo); atmospheric/plume modeling and monitoring (University at Albany); drone and remote sensing (Rochester Institute of Technology)

Figure S-1 identifies and organizes topics within the four R&D categories to identify priority nuclear R&D topics for near-term investment in New York State. The X-axis plots the Role for New York State, evaluating New York State's strengths in the topic area and the potential for independent impact. The Y-axis plots the Relevance to Deployment, evaluating the relevance of the topic area to prioritized reactor types and the overall risk to deployment from failing to advance the R&D topic. The high-priority R&D topics are those where New York State investment has the most potential to impact deployment in the near term. Further analysis of the industries and companies in New York State that could support innovations in those areas

may identify additional strengths. Specific topics within the four R&D categories are identified within the figure, beneath the graphic. This report provides additional detail on the scoring for each of these four categories, across the various R&D topics.

Figure S-1. Summary of R&D Priorities



	Manufacturing & Project Delivery
M1	Streamline qualification pathways
M2	Reduce cost and complexity of NQA-1
M3	Capital investment barriers
M4	Modularization and factory fabrication
M5	NDE and inspection techniques
M6	Mitigating liability barriers
M7	Constructability and delivery model modernization
M8	Construction and manufacturing workforce

	Fuel & Fuel Cycle
F1	Establish reliable HALEU supply chain
F2	Scale TRISO fuel fabrication and qualification
F3	Metallic fast reactor fuel development
F4	Gen III+ fuel lifetime
F5	Fuel qualification acceleration and simulation
F6	Used-fuel management and disposal pathways
F7	Reprocessing options and safeguards
F8	Thorium as fuel

	Materials & Components
C1	Qualification adv. high-T alloys and coatings
C2	Coolant compatibility and corrosion performance
C3	Irradiation testing & lifetime data
C4	PM-HIP & AM
C5	Validated methods for advanced manufacturing
C6	Supply chains for critical reactor materials
C7	Qualification of high-T passive safety systems
C8	Radiation and high-T instrumentation

	Site Characterization & Preparation
S1	Modular, reactor-specific site templates
S2	Predictive modeling tools
S3	Streamlining data requirements for EPZ
S4	Integrating reactors at existing nonnuclear sites
S5	Early-phase environmental baselining methods
S6	Standard geotech and subsurface protocols

Findings

New York State's robust research expertise can be strengthened through coordination. The State is home to globally recognized universities and research institutions that represent significant assets for advancing nuclear energy innovation. Premier institutions, including RPI, Stony Brook University, and BNL, conduct research across a wide range of advanced nuclear energy technology disciplines. However, the State lacks a centralized advanced nuclear R&D support organization to improve coordination across New York State and avoid fragmented, duplicative efforts. Building partnerships within the State R&D ecosystem, as well as with national laboratories and private industry, is critical to ensuring innovators have access to cutting-edge tools and necessary testing infrastructure and to focus on the most impactful issues.

State-level research and innovation can address key opportunities in each of the R&D categories:

- In the **manufacturing and project delivery** category, the State's non-nuclear expertise can be leveraged to improve project economics across technology types through innovations in construction management, project-delivery, and advanced manufacturing. The needed innovations closely represent applied research and plant delivery that can drive practical implementation as opposed to fundamental science. They are therefore not dependent solely on the capabilities of national labs and the State has high potential for independent impact. Many of the R&D topics were identified as high-priority areas for New York State.

- In the **site characterization and preparation** category, innovative solutions that are faster and more standardized are necessary to reduce cost and time for project pre-development and accelerate deployment. These solutions and tools apply across technology types with more potential for impact on small modular reactors and microreactors. Civil, structural, and environmental expertise in New York State can be leveraged. Similar to manufacturing and project delivery, these innovations are closer to applied research with a high potential for independent impact, and many topics were identified as high priority for New York State.

- In the **materials and components** category, New York State has significant strengths in developing advanced alloys, ceramics and coatings, radiation effects modeling, and extreme-environment materials characterization that could complement the capabilities at national labs and are particularly relevant for Gen IV reactors and fusion energy technologies. However, innovators are dependent on access to specialized testing and validation infrastructure located out of the state to validate solutions for commercial deployment. This

dependence and overlap with federal funding limits New York State's potential for independent impact in this category.

- In the **fuel, fuel cycle, and spent fuel reprocessing** category, R&D, such as novel fuel forms, enrichment, and large-scale fabrication, is nationally concentrated and federally led, and there is a limited potential for impact at the State level. It was therefore identified as a lower priority for New York State. Evaluating long-term reprocessing and recycling options, used fuel management, and spent fuel disposal pathways warrant investment, but are not necessarily a high-priority in the near term.

Nationwide constraints in testing and validation infrastructure are delaying innovative solutions from reaching commercial-ready status. New York State researchers require improved access to specialized testing and validation infrastructure to have a significant impact. In the near term, priorities should include facilitating collaboration and partnerships between NYS innovators and national laboratories, such as Idaho National Laboratory (INL), Oak Ridge National Laboratory (ORNL), and BNL, as well as other entities with specialized capabilities and finding ways to leverage existing capabilities. However, to truly address this, existing facilities would need to be expanded or new facilities constructed.

New York State has a strong fusion energy R&D ecosystem. The University of Rochester's Laboratory for Laser Energetics provides world-class inertial-fusion and high-energy-density physics capabilities; BNL offers superconducting magnet expertise, materials characterization, and accelerator-based irradiation capabilities; and universities including Columbia, Cornell, RPI, Stony Brook provide complementary expertise in plasma physics, materials, nuclear engineering, diagnostics, and modeling. In addition, the State has a base of relevant manufacturers in optics, superconductors, precision fabrication, controls, and advanced materials that could partner in applied R&D. BNL's strengths in advanced characterization, accelerator-based irradiation, and materials science could position New York State to play a critical upstream and midstream role in the fusion materials ecosystem, complementing national facilities that specialize in high-flux testing. These strengths are in several areas that are critical across multiple fusion technology approaches and create opportunities for the state to contribute to fusion development.

Building a cohesive nuclear innovation ecosystem with an emphasis on partnerships is a priority. This could be achieved by establishing a centralized operating vehicle focused on advanced nuclear innovation that could serve as a centralized coordinator and facilitator of advanced nuclear research around a shared R&D agenda. This entity could coordinate research activities and knowledge sharing in priority R&D topics identified in this study for nuclear fission and fusion energy and facilitate academic-industry-government collaboration and public–private

partnerships. Such an entity could strengthen and build naturally on assets the state already has or could assemble.

Conclusions

1. **Establish an advanced nuclear fission and fusion R&D consortium that can serve as a centralized support hub for advanced nuclear innovation by facilitating knowledge sharing, public-private partnerships and coordinated research efforts.**

2. **Evaluate NYSERDA's advanced nuclear R&D funding priorities based on the near-term opportunities for manufacturing, project delivery, site characterization and preparation identified in this study, as well as further stakeholder input.**

1. Introduction

This Research and Development (R&D) Study is one of a collection of studies prepared by the New York State Energy Research and Development Authority (NYSERDA) and the Department of Public Service (DPS) as part of the "Master Plan for Responsible Advanced Nuclear Development in New York" (Master Plan). Collectively, these studies examine the technical, economic, workforce, supply chain, regulatory, environmental, community, and infrastructure considerations associated with deploying advanced nuclear technologies in New York State.

NYSERDA and DPS acknowledge the contributions of The Brattle Group and Solestiss, working as a subcontractor to The Brattle Group, in preparing this study. At the direction of NYSERDA and DPS, contractor Eastern Research Group (ERG) convened and facilitated a Research and Development Technical Working Group (R&D–TWG) and a Fusion Energy Technical Working Group (FUS–TWG) made up of relevant and expert stakeholders to inform and validate this study.[1]

As part of the Master Plan, NYSERDA and DPS staff are presenting this study to evaluate the need for research and development and to identify initial priorities and opportunities for New York State to address these needs. The study examines R&D both in respect of nuclear fission and fusion energy technologies.

The objectives of this study are threefold:

1. To categorize and prioritize the most critical challenges to advanced nuclear deployment that R&D can help to address
2. To identify and map existing R&D expertise, capabilities, partnerships, and facilities in New York State that can be leveraged and expanded to address the R&D challenges identified
3. To identify opportunities for State action, that can fill gaps and further strengthen New York State's capacity

The Research and Development Study includes the following sections:

- **Section 2, Advanced Reactor R&D Landscape,** discusses the federal and State landscape for nuclear R&D.
- **Section 3, Manufacturing and Project Delivery,** identifies key R&D challenges and evaluates the strengths of NYS institutions in this category.
- **Section 4, Materials and Components,** identifies key R&D challenges and evaluates the strengths of NYS institutions in this category.

- **Section 5, Fuel and Fuel Cycle,** identifies key R&D challenges and evaluates the strengths of NYS institutions in this category.
- **Section 6, Site Characterization and Preparation,** identifies key R&D challenges and evaluates the strengths of NYS institutions in this category.
- **Section 7, Testing and Validation Infrastructure,** explores the nationwide gap in testing and validation infrastructure for advanced nuclear R&D and possible options for New York State to bridge this gap.
- **Section 8, Fusion Energy R&D,** identifies key R&D challenges and evaluates the strengths of NYS institutions in this emerging ecosystem.
- **Section 9, Findings and Conclusions,** concludes and provides a holistic look at the categories and discusses options for the State to support advanced nuclear R&D.

Additional information and data supporting the evaluations presented are provided in the following appendices:

- Appendix A: Methodology Details
- Appendix B: R&D Investments by Reactor Technology
- Appendix C: Nuclear R&D Funding Detail
- Appendix D: State and University R&D Catalog
- Appendix E: New York State R&D Capabilities

1.1 Study Approach

For this study, R&D for advanced nuclear includes not just technical advances in reactor technology, materials, and components, as well as balance-of-plant innovations, but also the innovations needed to streamline certification, inspection, and qualification of materials and components to reach commercialization. This study also identifies R&D knowledge gaps for advanced nuclear on safety and siting that can be addressed through targeted research, information gathering, and modeling/simulation efforts.

The R&D strengths identified in this report reflect New York State (NYS)-based universities, national laboratories, and other institutions; Appendix E includes a list of these institutions and their identified capabilities. In general, private institutions were included if they have received or continue to receive federal funds.

The R&D topics for advanced nuclear were organized into five fission technology categories, with fusion energy discussed separately.

Fission categories:

- **Manufacturing and Project Delivery:** Reliable and timely project delivery remains one of the most significant challenges for both Generation III+ (Gen III+) and Generation IV (Gen IV) reactors and adds to construction risk. Much of the risk stems from project management considerations, supply-chain constraints, and vendor qualification barriers.
- **Materials and Components:** Gen IV reactor technologies may incorporate new materials and components and can involve harsher operating environments.
- **Fuel, Fuel Cycle, and Spent Nuclear Fuel:** Innovations are needed for Gen III+ and Gen IV reactor technologies across the nuclear fuel cycle, spanning mining, conversion, enrichment, fabrication, spent nuclear fuel (SNF) disposal, and reprocessing feasibility.
- **Site Characterization and Preparation**: New nuclear generation could be installed at existing nuclear sites, brownfield, and/or greenfield sites. Site characterization requirements and processes differ according to reactor type, size, and manufacturing and construction approaches.
- **Testing and Validation Infrastructure** is discussed as a cross-cutting issue. For both Gen III+ and Gen IV designs, access to the facilities and infrastructure required to test and validate is often a pacing bottleneck and is stalling technology maturation. This includes research reactors, irradiation facilities, component-scale testbeds, test loops and special instrumentation, hot cells and manipulators, and special transportation means.

Across each of the fission categories as well as fusion energy, a number of key R&D topics are identified.

For each R&D topic identified in this study, the reactor-relevant technology type is noted:

- Fission technologies: Gen III+ light water reactors (LWRs) and Gen IV non-LWRs. Gen IV reactors differ by coolant. The study focuses on high-temperature gas reactors (HTGRs) and sodium-cooled reactors, and notes other reactors where relevant, namely molten salt reactors (MSRs), and reactors cooled by metals other than sodium, such as lead.

- Fusion technologies: magnetic confinement fusion (MCF), inertial confinement fusion (ICF), and magneto-inertial fusion (MIF).

In addition to assessing reactor relevance for both fission and fusion, the study provides further indicators of R&D needs in the key topics in the form of risk to deployment and independent impact potential.

For both fission and fusion, the study also presents an assessment of NYS strengths and the State's potential to advance the research area.

Further details on the study approach are provided in Appendix A.

2. Advanced Reactor R&D Landscape

2.1 Commercial Readiness of Advanced Nuclear Technologies

Advanced nuclear technologies are newer designs that build on the conventional LWR technology currently used by the existing fleet of U.S. reactors. LWRs use water to moderate the nuclear fission reaction and serve as the reactor's coolant. The advanced reactor technologies considered in this study span Gen III+ and Gen IV. This section provides an overview of the commercial readiness of advanced nuclear technologies from a technical, supply chain, and workforce perspective. The technology readiness of advanced reactor technologies is discussed in more detail in the *Zero by 2040 Technoeconomic Assessment* released in September 2025, [2] and a Technology Maturity Assessment is included with the *New York Advanced Nuclear Policy Options Paper* released in June 2026.[3]

2.1.1 Gen III+ and Gen IV Distinctions

While both generations of nuclear plants face supply-chain and project-delivery constraints, their primary risks to deployment differ.

For Gen III+ reactors, the underlying light-water reactor technology, materials, and fuel forms are well established through decades of operating experience. They therefore face fewer fundamental technology gaps. The Gen III+ designs typically run at the same operating pressures and temperatures as the existing fleet. They can accordingly use the same materials and components verified for use under the selected design's specification, service conditions, and applicable qualification requirements. Technical challenges remain, including fuel optimization, long-term materials aging, and performance improvements, but these are largely incremental rather than foundational. As a result, deployment risk for Gen III+ systems is driven more heavily by logistical and execution factors, including constructability, supplier qualification, supply-chain constraints, workforce availability, and project-delivery models.

In contrast, Gen IV designs include novel coolants, new fuel forms, and advanced materials that operate at higher temperatures and pressures, and for some designs, using fast neutrons, instead of the thermal neutrons typically used in existing LWR designs. They therefore require substantial new research, and new materials need to be validated and qualified in these new operating environments before they can be commercially deployed. Their deployment challenges are therefore both technical and logistical: they must close materials and fuel data

gaps while simultaneously establishing manufacturing readiness, and supply-chain and workforce capacity. The flow chart in Figure 1 summarizes how the various technology pathways considered in this study depend on different fuel pathways, coolants, moderators, and fuel forms.

Figure 1. Advanced nuclear technology pathways

Advanced nuclear technology pathways differ based on fuel pathways, coolants, moderators, and fuel forms.

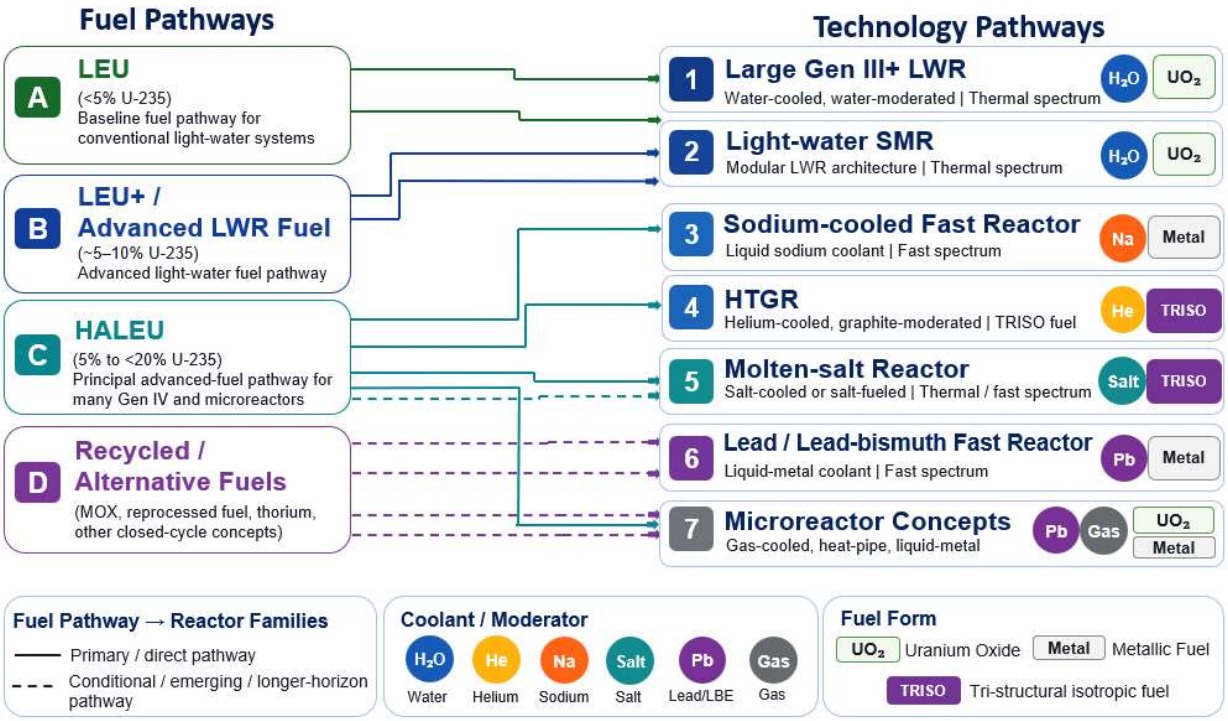


Table 1 provides a high-level summary of the commercial status of advanced reactor technologies and highlights examples of some of the R&D topics identified in this study. Appendix B includes additional information on Gen III+ and Gen IV technologies, including sodium-cooled and HTGRs, along with order-of-magnitude estimates of the investment scale typically associated with each R&D area.

Table 1. Example R&D Topics for Select Advanced Reactor Technologies

Advanced Reactor Technology	Development Status	Example R&D Topics
Large and Small LWR	Large LWR – Commercial (in operation) Small LWR: Commercial (under construction): first BWRX-300 units under construction in Ontario	• Fuel optimization and long-term performance • Reduce cost and accelerate construction • Site characterization
Gen IV Sodium/Metal Cooled Fast Reactors	Component and prototype validation → demonstration Natrium: NRC issued a construction permit in March 2026	• Sodium test loops • Metallic fuel qualification • Structural materials qualification • Sodium-compatible component development and qualification • Spent metallic fuel handling and storage
Gen IV HTGR	Component and prototype validation → demonstration. Xe-100: construction permit application under review by the U.S. Nuclear Regulatory Commission (NRC)	• TRISO fuel qualification and manufacturing • Helium test loops • Graphite moderator and high-temperature component qualification • TRISO spent fuel storage and disposal

2.1.2 Supply Chain Challenges

Supply chain challenges differ across advanced reactor technologies. Gen III+ deployment primarily requires rebuilding and scaling existing manufacturing capabilities, while Gen IV technologies generally require developing and qualifying new fuels, materials, and specialized components. The Master Plan Supply Chain Study provides an in-depth assessment of New York State's capabilities across three tiers of the supply chain and identifies near term projects, longer term opportunities, and provisional external dependencies for specific suppliers. The Master Plan Supply Chain Study concludes to develop a supplier readiness program to identify, qualify, and prepare firms for nuclear procurement through targeted technical assistance and supplier qualification to overcome some of these challenges. Targeted R&D topics identified in this report can also help address these gaps, accelerate supply chain strengthening, and support broader nuclear deployment.

2.1.3 Workforce Challenges

Scaling deployment from today's fleet to double the capacity (and likely hundreds of gigawatts nationwide) will require a significant expansion in the availability of skilled labor. Estimates suggest that to support a tripling or quadrupling of U.S. nuclear capacity (from 100 GW to 400 GW), the U.S. nuclear workforce would need to grow by approximately 375,000 workers beyond the roughly 100,000 employed today, providing the skill sets needed for construction, manufacturing, operations, and the supply chain.[4]

A substantial portion of the current nuclear workforce is nearing retirement age. Many of these individuals represent the final generation with direct experience from the last major U.S. nuclear build-out in the 1970s and 1980s. As they retire, the industry faces a growing experience gap as younger workers enter the profession. In addition, because large-scale nuclear construction activity has been limited for several decades, many trades have lacked sustained reason to maintain nuclear-specific training pathways. As a result, key craft occupations may lack recent nuclear quality and safety experience, even where general trade skills remain strong.

This study does not consider the workforce in great detail, although it discusses some R&D topics related to developing a skilled workforce in the Manufacturing and Project Delivery category. The Master Plan Workforce Development Study provides an in-depth look at the projected workforce demands, critical occupations, and workforce ecosystem in New York State.

Table 2 highlights key gaps identified in the supply chain and workforce where investment in R&D could support the development of tools and products to support and streamline supplier qualifications and training pipelines and investigate workforce needs.

Table 2. Supply Chain and Workforce Gaps and Associated R&D Topics by Reactor Class

Reactor Class	Key Supply Chain and Workforce Gaps	Associated R&D Topics
Gen III+ Reactors (LWRs)	• Limited nuclear-qualified manufacturing capacity (N-stamp suppliers) • Long lead times for large forgings and heavy components • Workforce constraints in nuclear construction trades	• Manufacturing scale-up and supplier qualification • Construction and project delivery • Fuel optimization and long-term performance • Site characterization for new and brownfield sites
Gen IV Reactors (Non-LWRs)	• Limited availability of advanced fuels (HALEU, TRISO) • Specialized materials (nuclear-grade graphite, high-temperature alloys) • Novel components (sodium systems, helium circulators, electromagnetic pumps)	• Fuel cycle development and fuel qualification • High-temperature materials research and qualification • Prototype testing and validation of novel components
Cross-Cutting (All Technologies)	• Workforce shortages across nuclear trades • Limited QA/N-stamp suppliers and inspection capacity • Testing and validation infrastructure constraints	• Supplier qualification and advanced QA methods • Component testing and demonstration facilities

2.2 Federal and State Nuclear Research & Development Landscape

In the US, the federal government leads most nuclear research, which shapes the opportunity for state investment. Federal laboratories conduct the most capital-intensive research activities, while in general states focus where there is more potential for independent impact. States also leverage proximity to national laboratories and their academic institutions to host technology testbeds and research reactors. This section provides an overview of the federal programs providing funding for nuclear R&D, the R&D capabilities at national laboratories, and support at the state-level.

2.2.1 Federal Programs Funding Nuclear R&D

Federally funded nuclear research, development, and testing are done at the U.S. Department of Energy (DOE) national labs and at educational institutions, which are often federally funded. The DOE Office of Nuclear Energy's (NE) budget has multiple line items funding the demonstration of nuclear technologies as well as R&D (Table 3), with a FY2026 appropriated budget totaling

$1.685 billion.[5] The scale of federal funding shapes, rather than eliminates, the case for State investment. Where DOE programs are large, and the work is inherently tied to federal facilities, the appropriate State posture is partnership: cost-share, access agreements, and positioning NYS institutions to successfully compete for federally funded work rather than duplicating infrastructure. Where federal funding is low relative to need, or where topics are applied and deployment-facing, State investment can fill gaps directly and capture significant long-term benefits for New York State. The category discussions that follow apply this logic through the Potential for Independent Impact factor: topics rated highly dependent on federal facilities or national bodies are candidates for cost-share and advocacy; topics with low dependency and existing NYS strength are candidates for direct State-led investment.

Table 3. Key DOE NE Budget Line Items: Nuclear R&D Funding

Note: FY2026 program funding totals $1.785 billion, of which $100 million within the Advanced Reactor Demonstration Program (Risk Reduction for Future Demonstrations) is funded from prior-year unobligated balances rather than new budget authority.

Program Area	FY2025 Enacted	FY2026 Enacted
University and Competitive Research (NEUP/SBIR/TCF)	$140 million	$146 million
Reactor Concepts R&D	$128 million	$177 million
Fuel Cycle R&D (incl. HALEU availability)	$445 million	$490 million
Nuclear Energy Enabling Technologies	$94 million	$113 million
Advanced Reactor Demonstration Program (incl. NRIC/DOME, LOTUS)	$303 million	$269 million
Infrastructure, Security, and Program Direction	$576 million	$590 million
Total Office of Nuclear Energy	**$1.69 billion**	**$1.79 billion**

The DOE NE budget also provides for the Reactor Pilot Program, which was established by Executive Order (EO) 14301. The program provides an authorization pathway through the DOE regulatory framework, including testing and validation of new technologies. The program's primary target was to have at least three private reactor designs reach a self-sustaining nuclear chain reaction (i.e., criticality) by June 4, 2026. The program allows companies to leverage their data and proven reactor concepts to accelerate NRC approval, which is the only approval mechanism that will allow the technologies to be deployed commercially. In fact, four developers met the goal of achieving zero-power fueled criticality. The NRC is engaged in the program to avoid overlap and streamline the approval process.

Additionally, the Department of Defense (DOD) has several programs to pursue advanced nuclear power for use at its installations. Project Pele, launched in 2020, focuses on design, construction, and demonstration of a prototype for a portable microreactor. The demonstration is taking place at Idaho National Laboratory. In a subsequent step, EO 14299 was issued in May 2025, directing DOD to commence operation of a U.S. Army-regulated nuclear reactor at a domestic military base no later than September 2028. In response, DOD initiated the Janus program, which uses data, labs, expertise, and technology pathways from DOE programs to build commercially owned microreactors at the installations. The Janus program selected from the technologies DOE is evaluating in the Reactor Pilot Program. Because the microreactors will meet a mission-critical need for DOD, a regulatory pathway that includes DOD approval can be used for the installations.

In August 2026, Fort Drum became the first site in New York selected as one of five installations to host a microreactor under the Janus Program and awarded the contract to Westinghouse Government Services for its eVinci microreactor[6]. The project is a significant milestone for advanced nuclear in New York and positions New York as an early proving ground for technology that could later be employed commercially in the State and may provide opportunities for NYS engagement.

In addition to DOE NE, five major federal funding programs support nuclear R&D:

1. Advanced Reactor Demonstration Program
2. DOE Office of Energy Dominance Financing
3. National Nuclear Security Administration (NNSA)
4. Inflation Reduction Act of 2022 (IRA) investments
5. NNSA University Consortium

These programs provide broad support through loans, cost-share grants, tax credits, public–private partnerships, and university consortiums.

The Naval Nuclear Laboratory (NNL) also supports nuclear innovation with a focus on nuclear propulsion and technologies that support the Navy's submarine and aircraft carrier fleets. NNL supports the Naval Nuclear Propulsion Program (NNPP) and is jointly funded by the Department of the Navy and DOE. Work is conducted at NNL sites in New York, Pittsburgh, Idaho, and South Carolina in addition to sponsored work at DOE National Labs, suppliers, and universities[7]. New York State has two primary NNL facilities: the Knolls Site, a research, development, and remote

fleet support facility in Niskayuna and the Kesselring Site, which has an operating nuclear reactor for technology development and training Navy sailors in West Milton.

In the United States, fusion research is supported primarily through the DOE's Fusion Energy Sciences (FES) program, which funds work at national laboratories such as Lawrence Livermore National Laboratory (LLNL), Princeton Plasma Physics Laboratory (PPPL), and ORNL, as well as university-based research programs, including the University of Rochester's Laboratory for Laser Energetics (LLE). These institutions conduct research comprising plasma physics, high-energy-density physics, materials science, and reactor technology, and provide critical capabilities in high-performance computing and advanced modeling. The DOE's FES program has expanded funding for programs to accelerate the development and validation of technologies needed for fusion energy systems, such programs include Innovation Network for Fusion Energy (INFUSE), Fusion Innovation Research Engine Collaboratives, and Fusion Milestone Program.[8] Beyond just funding, these programs increase access to national laboratory expertise and facilities, facilitate public-private collaborations, and organize lab-, university-, and industry- teams around particular technology challenges.

An additional DOE initiative, in partnership with the Office of Science, Technology and Policy (OSTP), is the Genesis mission, which DOE notes aims to build the world's most powerful scientific platform to accelerate discovery, strengthen national security, and drive energy innovation. As part of Genesis, the DOE has selected the Prometheus project to receive a Phase II award of $60 million over 3 years (subject to appropriations).[9] Prometheus will leverage artificial intelligence (AI) to design, license, manufacture, construct, and operate nuclear reactors with human-in-the-loop workflows; integrate AI into nuclear fuel fabrication; and use AI for nuclear legacy document management.

These initiatives from the various offices in DOE, OSTP, and DOD may create opportunities for collaboration on research areas such as digital automation and progress on advanced technologies, particularly microreactors.

2.2.2 Nuclear R&D at National Laboratories

Federal nuclear power R&D in the U.S., for fission and fusion, is concentrated in ten national laboratories and a small number of federally supported test facilities, where capital-intensive and nationally coordinated research is conducted. These activities include reactor physics and system design, irradiation testing, post-irradiation examination (PIE), advanced coolant and

materials testing, and first-of-a-kind demonstration projects, as shown in Table 4. Appendix C provides details on national laboratory funding.

In New York State, Brookhaven National Laboratory had a FY2026 federal nuclear budget request of $676 million, relative to its total lab budget of $884.3 million in FY2024. The lab's expertise in this area lies in fundamental nuclear physics, generating radioisotopes, materials characterization, and photon sciences. Brookhaven National Laboratory's nuclear capabilities center on the National Synchrotron Light Source II (NSLS-II), the Electron-Ion Collider (EIC) accelerator complex, the Brookhaven National Laboratory's Linac Isotope Producer (BLIP), as well as in its Nuclear Science & Security Department. The Nuclear Science & Security Department has developed technologies for radiation detection and emerging safeguards technologies. Within this department, the Reactor Systems and Risk Analysis group completes probabilistic assessments of LWRs and advanced reactor high-level decision criteria to base regulations, while the Materials for Energy Applications group is working on innovations in molten salts, metal interactions, as well as combinatorial materials discovery for alloys for nuclear applications. The BNL National Nuclear Data Center has data used worldwide for assessing nuclear reactions, emergency response, and waste characterization.

Under the Inflation Reduction Act, Brookhaven National Laboratory received $105 million to construct the Electron-Ion Collider, a next-generation facility for nuclear physics, and $18.5 million to expand the beamline capabilities at NSLS-II, which allows researchers to map out characteristics of materials, many with potential applications for nuclear energy technologies.[10]

Table 4. R&D Activity Taxonomy (Federal)

Research Area	Primary Activities	Primary Locations
Reactor Physics and System Design	Core design, reactor physics modeling, safety analysis, integrated system design	• Idaho National Laboratory (INL) • ORNL • Argonne National Laboratory (ANL) • Brookhaven National Laboratory (BNL)
Irradiation Testing of Fuels and Materials	In-reactor testing of fuels, cladding, and structural materials under representative conditions	• INL Advanced Test Reactor (ATR) • INL Materials and Fuels Complex
PIE	Hot-cell examination and degradation analysis of irradiated fuels and materials	• INL hot-cell facilities • ORNL hot-cell facilities
Coolant Chemistry and High-Temperature Materials	Testing of sodium, molten salt, gas, and other coolant systems; corrosion and thermal performance	• ORNL specialized test loops • National lab facilities
First-of-a-Kind Demonstrations	Prototype and demonstration reactor construction and operation	• Advanced Reactor Development Programs (ARDP) • INL NRIC testbeds (DOME, LOTUS)
Nuclear Data and Cross-Sections	Neutron cross-section measurements, criticality benchmark data for reactor design and safety	• RPI Gaerttner LINAC Center • ORNL • LANL
Reactor Safety, Security and Transportation Testing	Severe accident testing and analysis, transportation and storage cask qualification, security and risk assessment	• Sandia National Laboratory (SNL)
Spent Fuel, Waste Processing and Environmental Management	Radiochemical processing and separations, waste form development and qualification, TRISO waste volume reduction, tritium processing, environmental remediation, repository design	• Savannah River National Laboratory (SRNL) • Pacific Northwest National Laboratory (PNNL) • LANL
Fusion-specific test facilities	Construction and operation of complex research infrastructure, e.g. tokamaks, laser systems, and high-performance computing	• PPPL • LLNL • ORNL • SNL

2.2.3 Nuclear R&D at the State Level

State-level nuclear R&D efforts typically focus on applied research and deployment readiness. These activities include manufacturing innovation, streamlining siting and permitting processes, supply-chain innovations, and preparation for future demonstrations. Table 5 provides typical state-level activities and illustrative examples. States that have positioned themselves strategically often leverage proximity to federal laboratories, align with existing industrial strengths, and focus on reducing non-technical barriers to commercialization. For example, Tennessee is leveraging its proximity to ORNL, pairing state economic development incentives with Oak Ridge National Laboratory partnerships and a proposed university test reactor to anchor advanced nuclear manufacturing and fuel cycle investment in the state (see Appendix D). Several universities have grown connections with specific federal agencies to conduct classified research for DOD and DOE, such as the Pennsylvania State University's Applied Research Lab, Johns Hopkins University's Applied Physics Laboratory, and Cornell University's Laboratory of Plasma Studies. Given the interest in growing nuclear power to meet rising power demand and clean energy needs, state-level R&D activity has increased. Understanding this landscape provides insights into research gaps that New York State may be able to fill.

Table 5. State-level Nuclear R&D Approaches

Focus Area	Typical State Activity	Illustrative States and Examples
Applied Deployment Research	Applied R&D on reducing cost, schedule, execution risk	• Idaho and Tennessee programs linked to national labs • Pennsylvania and Maryland programs linked to universities • Virginia linked to universities
Manufacturing and Siting Readiness	Supply chains, manufacturing readiness, siting, permitting, grid integration	• Texas, Tennessee, Illinois manufacturing and siting initiatives
Demonstration Readiness	Site prep, balance-of-plant analysis, stakeholder coordination	• Idaho microreactor demos • Virginia SMR feasibility
Workforce and Supplier Development	Training pipelines, supplier qualification, component manufacturing	Regional workforce ecosystems in: • Tennessee • North Carolina • South Carolina • Pennsylvania
Alignment with Existing Strengths	Targeted investments tied to local institutions and industrial bases	• Washington (fuel fab and PNNL) • Illinois (ANL) • Pennsylvania (vendors) • Oregon (OSU Glovebox for Experimental Liquid Sodium) • North Carolina (NC State PULSTAR) • Massachusetts (MIT Plasma Science and Fusion Center) • Tennessee (ORNL) • New Mexico (SNL)

Figure 2 illustrates the current landscape of U.S. nuclear R&D activity across 29 active states and 10 DOE national laboratories. The states are organized into four tiers based on their American Nuclear Society (ANS) ranking and policy activity. ANS is the professional society for the U.S. nuclear science and technology community. Its state ranking reflects the breadth of each state's advanced nuclear activity, considering factors such as the operating reactor fleet and new build activity, state policy and funding support, nuclear-focused educational institutions and research reactors, and workforce and supply chain presence. A top 10 ANS position indicates a state at the leading edge of advanced nuclear activity nationally.[11]

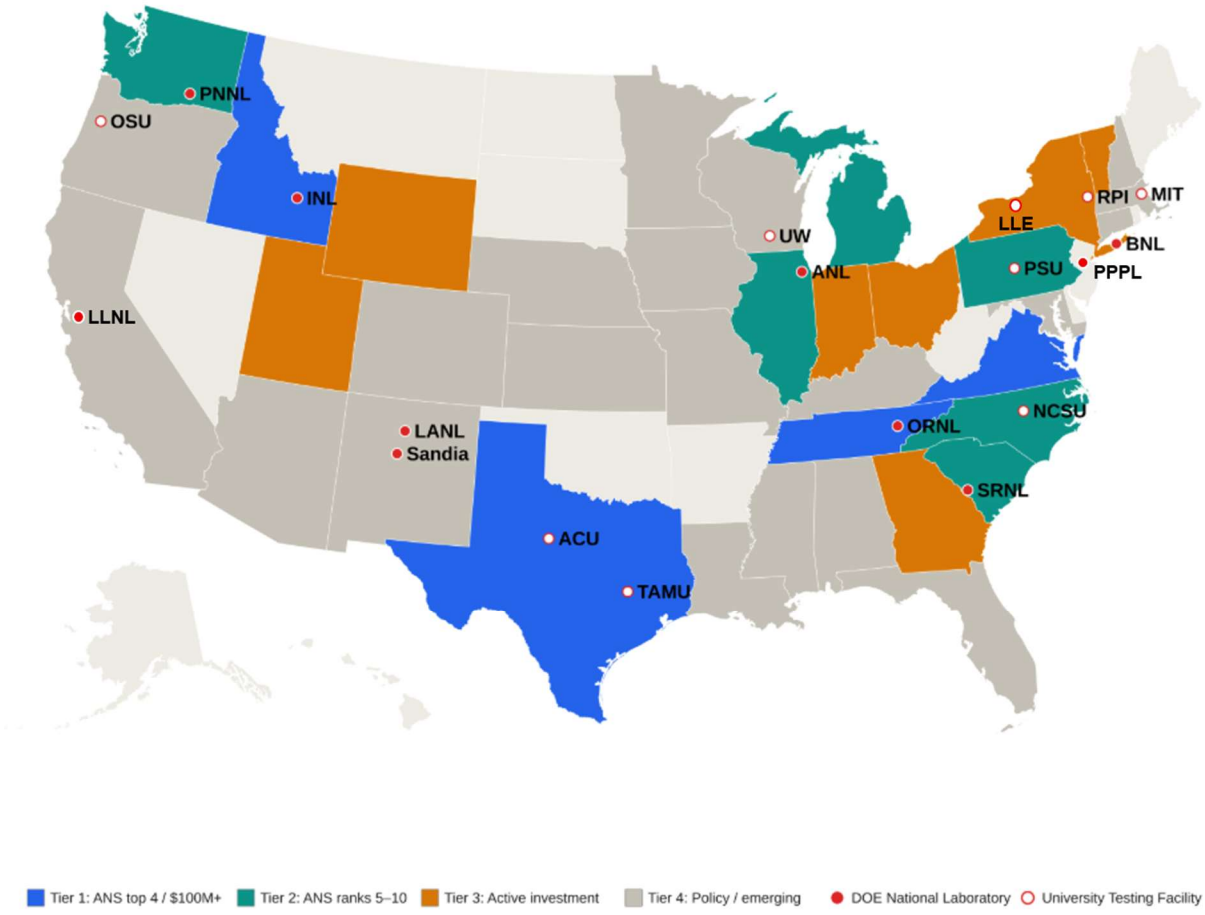
- Tier 1 (blue): ANS top 4 states includes Tennessee, Texas, Idaho, and Virginia.
- Tier 2 (teal): ANS ranks 5–10, characterized by a significant fleet, pipeline, or policy momentum; includes Washington, North Carolina, Illinois, South Carolina, Pennsylvania, and Michigan.
- Tier 3 (amber): States with active investment or deployment commitments; includes New York, Utah, Wyoming, Georgia, Ohio, Indiana, and Vermont.
- Tier 4 (gray): States with policy actions, operating fleets, or emerging nuclear programs; includes 20 additional states from Maryland to Missouri.

Tables D-1 and D-2 in Appendix D provide the underlying data for each state, reactor fleet and pipeline details, fuel cycle facilities, and key R&D infrastructure. National laboratories and federal research facilities are shown, as well as university testing facilities that meet at least one of the following criteria:

1. Operate an NRC-licensed research or test reactor
2. Provide irradiation or testing access to external users through a national program such as the DOE Nuclear Science User Facilities network
3. Directly support a named advanced reactor demonstration or qualification program

Smaller university laboratories and test loops are not individually cataloged. NYS institutions' testing and validation capabilities, including facilities that fall below these thresholds, are addressed separately in the New York Strength Assessments and in Appendix E.

Figure 2. Map of Current U.S. Nuclear R&D Landscape



In Figure 2, New York State is categorized as Tier 3 due to its stated commitment to the development of 5 GWe backbone of advanced nuclear, four operating nuclear reactors at three sites (Nine Mile Point Clean Energy Center Units 1 and 2, James A. FitzPatrick Clean Energy Center, and R.E. Ginna Clean Energy Center), and position as co-chair of the National Association of State Energy Officials (NASEO) Advanced Nuclear First Mover Initiative.[12] The map includes three locations in New York State: Brookhaven National Laboratory (discussed previously), RPI, and the University of Rochester's LLE.

RPI operates the Gaerttner Linear Accelerator (LINAC) Center, a high-power, 60 MeV electron linear accelerator, and is the only facility of its kind in the U.S. The facility supports research studying how neutrons interact with materials, including metals, composites, and others, leading to improvements in nuclear technology and safety.[13] In addition, the RPI facility has worked collaboratively with the NNL to build a deep and accurate understanding of nuclear material properties[14].

The University of Rochester's LLE is one of the world's leading inertial confinement fusion research institutions and optics programs, generally.[15] LLE operates the OMEGA laser facilities.[16] Beyond research, LLE serves as a key workforce development and technology hub for high-power laser systems, training engineers and scientists with direct experience in fusion-relevant photonics and plasma diagnostics.

In addition to the major federal facilities shown on the map in Figure 2, universities provide a favorable environment for testing facilities, including advanced nuclear reactor technologies and microreactors. Historically, many colleges have volunteered to host nuclear reactors on or near campus to further research or for education and workforce training. The U.S. has 25 fission research reactors at universities in states including Massachusetts, Indiana, Missouri, Illinois, and Texas.[17]

2.2.4 Comparison of Federal and State Roles

Nuclear R&D by the federal government shapes, rather than eliminates, the case for State investment. Federal laboratories conduct the most capital-intensive research activities, while states tend to focus on applied research and deployment readiness that can accelerate commercialization.

Where DOE programs are large, and the work is inherently tied to federal facilities, the appropriate State posture is partnership: cost-share, access agreements, and positioning NYS institutions to compete successfully for federally funded work. Where federal funding is thin relative to need, or where topics are applied and deployment-facing, State investment can fill gaps directly and capture disproportionate benefits for New York State. For example, support for test facilities aligned with identified DOE development goals that support and address the capabilities and needs of industry and research institutions located in the state. And finally, State support can be used for technology commercialization and startup formation. For New York State, this suggests that the most strategic opportunities may lie in areas that leverage the State's academic institutions, industrial capabilities, and supply chain while complementing federal research infrastructure rather than duplicating it. Additional opportunities may exist through direct partnership with industry.

States leverage proximity to national laboratories and their academic institutions to host demonstration projects. Universities provide a favorable environment for technology testbeds and research reactors; in addition to advancing research, these facilities provide opportunities for education and workforce training. New York State has no operating research reactors,

although RPI's well-established nuclear program previously operated the Walthousen Reactor Critical Facility and provides the most likely option to support a new larger research reactor.

While New York State's policy commitment to advanced nuclear is now among the strongest in the country, its historical level of advanced nuclear-specific R&D investment and demonstration activity does not place it in the top 10 states for nuclear activity, many of which host major DOE facilities or active demonstration projects. The Backbone initiative and the investments contemplated under the Master Plan would be expected to strengthen this position over time.

3. Manufacturing and Project Delivery

3.1 Background Information

Reliable and timely project delivery remains one of the most significant challenges for Gen III+ and expected to remain one for Gen IV reactors. Much of the risk stems from project management considerations, supply-chain constraints, vendor qualification barriers, workforce shortages, and the absence of predictable, large-scale demand for new nuclear reactors and the necessary supply chain components.

3.1.1 What R&D Effort Entails in Practice

Advancing manufacturing and project-delivery readiness requires a mix of demonstration, qualification, and cross-industry collaboration. Key activities include establishing new production lines for nuclear-qualified components, fabricating prototypes, and testing using advanced processes. These activities depend on close coordination with national laboratories, standards bodies, private manufacturers, and DOE programs.

3.1.2 Requirements for Manufacturing

Shortages in nuclear-certified fabrication/quality assurance (QA) capability constrain safety-related nuclear components and the downstream work required to make nuclear-grade components acceptable for service. The pinch points show up most acutely in:

- Large reactor major components and associated nuclear-grade fabrication work (e.g., large pressure-boundary components and other critical-path structures, systems, and components).
- Post-forging and final fabrication steps that control throughput even when raw forging capacity exists: machining, welding, heat treatment, inspection, and non-destructive evaluation (NDE).

For advanced or high-temperature systems, the constraint often shifts to component development, testing, and qualification (not just manufacturing), including specialized heat exchangers, valves, piping, and instrumentation.

The safety-related suppliers most directly affected by the cost and time burden of adopting and maintaining nuclear QA requirements generally fall into the following groups:

- Nuclear-capable fabrication and machine shops (including welding and specialty processing) that produce safety-related hardware and documentation packages

- Safety-related active mechanical component manufacturers and OEMs (e.g., valves, pumps, actuators, specialty mechanical equipment)
- Safety-related electrical and instrumentation and control suppliers (e.g., sensors, control cabinets, software-bearing systems)

The Master Plan Supply Chain Study discusses qualification, certification, and procurement barriers in detail; it identifies nuclear certification pathways as a supply chain bottleneck and recommends mitigation strategies and potential support options to meet current requirements.

3.1.3 Priority, Readiness, and Timeline Considerations

Manufacturing and project-delivery R&D is widely regarded as high-priority because deployment cannot scale without solving cost, schedule, and supply-chain challenges. Many tools already exist in adjacent industries but must be adapted and code-qualified for nuclear power, indicating that demonstration rather than fundamental research is now the primary need for existing technologies.

Over the next 3–5 years, targeted R&D can enable qualification of fabrication methods, scale modularization approaches, and develop validated digital-engineering platforms. Larger capital investment to expand forging and machining capacity remains a longer-term challenge and will likely depend on market formation, aggregated demand, and federal cost-sharing mechanisms.

3.2 Key R&D Topics

3.2.1 Streamline Qualification Pathways to Expand the Nuclear-Qualified Supplier Base (M1)

The NRC is the ultimate authority over the U.S. commercial nuclear power industry and adopts established industry standards to meet its regulations. A relevant example is the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, a comprehensive set of standards for designing, constructing, and testing pressure vessels and other mechanical equipment to ensure each component meets its intended function. This Code was established in the early 1900s to address significant safety hazards associated with boilers, has a strong safety record, and has evolved over time with new materials and applications.

National initiatives to reduce reliance on N-stamp procurement, through commercial grade dedication and risk-informed narrowing of safety-related scope, are complementary and are discussed under the Nuclear Quality Assurance-1 (NQA-1) topic below.

The ASME N-stamp certifies that a manufacturer can produce safety-related components to ASME nuclear codes and that its quality assurance program has passed a rigorous survey verifying adequacy and effective implementation; NQA-1 documents the underlying QA program requirements that certified suppliers must follow. Originally developed from U.S. Navy requirements for NNPP reactor components, the N-stamp is the global benchmark for nuclear construction. The U.S. has experienced a steep decline in both N-stamp holders and NQA-1 certified suppliers, constraining the ability to manufacture nuclear-grade components at scale: the Solestiss supply-chain landscape assessment found that the number of U.S. companies supplying nuclear components has fallen by more than 80% since the late 1980s. ASME N-type certificate holders have declined by more than 78% over the same period.[18] Obtaining and maintaining these certifications is expensive and time-consuming, often requiring dedicated staff, extensive documentation, and frequent audits. R&D could support streamlined, risk-informed qualification pathways and improved data systems that allow suppliers to adopt nuclear QA requirements more efficiently.

A key concept in asset management is called "establish-versus-maintain." This approach refers to establishing frameworks, processes, and relationships, and then monitoring and sustaining these elements during the project life cycle. Quantified establish-versus-maintain cost and time estimates for NQA-1 remain available. A targeted R&D product would be a quantitative benchmark of the relevant establish-versus-maintain costs and durations for certification across supplier classes, giving policymakers a defensible basis for streamlining and incentive design. The barriers are widely viewed as high overhead and bureaucracy, with meaningful recurring costs tied to audits, documentation, software controls, training, corrective action programs, supplier oversight, and other prescriptive QA elements. Streamlining these barriers without compromising the safety standards they ensure will enable cost and schedule efficiencies.

For the ASME N-stamp, some suppliers state that obtaining the stamp can take more than a year and cost hundreds of thousands of dollars.

Another factor related to the constrained ability to manufacture nuclear-grade components at scale is the trade-offs and business decisions manufacturers will make about whether to invest in becoming a certified supplier, given the demand for nonnuclear-grade materials, components, and supplies. Given the growing need for onshore manufacturing capacity to support existing and new industries, and the lack of guaranteed order books for new nuclear

power, increasing R&D to streamline pathways for N-stamp suppliers could provide substantial value.

Reactor Relevance: All technologies
Risk to Deployment: Moderate
Independent Impact Potential: Moderate

3.2.2 Reduce the Cost and Complexity of NQA-1 Programs (M2)

Suppliers frequently cite NQA-1 as a top barrier to entering the nuclear market. Maintaining a compliant program can require millions in guaranteed annual revenue, creating a structural deterrent for otherwise capable manufacturers. R&D should explore developing digital quality systems, harmonizing NQA-1 with international standards given the growing commercial market in Europe, expanding commercial-grade dedication frameworks, and policy research to identify risk-informed qualification criteria to reduce NQA-1 burdens. Additional research on narrowing the safety-related components that must meet NQA-1 requirements could increase the utility of expanding this topical area and decrease expenses. While research by NYS institutions could support these topics, code reform and adoption are primarily national-level decisions. RPI possesses specialized expertise in creating AI-assisted quality assurance and anomaly detection tools for nuclear manufacturing processes to support NQA-1 compliance and defect reduction, alongside risk-informed assessments of licensing and qualification programs.

Reactor Relevance: All technologies
Risk to Deployment: Moderate
Burden falls hardest on the new entrant and smaller suppliers needed for SMR and Gen IV deployment
Independent Impact Potential: Low

3.2.3 Address Capital-Investment Barriers for Forging and Specialized Component Production (M3)

The capital commitments associated with expanding nuclear manufacturing capacity, whether for heavy manufacturing infrastructure, major component fabrication capability, or specialized equipment, are often in the nine-figure range.[19] As a result, suppliers are generally unwilling to move forward with large investments based on one or two initial projects, given the nuclear industry's historically unpredictable demand and the risk that expensive assets could remain underutilized between orders.[20] The Master Plan Supply Chain Study discusses the market feedback and demand signals suppliers need to invest in this space. Two primary needs

identified include credible project commitments and demand visibility, and direction on reactor technologies

The Master Plan Supply Chain Study provides options to address investment barriers; however, additional research could identify other innovative approaches. R&D could evaluate aggregation mechanisms, including modularization, contractual aggregation (such as engineering, procurement, and construction (EPC) contracts or small specialized contracts), and integrated project schedule and reporting systems. Multistate coordination efforts could support evaluation of aggregation mechanisms and regional production models to address these barriers. Additionally, R&D could focus on public–private risk-sharing and standardization strategies, including using a standard, mature design across multiple plants and streamlining licensing approaches to reduce demand volatility.

Reactor Relevance: All technologies
Risk to Deployment: Moderate
Heavy-component capital requirements are greatest for gigawatt-scale Gen III+ builds
Independent Impact Potential: Moderate

3.2.4 Advanced Modularization, Factory Fabrication, and Automated Assembly (M4)

Modularization is widely viewed as a key strategy for reducing construction cost and schedule risk, particularly for SMRs and microreactors. By shifting labor from field construction to controlled factory environments, modular approaches can improve quality control, shorten site schedules, and enhance repeatability across multiunit builds. However, modularization effectiveness depends on more than fabrication capability alone, and repeatable modularization is essential for scaling beyond early units. Three distinct but related challenges affect deployment:

1. Modularization as a construction strategy depends on repeatable plant designs and stable demand. Without building multiple units to a consistent design, the economic benefits of factory fabrication become difficult to achieve.
2. Fabrication capability must accommodate large-module production, including transportation logistics and integration sequencing. While conventional manufacturing methods often suffice, supply-chain coordination and scaling of production lines present ongoing practical challenges.

3. Institutional factors, particularly ASME code qualification, inspection requirements, and regulatory acceptance of factory-fabricated assemblies, can limit the repeatable use of modular strategies.

Even when fabrication capability exists, uncertainty around inspection regimes and documentation requirements can erode the anticipated cost and schedule advantages of modularization.

R&D in this area should therefore focus on validating repeatable modular interface standards, developing digital engineering tools that support factory-to-field integration, and clarifying code and inspection pathways for factory-fabricated assemblies. While advanced manufacturing methods such as additive manufacturing (AM) may provide long-term benefits, they are not currently the primary bottleneck preventing modular deployment at scale. The need for and impact of R&D on this topic depends on reaching national-scale deployment that requires repeated modular production and is expected to grow with further deployments. General investments in developing and scaling up advanced manufacturing technologies including laser powder bed fusion, directed energy deposition, and PM-HIP with nuclear-relevant materials provides a versatile base for fabricating components that will likely unlock supply chain challenges in the future.

Reactor Relevance: All technologies, particularly SMRs and microreactors
Risk to Deployment: Moderate
Independent Impact Potential: High

3.2.5 Improve Nondestructive Evaluation and Inspection Techniques (M5)

Nondestructive evaluation or testing is a crucial process used to inspect product integrity without causing damage, ensuring products meet specific standards and are safe for use. Nondestructive evaluations (NDEs) can include visual testing, liquid penetrant testing, ultrasonic testing, radiography using X-rays or gamma rays, and microwave testing. These types of facilities are available at some NYS institutions. Existing NDE methods are often insufficient for advanced alloys, compact heat exchangers, and additive-manufactured components. Inspection limitations may delay qualifying novel components for advanced reactors. R&D focused on materials and inspection technologies may support the evolution of these techniques by developing

radiographic, ultrasonic, and AI-assisted inspection approaches and promoting "design for inspection" practices.

Reactor Relevance: All technologies
Risk to Deployment: Moderate
Inspection gaps are concentrated in the advanced alloys, compact heat exchangers, and additively manufactured components used in Gen IV and SMR designs
Independent Impact Potential: High

3.2.6 Mitigate Liability Barriers for Commercial Suppliers (M6)

Commercial suppliers often refuse to take on nuclear liability (i.e., nuclear certification and qualification liability), even for standard components, forcing nuclear buyers to assume qualification risk. This can deter supplier participation in nuclear projects without some guarantee of cost insurance or additional liability coverage. Project management and policy-focused R&D could support clearer risk-allocation and liability frameworks, qualification-as-a-service models, and clearer guidance on supplier versus integrator responsibilities. Clarifying roles and assigning risk for project delivery across partners would benefit suppliers.

Reactor Relevance: All technologies
Risk to Deployment: Moderate
Independent Impact Potential: High

3.2.7 Improve Constructability and Modernizing Project-Delivery Models (M7)

Lessons from recent U.S. projects highlight the need for digital-twin planning tools, improved sequencing, and integrated project-delivery frameworks that reduce contractual fragmentation.[21] This is especially needed for follow-on units after the first deployment, where cost competitiveness is increasingly essential. Developing a deeper understanding of traditional and adaptive project management approaches based on risk appetite and sharing could benefit NYS-specific construction activities. R&D in these areas could meaningfully reduce cost and schedule uncertainty. Institutions like Stony Brook University, the University at Buffalo, and Binghamton University could leverage existing nonnuclear digital twin and engineering expertise to advance project sequencing for nuclear projects.

The R&D-TWG identified during meetings an opportunity to develop integrated site evaluation frameworks that combine geotechnical, environmental, and grid data into reusable, reactor-agnostic site templates; that input is reflected in the topics below.

Reactor Relevance: All technologies
Risk to Deployment: Moderate
Informed primarily by recent gigawatt-scale Gen III+ construction expertise, with benefits extending to follow-on units of all designs
Independent Impact Potential: High

3.2.8 Strengthening the Construction and Manufacturing Workforce (M8)

Scaling deployment from today's fleet to double the capacity (potentially reaching hundreds of gigawatts nationwide) will require a substantial increase in skilled labor availability. Limited large-scale nuclear construction activity over the past several decades has left many trades without sustained incentive to maintain nuclear-specific training pathways. As a result, key craft occupations may lack recent nuclear quality and safety experience, even as general trade skills remain strong.

R&D can help address these challenges through human factors R&D, novel staffing models, and advanced simulators and mockups that can accelerate skill acquisition. New York State has the potential to meet the need to strengthen the nuclear-grade qualifications for the expanding workforce.

Reactor Relevance: All technologies
Risk to Deployment: Moderate
Independent Impact Potential: High

3.3 New York State Strengths Assessment

New York State has an established manufacturing base, operating nuclear facilities, and a strong organized labor presence. The Naval Nuclear Laboratory's Knolls Site, which focuses on nuclear propulsion and military applications, may offer a wealth of relevant expertise related to nondestructive testing and operator training. The State also has strong in-state engineering,

project management, and construction management programs that position it well to advance many of the topics in this category. For example:

- Collaboration with the supply chain base can streamline qualification pathways and mitigate liability barriers.
- RPI and University at Buffalo have direct and indirect experience developing virtual simulation development and integrated delivery frameworks relevant for improving constructability and project delivery.
- RPI also has multiple initiatives focused on AI-assisted QA tools and process workflows.
- The Rochester Institute of Technology (RIT) specializes in sustainable and intelligent manufacturing in other industries, which could support advances in modularization and factory fabrication, advanced NDE validation, and AI-assisted inspection development.
- Columbia University's Center on Global Energy Policy conducts research on nuclear regulatory pathways and policies, including risk analysis, and could support the analysis of liability frameworks, risk-allocation structures, and contractual mechanisms needed to reduce supplier exposure.

New York State offers multiple workforce-related resources through its educational institutions and the capacity and political support to address the need for increasing skills and workforce in trades, and engineering. The State has taken steps by announcing $40 million in new annual workforce development funding and launching the NextGen Nuclear initiative to develop the workforce needed to support advanced nuclear energy in Upstate New York. These resources and actions position New York State well to support R&D that can accelerate skills acquisition and explore novel staffing models.

Table 6 summarizes New York State's strengths, categorizing them as high, moderate, or low. Higher strengths reflect directly applicable work, while moderate and low strengths indicating expertise that is relevant and could be expanded upon with investment to meet the need. Appendix E has additional details on the specific expertise identified at these institutions. Strengths from New York State's existing nuclear industry and private sector are not included in Table 6 and not all NYS universities and colleges are listed.

Table 6. New York Institutional Strengths—Manufacturing and Project Delivery R&D Topics

Note: NYS Strength is represented by H=High, M=Moderate, and L=Low. High indicates expertise with direct correlation to the R&D topic; Moderate indicates relevant expertise that can be adapted to address the R&D topic, including in other focus areas; and Low indicates limited overlap.

NYS Institution	M1	M2	M3	M4	M5	M6	M7	M8
Binghamton University							M	
University at Buffalo							M	
Columbia University	M		M			M		
Naval Nuclear Lab	H				H			M
NYU							M	
RIT				M	M			
RPI	H	H	H	H	H		H	H
Stony Brook University	H	M						
SUNY Oswego								H
Overall NYS Strength	H	M	M	M	H	L	H	H

3.4 Potential Role for New York State

Table 7 summarizes the assessment of manufacturing and project-delivery R&D topics identified in this study; it includes the assessment of their risk to deployment, degree of NYS strength, independent impact potential, and reactor relevance. Ratings of high, moderate, and low are shown using the color scale in the legend beneath the table, with the highest priorities being non-technology specific and not dependent on a regulatory change or other external modification.

Table 7. Assessment Summary of Manufacturing and Project-Delivery R&D Topics

R&D Topic Number	Risk to Deployment	Degree of NYS Strength	Independent Impact Potential	Reactor Relevance
M1	Moderate	High	Moderate	High
M2	Moderate	Moderate	Low	High
M3	Moderate	Moderate	High	High
M4	Moderate	Moderate	High	High
M5	Moderate	High	High	High
M6	Moderate	Low	High	High
M7	Moderate	High	High	High
M8	High	High	High	High

Two topics discussed in this category (streamlining qualification pathways (M2) and reducing cost and complexity of NQA-1 programs (M6)) depend on national regulatory bodies to consider or adopt any solutions developed.

Instead of starting from scratch, the State can leverage its large nonnuclear footprint in machine learning and digital twins (via schools such as University at Buffalo, RPI, and Stony Brook University) to streamline factory fabrication and component tracking. R&D topics that could leverage this expertise include reducing the cost and complexity of NQA-1, improving NDE and inspection techniques, and modernizing constructability and delivery models.

Workforce development and improvements in project delivery models represent the areas where New York may have the greatest opportunity to contribute to advanced reactor deployment. At the same time, other manufacturing challenges, such as supplier qualification and modularization, will depend largely on broader national supply-chain development.

Three topics have been identified as high priority for near-term investment:

- Improving non-destructive evaluation and inspection techniques (M5) by developing radiographic, ultrasonic, and AI-assisted inspection approaches,
- Modernizing constructability and delivery models (M7) through digital-twin planning tools, improved sequencing, and integrated project delivery frameworks
- Strengthening the construction and manufacturing workforce (M8) with novel staffing models, human factors R&D, and advanced simulators

4. Materials and Components

4.1 Background Information

Advanced nuclear reactors introduce new operational regimes relative to the existing light-water fleet of reactors for which much research has been conducted in support of industry: higher temperatures, a fast neutron spectrum, and gaseous, metallic, and salt coolants that place different demands on structural materials, components, and instrumentation. While Gen III+ reactors rely primarily on well-characterized alloys and manufacturing methods, Gen IV systems may require extensive validation of high-temperature capable materials, specialty graphite, sodium- and salt-compatible steels, and novel high-performance alloys. Across all designs, R&D must close gaps in material lifetime data, corrosion behavior, irradiation effects, and manufacturing readiness. Supply chain risks for critical raw materials add further urgency.

4.1.1 Code Qualification Timelines and Regulatory Constraints

Qualifying new materials under ASME Section III, which is the portion of the ASME Code that establishes rules for constructing components in nuclear facilities, can take a decade or more. Alloy 709 required roughly 10 years to complete testing and code adoption due to long-duration creep, fatigue, and corrosion experiments.[22] The same applies to AM and powder metallurgy–hot isostatic pressing (PM-HIP), an AM method for forming resilient materials. Without code cases, other approvals, and validated in-situ inspection methods, these techniques cannot be widely adopted. As one developer noted in a recent Solestiss interview,[23] even alloys already in use (e.g., 316H) have supply-chain constraints for nuclear-qualified forms, illustrating that code qualification alone does not guarantee availability.

4.1.2 Global Supply Chain Volatility and Post-COVID-19 Constraints

Solestiss interviewees emphasized that global metal markets—especially brass, copper, and steel—have fundamentally shifted since COVID-19. Systemic risk in these materials is impacting renewable energy grid infrastructure and industrial manufacturing. Supply disruptions have eliminated negotiating leverage and forced buyers into stockpiling behaviors, increasing project cost and uncertainty. This volatility affects everything from heat-exchanger tubing to reactor-grade alloys and is now considered a persistent risk rather than a temporary anomaly.

4.1.3 Limited U.S. Infrastructure for Gen IV Testing in Relevant Environments

While the U.S. has strong facilities for LWR materials testing, it lacks adequate sodium loops, molten-salt testbeds, high-temperature helium rigs, and facilities to validate large high-temperature components. Developers increasingly rely on foreign partners for essential testing, which introduces delays and export-control complications. Expanding domestic infrastructure is therefore essential for timely qualification of materials and components used in advanced technologies and represents an opportunity for New York State to explore.

4.1.4 Data Gaps for Novel Materials and Coolants

The existing nuclear materials database is built on 50 years of LWR experience. For sodium, molten salts, graphite under extreme fluence, and many fast-spectrum alloys, data remain sparse, based on limited experimental reactors of 1950s and 1960s vintage. Regulators must therefore take conservative positions, increasing analysis and testing burdens for developers. Ongoing efforts to digitize and reuse historical DOE materials data can help, but substantial new testing is still required.

4.1.5 Different Challenges for Gen III+ and Gen IV Reactors

Gen IV reactors face the most intense materials challenges due to novel coolants, higher temperatures, and fast-neutron spectra. The high-temperature reactors rely on graphite to moderate the fission process. Although graphite is already used in other industrial applications and was used in early nuclear research, testing and analyses will be needed to ensure graphite retains its structural integrity under high temperature and high neutron flux, and to quantify and analyze the impact of graphite dust on other systems and components.

The high-temperature reactors are cooled either by helium gas or by molten salt, both of which depart from the designs of the current fleet of operating reactors that use water. Perhaps the most novel design is the sodium fast reactor (SFR), which uses liquid sodium as the reactor coolant. As noted, constructing test loops for helium, molten salt and liquid sodium is necessary to understand their physical properties under normal and accident conditions.

Gen III+ reactors, both large-scale and SMRs, rely primarily on established materials but still need updated component qualification (emergency core cooling system valves, passive safety systems) and research on concrete aging, corrosion mitigation, and long-term structural behavior. The qualifications of accident-tolerant fuels and advanced fuel claddings also apply to the LWR fleet.

4.2 Key R&D Topics

4.2.1 Qualification of Advanced High-Temperature Alloys and Coatings (C1)

Gen IV systems operate at temperatures far beyond LWR norms, 750^{0}C for a HTGR's helium coolant and 500^{0}C–550^{0}C for a sodium fast reactor's liquid sodium coolant, necessitating alloys with excellent creep, fatigue, and irradiation resistance. Currently there are six ASME qualified construction materials for advanced high temperature reaction applications. These are listed in ASME Section III, Division 5, which governs high temperature nuclear components. Most of these materials were introduced to the ASME code several years ago. R&D is needed to expand the materials database for Alloy 617, Alloy 709, advanced stainless steels, ferritic-martensitic steels (e.g., HT9), and high-temperature coatings.[24] These data must feed into ASME Section III, Division 5 code updates to support long service lifetimes.

R&D in this area can benefit LWRs and advanced reactors. Introducing and updating advanced materials with enhanced mechanical properties into the ASME code will allow designers to remove constraints imposed by the current code and improve the performance, cost, and safety of nuclear designs. For example, advanced alloys could reduce the required thickness of pressure vessels and enable small ring forgings; in turn, this could reduce the cost of large forgings and enable more domestic production that requires less material and shorter manufacturing times.

Although ASME qualification-scale validation of advanced high-temperature alloys must take place in a reactor or high-flux environment, other research may be conducted without using reactor assets or neutron flux sources. For example, ion beam facilities may be useful for some testing, such as corrosion testing. Specialized high-temperature irradiation and materials testing infrastructure is not currently available in New York State, but other facilities are. This infrastructure is discussed in more detail in the Testing and Validation Infrastructure category (Section 7). Smaller-scale testing facilities in the State, including the Ion Beam Lab at the University at Albany, support some R&D progress in this area. Partnering with existing high-temperature irradiation facilities elsewhere can help advance this work further.

Reactor Relevance: All reactor types
Risk to Deployment: Moderate
Independent Impact Potential: Moderate

4.2.2 Coolant Compatibility and Corrosion Performance in Sodium, Helium, and Molten Salts (C2)

Different coolants impose different degradation mechanisms: sodium can dissolve protective oxide layers on steels in the presence of oxygen; molten salts require extensive corrosion-chemistry control; and helium systems are sensitive to impurities that can oxidize components at high temperatures. Reactor developers and EPRI have identified corrosion as a key issue for extended service.[25]

R&D is needed to leverage existing corrosion studies, apply the findings to proposed nuclear applications, and conduct new R&D, as needed, to rigorously affirm corrosion rates, validate protective coatings, develop chemistry control systems, and quantify long-duration effects under irradiation. R&D in this topic area requires access to coolant-specific test loops, molten salt rigs, and helium facilities not currently identified in New York State. This is discussed in detail in the Testing and Validation Infrastructure section (Section 7). RPI has ongoing research funded by DOE's Nuclear Energy University Research Program to develop functionally graded coatings on alloys to improve corrosion resistance for MSRs, as well as an environmentally controlled glovebox for corrosion testing.[26]

Reactor Relevance: SFRs (sodium) and HTGRs (helium)
Risk to Deployment: Moderate
Independent Impact Potential: Low

4.2.3 Irradiation Testing and Lifetime Data for Graphite, Concrete, and Structural Alloys (C3)

HTGRs require large volumes of ultra-pure graphite. As noted, graphite is new to the U.S. commercial power industry. Key irradiation-performance data, especially at high fluence, remain limited. Fast-reactor alloys require further testing on swelling, embrittlement, and creep. Concrete degradation under combined neutron and thermal loads is also a cross-cutting concern for all reactor classes. Similar to the corrosion issue, a review is needed to evaluate the scope and level of documentation for irradiation testing to date, determine its applicability to current nuclear applications, and identify gaps where further research is needed. While the State has no neutron irradiation facilities, PIE laboratories can evaluate material properties after

irradiation, such as the Post-Irradiation Examination and Research Laboratory (PEARL) at Stony Brook University.

Reactor Relevance: HTGRS (graphite and concrete aging), SFR (fast-spectrum steels and concrete aging), and LLWRs and small LWRs (concrete aging)
Risk to Deployment: Moderate for novel materials (Gen IV), but low for light water reactors
Independent Impact Potential: Moderate

4.2.4 Advanced Manufacturing for Primary Components (C4)

Advanced manufacturing includes techniques that build up components from smaller particles or weld material instead of the conventional approach of machining down a large piece of metal. Powder metallurgy – Hot Isostatic Pressing (PM-HIP), directed energy deposition, and AM such as laser powder bed fusion offer promising pathways to produce large, near-net-shape components without relying on massive forgings. PM-HIP is a process where finely divided metal powders are pressed to form solid parts using high temperature (below melting point) and under isostatic (uniform) gas pressure (such as argon) to consolidate materials. However:

- U.S. PM-HIP capacity remains constrained for nuclear-scale components; domestic HIP vessels, including large commercial units capable of processing up to about 6.5 ft in diameter,[27] may not readily accommodate full-scale reactor pressure vessel heads.
- PM-HIP and AM lack full acceptance in ASME nuclear codes, requiring case-by-case approval for primary pressure boundaries.
- AM parts encounter challenges such as anisotropy, density variation, and geometry that can limit in-situ or post-production inspection options.
- Vendors remain cautious about adding manufacturing-technology risk on top of FOAK reactor risk.
- R&D-TWG members reported no current PM-HIP pressure vessels. All large reactor pressure vessels are constructed from forged materials. Qualifying advanced alloys in the U.S., including necessary welding, would enable domestic forging with more advanced materials.
- Directed energy deposition techniques may provide benefits by accelerating production of larger components.

Despite these challenges, advanced manufacturing could eventually relieve forging and machining bottlenecks and improve schedule predictability. Research in this topic requires access to large-scale HIP units capable of processing near-net-shape components; powder characterization and qualification laboratories; laser powder bed fusion and directed energy

deposition systems rated for nuclear-grade alloys; and post-build mechanical, microstructural, and nondestructive evaluation capabilities sufficient to support ASME code qualification. RIT has directly applicable experience with laser-based and laser powder bed fusion AM for nuclear-specific components and reactors, while RPI also has expertise in 3D printing and AM.

Reactor Relevance: SMRs with integral vessels; HTGRs and SFRs for complex geometries
Risk to Deployment: Low
Independent Impact Potential: High

4.2.5 Developing Test Standards and Validated Methods for Advanced Manufacturing (C5)

As components manufactured with AM and PM-HIP are developed, they will need to be qualified before deployment in commercial reactors. Qualification of AM and PM-HIP components requires:

- New NDE techniques (e.g., advanced or AI-enhanced ultrasonic inspection, radiography for complex geometries)
- Acceptance criteria for porosity, microstructure, and anisotropy
- In-situ monitoring approaches regulators can accept

The absence of validated test protocols is a major barrier to adopting AM and PM-HIP components. Instituting these protocols will require coordination with national organizations such as the Electric Power Research Institute (EPRI) and discussion with regulators. The need for progress in this R&D topic will scale alongside the development of AM and PM-HIP components discussed earlier. Given expertise at RIT in advanced manufacturing, as well as at RPI, there are opportunities for applications. The ongoing focus by EPRI on these types of topics will facilitate the introduction and resolution of the lack of testing protocols available at this time. Key challenges include the unique material properties and applications for advanced manufacturing that will need to be accounted for in testing protocols.

Reactor Relevance: All designs (especially SFR and HTGR)
Risk to Deployment: Low
Independent Impact Potential: Low

4.2.6 Securing Supply Chains for Critical Reactor Materials (Graphite, Lithium-7, Helium, Metal Powders) (C6)

Advanced reactors depend on several materials without existing supply chains due to their unique applications that face acute availability, qualification, or geopolitical constraints.

- Graphite: Ultra-pure graphite is essential for HTGR cores and molten-salt structures, but more than 70% of global supply comes from China.[28] Qualification requires years of irradiation testing, and suppliers each produce proprietary grades with unique properties that must be characterized. While manageable with long lead times, it remains a strategic vulnerability for some reactor designs. Advanced reactor designs that rely on graphite require material that meets significantly higher purity and performance standards than conventional industrial graphite, which requires specialized feedstocks and controlled manufacturing conditions to remove neutron-absorbing impurities.
- Lithium-7: Required for pressurized water reactor (PWR) chemistry control and molten-salt reactors using the FliBe (lithium fluoride–beryllium fluoride) coolant. Domestic lithium-7 production ceased in the 1960s; today only Russia and China enrich lithium-7 at scale. The domestic column exchange (COLEX) liquid mercury-based process presented environmental and geopolitical challenges and was decommissioned. An alternative process like those used in Russia or China would likely be necessary if domestic production was restarted.
- Metal powders for AM and PM-HIP: High-purity powders are dominated by Japanese, German, Russian, Ukrainian, and Chinese suppliers. Without assured access to these materials, advanced manufacturing readiness suffers.
- Helium: HTGRs require large volumes of helium, and supply constraints could limit deployment of multiunit fleets.

These dependencies pose strategic risks, and addressing these critical reactor materials requires R&D as well as addressing the supply chain bottlenecks. The R&D needs include standardizing formulations across designs and modeling how the materials behave under high-neutron irradiation. New York State, through coordination with external facilities, can validate alternatives, expand domestic production, and strengthen material qualification pathways.

Reactor Relevance: HTGRs (graphite, helium), SFRs (Li-7 salt storage system), SMRs using AM/PM-HIP
Risk to Deployment: High
Independent Impact Potential: Moderate

4.2.7 Qualification of High-Temperature Passive Safety Systems and Specialized Components (C7)

Many Gen IV reactors operate at much higher temperatures than LWRs, and use non–water-coolant chemistry, requiring systems and specialized components with sufficient resistance to phenomena like creep and corrosion. For example, some molten salt designs include a safety (backup) system called a Direct Reactor Auxiliary Cooling System loop that uses natural thermal circulation to cool the core to prevent an accident. These systems operate in novel conditions and chemistries, and use high-temperature valves, compact heat exchangers, and control mechanisms (e.g., instrumentation) that require validation under temperatures and radiation environments well beyond LWR conditions. High-temperature gas reactor helium circulators may require development of magnetic bearings to prevent oil from contaminating the helium loop. Sodium-cooled fast reactors need electromagnetic pumps to achieve high flow rates required for cooling. SMR LWRs also require robust testing for passive emergency cooling valves and gravity-driven components, building on experience with Westinghouse's AP1000. Validation of these components and systems will ultimately require high-temperature irradiation testing infrastructure not currently established in NY. This validation will rely on infrastructure available outside of New York State.

Reactor Relevance: All advanced reactors, especially HTGRs and SFRs
Risk to Deployment: Low
Independent Impact Potential: Low

4.2.8 Radiation-Hardened Sensors and High-Temperature Instrumentation (C8)

Monitoring systems must survive high-temperature environments to ensure reliability. HTGRs and SFRs also operate in helium or sodium environments with significant neutron fluence. R&D is needed to develop durable thermocouples, in-core detectors, radiation-tolerant electronics, and remote monitoring technologies to support these reactor designs. These testing and instrumentation requirements are generally available for application. RIT and RPI have both reported ongoing research into sensors and instrumentations for nuclear applications. However, specialized testing under high neutron flux and high-temperature conditions is needed, which exceeds the available capabilities NYS facilities.

Reactor Relevance: HTGRs and SFRs
Degree of R&D Need: Low
Independent Impact Potential: Moderate

4.3 New York Strengths Assessment

It is important to note that NYS institutions have expertise in the fundamental science investigation of novel materials, with directly applicable research underway at RPI, Stony Brook University, and Brookhaven National Laboratory. For example, the Post-irradiation Examination and Research Laboratory at Stony Brook University recently secured $4 million in funding from DOE to expand its capabilities in analyzing and qualifying materials following irradiation. The Engineered Microstructures and Radiation Effects Laboratory at Stony Brook University includes capabilities for high-heat-flux, creep, and fracture testing, and ASME code qualification work is being done at the University. BNL has ongoing research programs related to material performance with the ability to generate large experimental datasets for model simulation. While not focused on nuclear materials, Cornell University has a robust materials science and characterization program that could expand into some of these topics. Though not currently focused on nuclear applications, the University at Buffalo's Center of Excellence in Materials Informatics helps companies innovate and commercialize new materials and funds collaborative applied research with advanced manufacturing companies.

Four facilities support this earlier-stage research: the Gaerttner LINAC Center at RPI, the National Synchrotron Light Source II at Brookhaven National Laboratory, the Ion Beam Lab at the University at Albany, and Lucideon M+P. These facilities support irradiation and testing of materials in extreme environments and can contribute to expanding the materials databases of surfaces and near-surfaces relevant to the development of coatings and claddings. Lucideon M+P has a facility in Schenectady, NY with deep experience and capability in nuclear materials testing. The facility can test a broad range of materials and chemistries to assess capability and support qualification of materials for new nuclear applications.

New York State is also competitive in applied sciences such as modeling and simulation that could be leveraged in collaboration with national laboratories and other universities with the appropriate test facilities to address some of these R&D needs. For example, RPI has developed artificial intelligence/machine learning (AI/ML) methods for surrogate modeling and accelerated evaluation of material and component performance and has previously collaborated with Idaho National Laboratory on multi-physics modeling. RIT also has relevant expertise in AM and 3D printing.

Table 8 summarizes New York State's strengths, categorizing them as high, moderate, or low. Higher strengths reflect directly applicable work, while moderate and low strengths indicate relevant expertise that could be expanded with additional investment. Appendix E has additional

details on the specific expertise identified at these institutions. Strengths from New York's existing nuclear industry and private sector are not included in Table 8, and not all NYS universities and colleges are listed.

Table 8. New York Institutional Strengths—Materials and Components R&D Topics.

Note: In the table, NYS Strength is represented by H=High, M=Moderate, and L=Low. High indicates expertise with direct correlation to the R&D topic; Moderate indicates relevant expertise that can be adapted to address the R&D topic, including in other focus areas; and Low indicates limited overlap.

NYS Institution	C1	C2	C3	C4	C5	C6	C7	C8
University at Albany	M							M
University at Buffalo				M				
BNL	H		H			M		
CUNY							H	
Cornell University	M		M			M		
Naval Nuclear Lab	H	M			M			
RIT			M	H	H	M		H
RPI	H	H	M	M		M	M	H
Stony Brook University	H		H			M		
Overall NYS Strength	H	M	H	M	M	M	M	H

4.4 Potential Role for New York State

Table 9 summarizes the evaluation of key R&D topics for materials and components. For each topic, the table indicates the risk to deployment, New York State strength, independent impact potential, and reactor relevance. Ratings of high, moderate, and low are shown using the color scale in the legend beneath the table, with the highest priorities being non-technology specific and not dependent on a regulatory change or other external modification.

Table 9. Materials and Components: Summary Assessment of R&D Needs, Risk to Deployment, and Potential Role for New York State

R&D Topic Number	Risk to Deployment	Degree of NYS Strength	Independent Impact Potential	Reactor Relevance
C1	Moderate	High	Moderate	High
C2	Moderate	Low	Low	Low
C3	Moderate	High	Low	High
C4	Low	Moderate	High	High
C5	Moderate	Low	Low	High
C6	High	Moderate	Moderate	High
C7	Low	Moderate	Low	Low
C8	Low	High	Low	Low

Most materials and components R&D topics are constrained in New York State by the absence of specialized irradiation and high-temperature testing infrastructure required to qualify advanced reactor materials and components; four out of eight topics depend heavily on testing and validation infrastructure currently located in other states, national laboratories, or overseas. New York State has significant expertise in two topics with moderate R&D needs (qualification of advanced alloys and coatings and irradiation testing and lifetime data) in this category, but its potential impact is limited by access to this specialized infrastructure. Section 7 further evaluates the need for additional testing and validation infrastructure. Prioritizing topics involving non-irradiation testing, modeling, and depending on sample-size material characterization would leverage the existing expertise at NYS institutions in materials science and characterization to address some of the identified challenges.

One topic area was identified as high priority: securing supply chain materials for critical reactor materials.

Options for the State to consider in this topic area include funding material characterization research at NYS universities, expanding partnerships with national laboratories (such as Oak Ridge National Laboratory or Idaho National Laboratory, which have testing facilities) for irradiation campaigns, and investing in building additional materials testing labs in the State. The estimated cost range for these options is $1 million–$50 million, which reflects a spectrum from Nuclear Energy University Program (NEUP) scale university research awards to building a full materials testing lab.

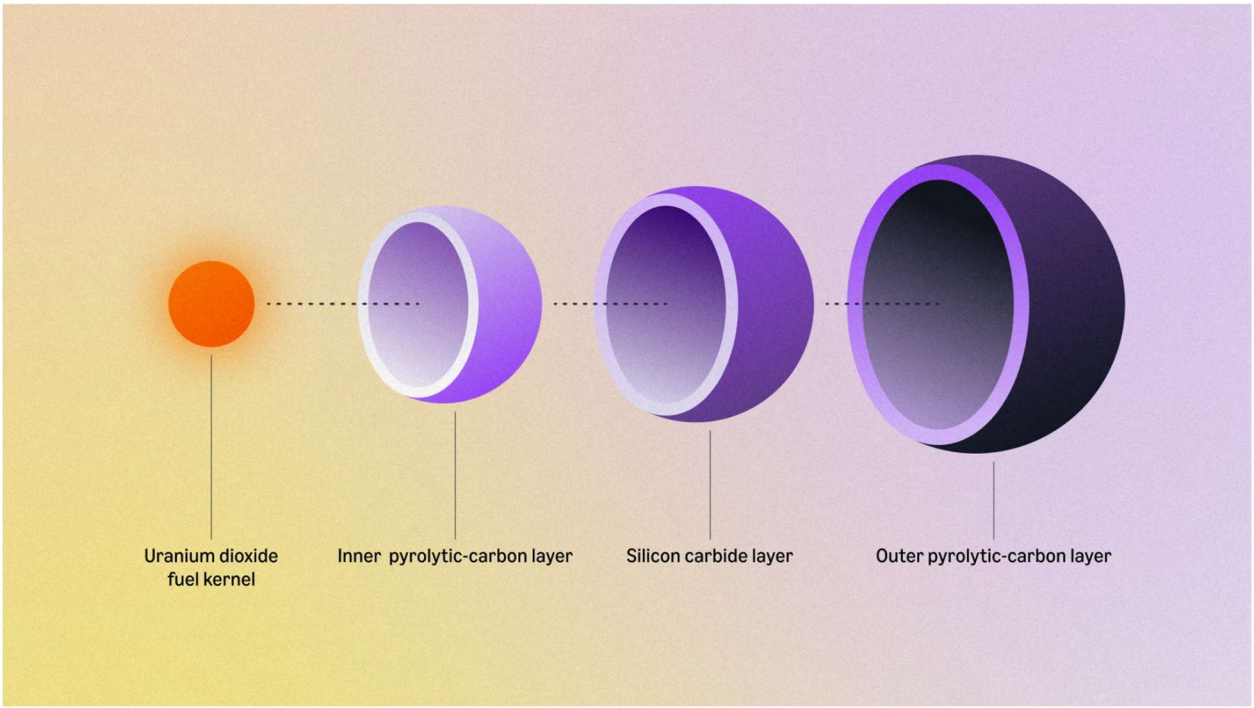
5. Fuel and Fuel Cycle

5.1 Background Information

The nuclear fuel cycle spans the full pathway from uranium mining through conversion to uranium hexafluoride (UF_6), enrichment, deconversion into solid fuel forms, fabrication into reactor-specific assemblies or particles, and ultimately spent-fuel management. In today's U.S. fleet, most reactors use low-enriched uranium (LEU) (3%–5% U-235), with some movement toward LEU+ (5%–10%). Many Gen IV designs require high-assay low-enriched uranium (HALEU) (5%–20% U-235), often in specialized forms such as TRISO particles or metallic fuel assemblies.

Tristructural isotropic (TRISO) fuel differs from the fuel used in existing reactors. TRISO fuel contains uranium kernels surrounded by three protective layers of carbon and silicon carbide, plus an outer layer of pyrolytic carbon, which protect against the release of fission products from the fuel. Figure 3 offers a graphic depiction of the TRISO fuel.[29]

Figure 3. TRISO Fuel Form



These advancements in fuel design create a front-end supply-chain discontinuity and a back-end waste-form discontinuity that together make fuel one of the most deployment-critical R&D areas for some advanced reactors. R&D needs vary by fuel form and by steps in the fuel cycle.

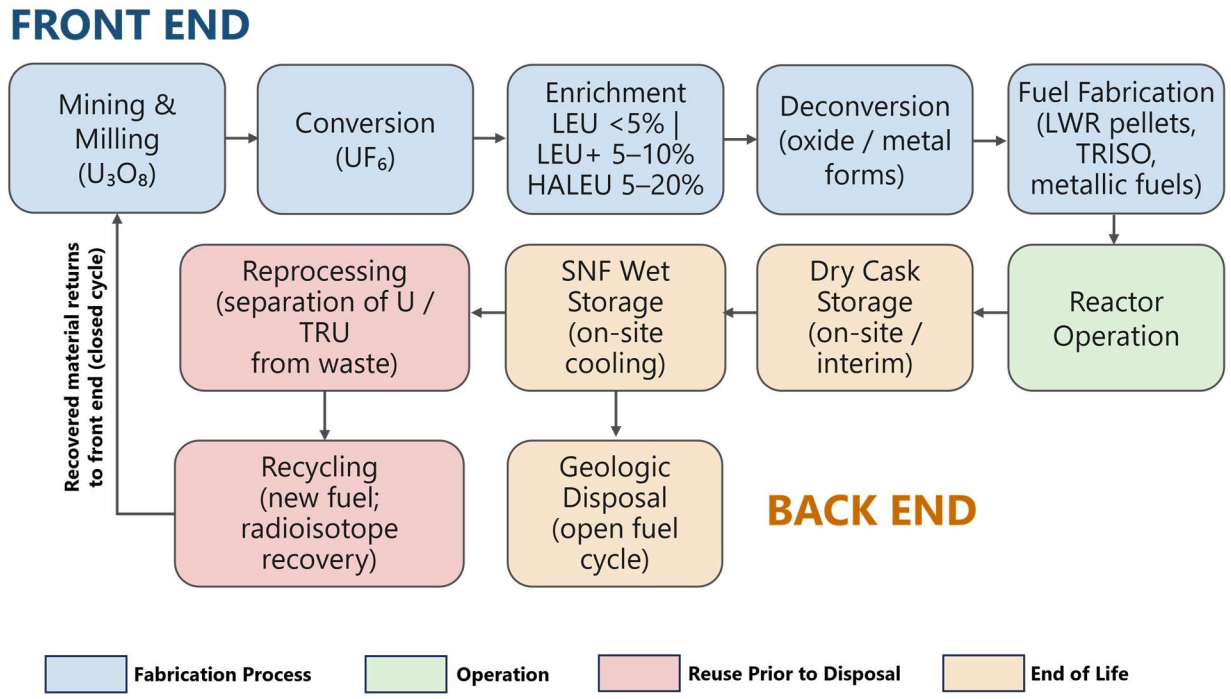
The qualification of advanced fuels is a long process and can be accelerated through NYS entities and national labs partnering to advance fuel characterization.

Spent nuclear fuel and high- and low-level waste are the subject of a dedicated Master Plan Waste Study, which provides additional details on waste generation for advanced reactors and reprocessing. It also identifies additional policy options on handling, storage, and transportation of nuclear waste, and research conclusions on State support and participation in federal and academic research and coordination on fuel cycle research.

5.1.1 Front-end Capacity Gaps Are Uneven (LEU versus HALEU)

LEU supply chains are mature and globally diversified. Scaling LEU/LEU+ expansion of global supply chains or a significant step change to domestic capacity for conversion and enrichment. HALEU, by contrast, requires additional buildout including more energy intensive enrichment to varying levels, deconversion, and custom fuel fabrication, including forming and assembly which varies significantly by reactor design. After consumption of downgraded highly enriched uranium (HEU), all fuel will require additional integrated front-end fuel cycle capacity including processing of uranium from natural ore into a specialized fuel form. Because HALEU is often enriched from LEU feedstock, large HALEU demand could also tighten LEU availability for Gen III+ markets, unless capacity grows in parallel. Figure 4 provides an overview of the nuclear fuel cycle from the mining and fabrication in the front end to disposal and reprocessing on the back end.

Figure 4. Nuclear Fuel Cycle from Mining to Disposal



5.1.2 Fuel Qualification Timelines Are a Pacing Bottleneck

Fuel qualification can take 5 to 10 years, structured around establishing manufacturing specifications, using irradiation testing to validate performance envelopes, and securing regulatory approval. A single qualification campaign (irradiation to target burnup plus PIE) typically spans multiple years, and facility queues add delays. For fast reactors, the lack of domestic fast neutron testing capability makes this risk more pronounced.

5.1.3 Nonstandard Fuels Risk Fragmentation without Coordination

As noted, traditional TRISO particles use ceramic kernels with highly standardized processing parameters. Introducing metallic fuel variants could undermine fabrication and qualification economies of scale, which are achieved when a universally qualified fuel type can be mass produced for multiple reactor designs. Coordinated R&D efforts that enable early coordination and standardization across developers (where technically feasible) will reduce cost, speed review, and strengthen supplier confidence. NYS institutions can work together to standardize fuel types by sharing information and advancing modeling.

5.1.4 Fuel Needs Differ by Reactor Class

Fuel needs cluster into two clear groups, with very different R&D urgency:

- Gen III+ LWRs use conventional LEU oxide fuel and will rely on existing capacity (with expansion) to meet growing demand. Their fuel R&D is more performance-driven than access-driven. Performance improvements to address burnup efficiency and improve fuel safety include fuel engineered to withstand severe accident conditions, such as a loss-of-cooling accident, for significantly longer than current technology, known as accident-tolerant fuel (ATF) and LEU+ options. R&D to improve these performance attributes is useful, but R&D for Gen III+ fuels is not a barrier to deployment of new reactors.
- Some Gen IV reactors such as HTGRs and SFRs depend on HALEU-based specialty fuels that do not exist at commercial scale today. Addressing the R&D needs and the issues associated with commercialization and scaling of the fuel is important to ensure HALEU availability, TRISO scale-up/qualification, metallic fuel qualification, and metallic or novel form spent-fuel disposition. Until these are solved, deployment timelines remain high-risk.

5.1.5 Spent Nuclear Fuel Reprocessing

The U.S. follows a once-through "open" fuel cycle that relies on direct disposal. In an "open" fuel cycle, SNF is not reprocessed or recycled; it is removed from the reactor, cooled in wet storage, and then transferred to a dry cask. In contrast, a "closed" fuel cycle involves reprocessing SNF through chemical dissolution or melting to separate uranium and plutonium from fission products, enabling the production of new fuel and reducing the volume of waste that must eventually be disposed of. The Master Plan Waste Study describes the historical and current policy context for reprocessing and recycling in the U.S. For context, reprocessing refers to separating usable material, and recycling refers to deploying the material. Today, SNF from existing reactors is stored at the sites where it was generated. It may be moved to an interim storage facility, which could facilitate later reprocessing. Interest in reprocessing is growing, in part because of the political obstacles to long-term geological storage with an open fuel cycle, and partly because of the opportunity to use SNF from existing reactors as feedstock for the next generation of reactors. Recycling used fuel involves processing the recovered uranium and plutonium to create new fuel assemblies. Additionally, SNF may offer opportunities to reuse SNF to access valuable radioisotopes for use in the medical and aerospace industries.[30] Both areas represent significant new opportunities for research and development. Assessing the costs of recycling compared to direct disposal is an important area for further research and modeling.

Additionally, HALEU and TRISO fuel present disposal and storage challenges. TRISO fuel is generally considered suitable for direct disposal, but for an HTGR application, the fuel pebbles contain graphite, which creates a much larger volume of spent fuel per unit of energy unless the materials are separated. This creates a need for R&D to reduce volume. HALEU must be stored in a manner that maintains subcriticality margins to ensure a nuclear chain reaction does not start. This may require new modeling.

The Master Plan Waste Study includes a section on SNF reprocessing and recycling with information on demonstration projects and operational experience to date, including at West Valley.

5.2 Key R&D Topics

5.2.1 Establish a Reliable HALEU Supply Chain (F1)

HALEU availability is a limiting factor for most non-LWR systems. The U.S. lacks commercial-scale HALEU enrichment and deconversion capacity, and logistical infrastructure (licensed transport packages, handling systems, safeguards pathways) is still emerging. R&D and expanded production are needed to accelerate HALEU production technologies, qualify deconversion routes into oxide and metal forms, and certify transportation/packaging suitable for HALEU materials. This is not only a technical challenge, but also a market-formation one because upstream investment depends on credible multi-unit demand signals. Without this end-to-end HALEU pathway, FOAK schedules for non–water-cooled technologies are vulnerable.

It has been reported by TerraPower that operation of its Gen IV demonstration reactors would be delayed at least two years because there would not be sufficient commercial capacity to manufacture HALEU in time to meet the proposed 2028 in-service date.[31] HALEU enrichment, deconversion, and fuel fabrication infrastructure are not currently present in New York State and require specialized nuclear fuel facilities.

Reactor Relevance: HTGRs, SFRs and MSRs
Risk to Deployment: High
Independent Impact Potential: Low

5.2.2 Scale TRISO Fuel Fabrication and Qualification for HTGRs (F2)

TRISO fuel is central to HTGRs. The DOE has called TRISO fuel the most robust nuclear fuel on earth because its unique multi-layered structure allows it to withstand extremely high

temperatures, resist impact and corrosion, and contain fission products. While its robustness is well demonstrated, today's production scale is insufficient for commercial fleets. Building new fuel fabrication capacity and qualification will need to be completed to match the time from Financial Investment Decision on new nuclear generation projects to fuel loading.[32] R&D should focus on increasing throughput, tightening quality-control methods (including high-confidence defect detection), expanding irradiation databases for lifetime/burnup claims, and completing standardized qualification pathways so TRISO can move from custom FOAK batches to reliable, repeatable Nth-of-a-kind (NOAK) supply. R&D activities should be coordinated with the respective reactor developers because each already has fuel fabrication and validation activities in progress. TRISO fabrication and irradiation testing require specialized fuel-development infrastructure, which is currently available at Idaho National Laboratory's Advanced Test Reactor Facility though it may have limited future capacity.

Reactor Relevance: HTGRs, MSRs
Risk to Deployment: Moderate
Independent Impact Potential: Low

5.2.3 Metallic Fast-Reactor Fuel Development, Behavior Modeling, and Commercial-Scale Production (F3)

The startup core of a sodium-cooled fast reactor relies on HALEU metallic fuel, which has legacy U.S. test-reactor pedigree but no commercial manufacturing base. R&D needs include modern irradiation campaigns to qualify performance under fast-spectrum conditions; cladding compatibility tests; high-fidelity swelling/fission-gas/constituent-migration modeling; and establishing an automated, nuclear-qualified production line capable of repeatable batch quality at scale. R&D activities should be coordinated with the respective reactor developers because each already has fuel fabrication and validation activities in progress. Qualification and production of metallic fast-reactor fuels depend on irradiation testing and fabrication infrastructure currently available at Idaho National Laboratory and Argonne National Laboratory.

Reactor Relevance: SFRs
Risk to Deployment: Moderate
Independent Impact Potential: Low

5.2.4 Extending Gen III+ Fuel Lifetime through Accident-Tolerant Fuel and LEU+ Pathways (F4)

For established LWR designs, fuel R&D is aimed at operational efficiency rather than feasibility. Priorities include ATF/cladding concepts, higher burnup validation, and potential LEU+ adoption to lengthen cycles and reduce refueling outage frequency. LWRs can leverage existing LEU in the short term, but ATF and LEU+ will further enhance performance of LWR designs. This R&D topic is important for long-term economics but is not deployment-gating the way HALEU is for Gen IV. National laboratories and reactor vendors primarily lead research on ATF and LEU+; partnerships with national labs and industry would be needed to contribute to this topic.

Reactor Relevance: LLWRs and small LWRs
Risk to Deployment: Low
Independent Impact Potential: Low

5.2.5 Advanced Fuel Qualification Acceleration and High-Fidelity Fuel Performance Simulation (F5)

Across novel fuel types, qualification timelines are long and facility limited. Fuel qualification requires irradiation and PIE facilities that are largely concentrated at national laboratories and specialized research reactors. R&D should support faster irradiation/PIE cycles, standardized qualification methodologies, and validated modeling approaches that reduce uncertainty and speed regulatory review. Given that TRISO fuel often consists of thousands of particles embedded in a graphite matrix, particle-level TRISO modeling that focuses on calculating the stress, fission product gas release, and failure probability of a single representative particle to determine the statistical failure rate of the entire fuel element is needed, as well as fast-reactor metallic fuel behavior codes.

Idaho National Laboratory is collaborating with NYS entities, such as RPI and Brookhaven National Laboratory, on advanced fuel fabrication and characterization that are accelerating understanding of novel fuel designs. This R&D would enhance performance rather than overcome a deployment barrier.

Reactor Relevance: HTGRs and SFRs
Risk to Deployment: Moderate given extensive timeframes needed for qualification
Independent Impact Potential: Moderate

5.2.6 Spent Fuel Management and Disposal Pathways for Non-Oxide Spent Fuels (F6)

Current storage, transportation, and disposal regulations are rooted in oxide-fuel LWR experience. Given the different fuel types used in advanced reactors, this framework presents some challenges and changes may be necessary to regulations. R&D to provide background and more certainty on the behavior of the new fuels can support regulatory updates. TRISO and sodium-bonded metallic fuels, as well as MSRs, create new spent fuel forms that may behave differently in interim storage and repositories. Specific R&D needs include:

- TRISO spent fuel disposition: Understanding graphite-embedded waste volumes, potential graphite separation and treatment needs, and repository acceptance criteria
- Metallic/sodium-bonded fuel disposal: Validating pathways for conditioning or treatment to address sodium reactivity; evaluating whether pyroprocessing or alternate conditioning is required

Research on disposal and storage pathways for TRISO and metallic fuels relies on specialized nuclear spent fuel research infrastructure. New York State has some activities addressing this need, including research at Stony Brook University.[33] Activities outside of New York State include patented research by SRNL that removes the graphite binder in the TRISO fuel without damaging the fuel particles. This research at Savannah River National Laboratory is continuing.

Reactor Relevance: HTGRs, SFRs (primary) and MSRs; LWRs (baseline oxide pathways)
Risk to Deployment: Moderate
Independent Impact Potential: Low

5.2.7 Evaluate Long-Term Reprocessing Options and Safeguards (F7)

The industry is contemplating fuel recycling or reprocessing to reduce waste burdens and improve resource utilization for both existing and next-generation reactors. Even if not required for FOAK, early R&D is needed on reprocessing feasibility, waste-stream characterization, and safeguards for any separated-materials pathways. Fuel-specific R&D will be needed for HTGRs, SFRs, and MSRs, given that enrichment and fuel form differ from existing LWR forms. This should be scoped carefully to avoid diverting resources from near-term HALEU and qualification bottlenecks. Still, investments could help de-risk longer-term sustainability, and establishing reprocessing pathways may accelerate deployment. Universities and policy institutions could support analytical research on reprocessing technologies, safeguards frameworks, and long-term fuel cycle strategies. In February 2026, the DOE awarded $19 million across five companies for reprocessing-related research,[34] based on the previously announced funding opportunity;

partnerships with these awardees could be sought to explore collaboration opportunities—federal support for reprocessing research. The Life Cycle Campus Initiative asks states to support reprocessing and disposal, and private-sector interest in advancing reprocessing technology could remove previous barriers related to reprocessing.

Reactor Relevance: HTGRs and SFRs (primary); broader applicability across all reactor types
Risk to Deployment: Low
Independent Impact Potential: Moderate

5.2.8 Use of Thorium as a Fuel (F8)

Thorium is a fertile material that is three to four times more plentiful than uranium. Discovered in 1828, it was initially used in applications like gas lantern mantles and early radioactivity experiments. Its potential as an energy source became clearer in the 1940s through the work of Glenn Seaborg and Alvin Weinberg.

Using thorium in the nuclear fuel cycle offers several characteristics and potential benefits:

- Alternative fissile production: Thorium produces uranium-233, an alternative fissile isotope.
- Improved fuel use: It has the potential for higher conversion rates in thermal and intermediate neutron energy spectra.
- Enhanced properties: When used as a solid fuel (thorium oxide), it offers enhanced thermophysical properties compared to uranium oxide.
- Proliferation resistance: The coproduction of the highly radioactive uranium-232 isotope presents recycling challenges but may provide self-protection in some proliferation scenarios.
- Sustainability: Dedicated breeder systems using a closed thorium/uranium-233 fuel cycle can offer increased resource sustainability and reduced waste management challenges.

Thorium's use can be classified into three main areas:

1. Additive to current cycles: It can improve the reuse of reprocessed uranium or plutonium in current pressurized heavy-water reactors (PHWRs) and LWRs.
2. Fuel for advanced reactors: Solid mixed fuels (e.g., with uranium or plutonium dioxide) can provide benefits in Gen III+ and Gen IV systems, such as high-temperature gas reactors.
3. Dedicated breeder systems: This includes initiatives using solid fuels in advanced PHWRs and liquid fuels in MSRs.

While thorium utilization has been demonstrated in various reactor types, the database and industrial experience for advanced uses remain limited and require further research and development. This information could be obtained by relying on developers, given interest from technology developers in the U.S. and New York State in pursuing thorium-based reactors, especially for microreactors. However, no programs dedicated to thorium R&D currently exist at the national laboratories or DOE, and no known activities in the State focus on researching thorium as a fuel. Given the lack of infrastructure or dedicated resources for this potential fuel type, advances would depend on a national effort.

Reactor Relevance: Low with general application for HTGRs
Risk to Deployment: Moderate
Independent Impact Potential: Low

5.3 New York Strengths Assessment

In this category, NYS institutions have expertise in materials characterization, fuel fabrication, and evaluation of advanced fuel performance. Stony Brook University has been awarded multiple Advanced Research Projects Agency—Energy (ARPA-E) grants focused on novel fuel forms to improve utilization, reduce waste, and mitigate nuclear waste. Brookhaven National Laboratory participates in several aspects of DOE NE's Fuel Cycle Technologies programs through which it evaluates the performance of advanced fuels, technoeconomic assessments, and domestic safeguards. It also has extensive experience in nuclear data measurements and decay.

RPI has been awarded multiple NEUP grants in this category, including work on the thermal properties of uranium dioxide fuel and corrosion resistance for MSR applications. Appendix E lists the institutions considered in this study with their relevant expertise areas.

Because New York State lacks specialized fuel fabrication and irradiation testing infrastructure, it may not be well positioned to advance R&D on the upstream fuel cycle in the near term. RPI and Brookhaven National Laboratory may contribute through fuel characterization, simulation, and modeling. In the long term, NYS institutions have relevant research focused on novel fuel forms, long-term fuel cycle strategies, and novel fabrication methods.

Regarding reprocessing options and safeguards, the State has existing technical expertise at RPI and Stony Brook University and a policy perspective at Columbia University; additionally, at least

one company, Exodys Energy, located in New York State, focuses on commercializing nuclear recycling facilities.

Table 10 summarizes New York State's strengths, categorizing them as high, moderate, and low. Higher strengths reflect directly applicable work, while moderate and low strengths indicate relevant expertise that could be expanded with additional investment. New York State demonstrates a high degree of strength in two areas:

1. Advanced fuel qualification acceleration and high-fidelity fuel performance simulation (F5)
2. Evaluating long-term reprocessing options and safeguards (F7)

Table 10. New York Institutional Strengths—Fuel and Fuel Cycle R&D Topics.

Note: In the table, NYS Strength is represented by H=High, M=Moderate, and L=Low. High indicates expertise with direct correlation to the R&D topic; Moderate indicates relevant expertise that can be adapted to address the R&D topic, including in other focus areas; and Low indicates limited overlap.

NYS Institution	F1	F2	F3	F4	F5	F6	F7	F8
BNL		H	H		H		H	
Columbia University							M	
Naval Nuclear Lab					M			
RIT				H			M	
RPI			M	H	H	H		
Stony Brook University		H			M	H	H	
Overall NYS Strength	L	M	M	M	H	M	H	L

5.4 Potential Role for New York State

Similar to the Materials and Components category, the State's ability to contribute in the fuel, fuel cycle, and spent fuel reprocessing category is limited by access to specialized testing and validation infrastructure and overlap with federal research. Furthermore, the federal government is leading much of the R&D on this topic with $490 million enacted by DOE in 2026, particularly around establishing a HALEU supply and scaling TRISO fuel qualification. These topics were therefore not identified as high priority for State support because of their low independent impact potential ratings despite in-state expertise in fuel qualification acceleration, fuel performance simulation, and disposal pathways for non-oxide spent fuels. Table 11 summarizes

the assessment of identified fuel and fuel-cycle R&D topics, including the risk to deployment, degree of New York State strength, independent impact potential, and reactor relevance. Expanding partnerships with institutions with specialized infrastructure to increase access and collaboration could support in-state research efforts and expertise.

Table 11. Fuel and Fuel Cycle: Summary Assessment of R&D Needs, Risk to Deployment, and Potential Role for New York State

R&D Topic Number	Risk to Deployment	Degree of NYS Strength	Independent Impact Potential	Reactor Relevance
F1	High	Low	Low	Low
F2	Moderate	Moderate	Low	Low
F3	Moderate	Moderate	Low	Low
F4	Low	Moderate	Low	High
F5	Low	High	Moderate	Low
F6	Moderate	Moderate	Low	High
F7	Low	High	Moderate	High
F8	Moderate	Low	Low	Low

Although identified as a moderate priority, advances in reprocessing and recycling of SNF (F7) represent an opportunity to address the long-standing issue of the lack of a geologic disposal facility in the U.S. and to support broader deployment readiness.

The primary option for New York State is to facilitate and build partnership opportunities with institutions possessing specialized infrastructure, such as Idaho National Laboratory or Oak Ridge National Laboratory, to expand access and collaboration opportunities for in-state researchers. Other options include partnering with Idaho National Laboratory on fuel cycle R&D or funding a radiochemistry program or waste form program. Costs for university fuel cycle research grants for dedicated program development could range from $1 million to $50 million.

6. Site Characterization and Preparation

6.1 Background Information

New nuclear generation is being considered at existing nuclear, brownfield, and greenfield sites. Site characterization and evaluation processes that are faster, more standardized, and more predictable than the current paradigm, which is designed around gigawatt-scale large LWRs, can help reduce pre-development costs and accelerate deployment timelines. The primary objectives of site characterization are to:

1. Evaluate what risks the site environment might impose on the nuclear facility through conditions such as harsh weather and seismic activity
2. Evaluate what risks the nuclear facility might impose on the environment through gaseous or liquid effluents, increased traffic and noise, and disturbance of wildlife.

The foundational requirements for collecting seismic and meteorological data as well as characterizing groundwater pathways are similar across reactor types, including LWRs, HTGRs, and SFRs, but the subsequent analysis of the collected data against the proposed plant varies across reactor types because of differences in design features. Site characterization requirements differ not only by reactor type but also by reactor size, particularly for emergency planning. That is, emergency planning for a microreactor will have a smaller emergency planning zone (EPZ) than that for a large reactor. Targeted R&D for site characterization and preparation can reduce uncertainty, streamline pre-application work, improve schedule efficiencies, and lower the cost and risk of early site decisions.

Site suitability criteria should reflect reactor-specific risk profiles. Applying LWR-era criteria to HTGRs and SFRs leads to over-scoping characterization activities. Tailored regulatory characterization criteria aligned to the magnitude, mix, and timing of radionuclides released into an environment following an unplanned event, known as the source term, coolant type, and thermal footprint would accelerate siting evaluations while maintaining safety.

6.1.1 Data Needed for Licensing and Data Needed for Construction Readiness Diverge

Pursuing an operating license for a nuclear facility requires both conservative bounding analyses and granular subsurface and hydrological detail. R&D should help clarify which datasets are needed to satisfy the requirements for the various stages of regulatory approval.

6.1.2 State and Regional Datasets Can Substitute for Site-Specific Collection if Validated

To reduce project-specific data burdens, additional R&D is needed to validate whether regional seismic, hydrological, and climate datasets are acceptable inputs for certain environmental and safety analyses. A formal process to facilitate engagement with the various State entities involved in the environmental portion of the site characterization efforts would help validate the data needed for licensing.

This area can be explored further as the State has capacity to meet these needs.

6.2 Key R&D Topics

6.2.1 Develop Modular, Reactor-Specific Site Characterization Templates (S1)

Current site characterization processes are universalized around large LWRs, even though HTGRs, SFRs, and microreactors have different thermal footprints, infrastructure needs, and environmental interactions. R&D at universities and State entities could support the creation of design-specific site data templates for:

- HTGRs: Air-cooled pathways, lower water-use profiles
- SFRs: Sodium handling systems, thermal plume management
- SMR and microreactor LWRs: Reduced EPZs, lower effluent loads

These templates would reduce redundant data collection and help project owners avoid collecting unnecessary datasets driven by large LWR site characterization needs. Given the broad applicability of these templates, the results of this research could be published in a guidance document by the Nuclear Energy Institute (NEI), the association responsible for developing and executing the industry's regulatory and federal legislative strategy. Historically, NEI has produced guidance documents on other generic issues. New York State could collaborate with NEI to develop the suggested site characterization template for non-LWR reactors. NYS institutions have programs and capabilities that could be directed to support this need including those at University at Buffalo. In addition to collaborating with external organizations to develop a site characterization template, opportunities may exist to work within the State to develop

integrated site evaluation frameworks that combine reactor modeling, environmental data, and risk assessment to support siting decisions.

Reactor Relevance: Cross-cutting for SMRs and microreactors
Risk to Deployment: High
Independent Impact Potential: High

6.2.2 Advance Predictive Modeling Tools for Environmental and Geotechnical Impacts (S2)

Environmental impact modeling is often deterministic and slow to update. R&D opportunities include:

- Hydrology and thermal plume models tuned to smaller-footprint SMRs, microreactors, and non–water-cooled systems
- AI-assisted geotechnical prediction for soil and rock mechanics at partially characterized sites
- Atmospheric dispersion modeling reflects reduced source terms for SMRs and Gen IVs

These models can shorten pre-application characterization and reduce conservatism-driven overdesign. Modeling expertise at research institutions could support the development of advanced hydrological, geotechnical, and atmospheric modeling tools for advanced reactors. The University at Albany has expertise in atmospheric dispersion modeling, while the University at Buffalo has ongoing research into AI and hydrology modeling that could potentially be expanded into nuclear applications.

Reactor Relevance: Cross-cutting for SMRs and microreactors
Risk to Deployment: Moderate
Independent Impact Potential: High

6.2.3 Streamline Data Requirements for Emergency Planning Zone Determinations (S3)

EPZs are critical elements of the Emergency Plan that the nuclear facility owner must develop, and the NRC must approve as part of the licensing process. The Emergency Plan is implemented throughout the facility's life. Two EPZs are defined for each nuclear facility. The smaller plume exposure EPZ defines the vicinity surrounding the plant where actions to shelter or evacuate the population will be taken. The larger ingestion pathway EPZ defines the vicinity surrounding the plant where actions will be taken to protect against the contamination of crops and livestock.

Coordinating support to execute activities within the EPZs is labor- and cost-intensive and could create siting challenges at new sites under the current 10-mile radius standard. As a result, many SMRs aim for a plume exposure EPZ that extends only to the site boundary rather than a 10-mile radius (the norm for existing large reactors). Especially for high-temperature gas and sodium-cooled reactors, R&D is needed to generate robust empirical and simulation data to demonstrate lower offsite consequences under credible events. This includes source term, atmospheric dispersion, radionuclide mobilization, and containment performance under various accident scenarios. Ultimately, EPZ determinations depend on reactor safety analysis and NRC regulatory processes. This R&D topic could be of particular interest if long-term planning for nuclear deployment includes new nonnuclear sites that are less remote.

Reactor Relevance: Cross-cutting for SMRS and microreactors of all types
Risk to Deployment: High
Independent Impact Potential: Low

6.2.4 Develop Approaches to Integrate Nuclear Reactors at Existing (Nonnuclear) Brownfield Sites (S4)

Co-location with energy-intensive, industrial heat users, or brownfield locations introduces unique infrastructure and site-characterization questions for which regulatory precedent is limited. Pairing nuclear generation with industrial facilities can provide onsite electrical supply and thermal energy for processing heat needs through cogeneration, or potentially for thermal energy only. In addition to meeting traditional industrial heat needs (such as refining, manufacturing, and food processing), co-location may also enable additional processes such as hydrogen production and thermal storage. Engineering and policy-based R&D could develop:

- Standardized approaches for identifying and evaluating external hazards to nuclear facilities posed by co-located industrial facilities
- Site-readiness checklists for co-located industrial facilities
- Standardized methods for heat and electricity load matching and interconnection of large loads co-located with nuclear power or other on-site generation
- Approaches for using previously collected geologic, environmental, or other characterization data for already developed land

This could support an emerging market for both behind-the-meter and front-of-the-meter nuclear installations at brownfield sites. This is an important and relevant issue for meeting growth demand. Federal policy initiatives such as the DOE Advanced Notice of Proposed

Rulemaking on the Interconnection of Large Loads and the Federal Energy Regulatory Commission pending policy decision on co-location would benefit from focused R&D efforts.

Collaboration with national laboratories could focus on improving state-specific information within the tools developed at the national scale. For example, Oak Ridge National Laboratory has developed the Oak Ridge—Siting Analysis for Power Generation Exploration (OR-SAGE) tool,[35] which uses geographic information systems and spatial modeling techniques to evaluate siting options, and Idaho National Laboratory has built on OR-SAGE to develop the Siting Tool for Advanced Nuclear Development (STAND), which allows for comparison of sites from a socioeconomic, proximity, and safety perspective.[36]

Reactor Relevance: Cross-cutting; especially Gen III+ SMRs and microreactors
Risk to Deployment: Moderate
Independent Impact Potential: High

6.2.5 Improve Early-Phase Environmental Baselining (S5)

Traditional multi-season environmental sampling can be a critical path activity because it may require erecting a physical tower to collect up to 2 years of meteorological data. R&D should explore:

- Remote environmental sensing methods (e.g., drones, hyperspectral imaging) to provide equivalent site characterization data without the traditional data and sample collection
- Rapid ecosystem mapping for wetlands, endangered species, migratory pathways
- Automated water- and air-quality monitoring packages
- Approaches for quantifying and documenting preexisting contamination, especially at brownfield sites, and incorporating these findings into the analyses for proposed nuclear facilities

These tools would not replace full Environmental Impact Statement and Environmental Assessment requirements but may front-load crucial data collection to reduce surprises later. R&D on this topic could develop faster baseline assessment approaches.

Reactor Relevance: Cross-cutting
Risk to Deployment: Moderate
Independent Impact Potential: High

6.2.6 Standardize Site Geotechnical and Subsurface Investigation Protocols (S6)

Most current geotechnical investigation standards assume massive basemat, foundations consisting of very thick (10 to 20 ft) reinforced concrete slabs with steel rebar, and deep foundations based on the needs of large LWRs. Many SMRs and microreactors have lighter, modular building footprints but still require deep excavations under current regulations. Targeted R&D should support:

- Foundation modeling for smaller, modular structures
- Seismic soil-structure interaction models streamlined based on the lower mass and smaller footprint of SMRs
- Standardized test-boring and sampling requirements optimized for SMR needs

Modeling to reflect actual SMR needs will significantly impact construction costs, allowing less concrete and rebar given the smaller structures.

Reactor Relevance: Cross-cutting for SMRs and microreactors.
Risk to Deployment: High
Independent Impact Potential: High

6.3 New York Strengths Assessment

New York's strengths in this area are centered in civil, structural, and environmental engineering departments at universities in the State. The University at Albany's Atmospheric Sciences Research Center specializes in atmospheric dispersion modeling, environmental monitoring and sensing, and atmospheric simulation data. The University at Buffalo has relevant expertise in seismic technologies, geotechnical analyses, and modeling and simulation expertise for environmental and site characterization. RIT's Center for Imaging Science has expertise in adjacent industries in remote sensing for site characterization, inspections, and assessment. RPI has ongoing research on accident consequence qualification and near-distance atmospheric transport and dispersion models applicable to predictive modeling tools and EPZ determinations.

Table 12 summarizes New York State's strengths, categorizing them as high, moderate, and low. Higher strengths reflect directly applicable work, while moderate and low strengths indicate relevant expertise that could be expanded with additional investment.

Table 12. New York Institutional Strengths: Site Characterization and Preparation R&D Topics.

Note: In the table, NYS Strength is represented by H=High, M=Moderate, and L=Low. High indicates expertise with direct correlation to the R&D topic; Moderate indicates relevant expertise that can be adapted to address the R&D topic, including in other focus areas; and Low indicates limited overlap.

NYS Institution	S1	S2	S3	S4	S5	S6
University at Albany	M	M	H		H	
University at Buffalo	H	M	M			M
RIT				H		
RPI		M	H		M	
Overall NYS Strength	M	M	H	L	M	L

6.4 Potential Role for New York State

Site characterization is one area where New York State has comparatively strong potential to contribute to advanced reactor deployment through modeling expertise, environmental data resources, and coordination across State agencies and authorities. Aside from data requirements for EPZ determinations, the R&D topics are largely independent of collaboration with the federal government, regulatory bodies, or specialized testing and validation infrastructure.

Table 13 summarizes the assessment of site characterization and preparation topics identified in this study; it includes the assessment of their risk to deployment, degree of NYS strength, independent impact potential, and reactor relevance. Ratings of high, moderate, and low are shown using the color scale in the legend beneath the table, with the highest priorities being non-technology specific and not dependent on a regulatory change or other external modification.

Table 13. Site Characterization and Preparation: Summary Assessment of R&D Needs, Risk to Deployment, and Potential Role for New York State

R&D Topic Number	Risk to Deployment	Degree of NYS Strength	Independent Impact Potential	Reactor Relevance
S1	High	Moderate	High	High
S2	High	Moderate	High	High
S3	High	High	Low	High
S4	Moderate	Low	High	High
S5	Moderate	Moderate	High	High
S6	Moderate	Low	High	High

Four topic areas were identified as high priorities for near-term investment:

1. Developing modular, reactor-specific site characterization templates, including integrated site evaluation frameworks that combine reactor modeling, environmental data, and risk assessment to support siting decisions (S1)
2. Advancing predictive modeling tools for environmental and geotechnical impacts (S2)
3. Generating robust data on offsite consequences under credible accident scenarios to streamline data requirements for EPZs (S3)
4. Improving early-phase environmental baselining methods with drone and remote-sensing technologies (S5)

Options for New York State to consider include commissioning site studies for NYS candidate locations, developing standardized siting templates, and funding environmental monitoring programs at universities. The estimated cost for these options ranges from $1 million to $4 million.

7. Testing and Validation Infrastructure

7.1 Background Information

Testing and validation of materials, components, and fuels underpins the entire advanced reactor deployment timeline. For both Gen III+ and Gen IV designs, access to the facilities and infrastructure required for testing and validation is often a pacing bottleneck and is inhibiting much needed innovations from maturing to commercial-ready products. This includes research reactors, irradiation facilities, component-scale testbeds, test loops and special instrumentation, hot cells and manipulators, and specialized transportation. If access to testing and demonstration facilities is expanded, this would support R&D that expands U.S. test capabilities, reduces qualification timelines, and enables data-sharing frameworks that prevent duplication. This section describes the cross-cutting issues and gaps that exist related to testing and validation infrastructure for various types of reactors. It also assesses New York State's strengths and capabilities to address these gaps, along with cost information from initiatives in other states, to provide an indicative estimate of what is needed to fill them.

As shown in Figure 2, the landscape map shows that most existing commercial nuclear testing facilities are concentrated at national laboratories and a few universities. Many of the universities shown have research reactors, such as the PULSTAR Nuclear Reactor (PULSTAR) at North Carolina State University (NC State), the Breazeale reactor at Pennsylvania State University (Penn State), and the Training, Research, Isotopes, General Atomics (TRIGA) and Aerojet General Nucleonics (AGN) reactors at Texas A&M University. Additionally, facilities at some NYS institutions can do smaller-scale material testing. As noted, separate from this study, Solestiss conducted a supply chain study by interviewing and documenting information from multiple suppliers. Based on those interviews, it concluded that inadequate testing infrastructure is inhibiting technology maturation and that testing capacity is the single most universal bottleneck**.**

These challenges and risks can be summarized across three points:

1. **Reliance on U.S. facilities with long queues, as well as on facilities in other countries for irradiation and PIE, presents risks.**
   Developers of sodium fast reactors, TRISO fuels, and molten salt technologies currently rely on international facilities for critical irradiation and PIE steps due to domestic capacity shortfalls, increasingly turning to European and Canadian test reactors. While national laboratories such as Oak Ridge National Laboratory and Idaho National Laboratory possess PIE capabilities, they face severe backlogs. The Nuclear

Science User Facilities (NSUF), a DOE program, provides researchers with no-cost access to nuclear research facilities, technical assistance, and the Nuclear Fuels and Materials Library, but access issues remain. As a result, developers sometimes look abroad to validate fuel designs, often collaborating with Canada (Chalk River Laboratories) and Europe (Jules Horowitz Reactor, under construction in France) in the future. Reliance on foreign facilities may require approvals under 10 CFR Part 810 and/or Part 110, introducing timing constraints and additional risk due to the extensive intergovernmental review process. New York State plays a limited role in addressing this need, but joining a consortium to expand access to testing capabilities may offer a pathway forward.

2. **New materials require new test standards.**
   Alloy 709, an advanced steel alloy designed to resist creep, required approximately 10 years to achieve ASME code qualification, highlighting the long timelines for new material approval. Specialized Gen IV materials could face even longer paths without targeted R&D. One consistent gap in developing new standards for advanced reactor alloys is the lack of facilities and physical data to test materials under the exact combination of extreme temperature, radiation, and corrosive coolants that new designs demand. This can make qualification programs more complex and schedule sensitive.
3. **Qualification timelines are fundamentally constrained by physics.**
   Qualifying new fuel can take decades because subatomic interactions cannot be sped up. Validation of fuel safety relies on understanding complex microscopic changes within the fuel over years of operation. Several fundamental constraints include:
   - High-energy neutrons bombard the fuel matrix, with microstructural changes taking years to manifest.
   - Burned fuel creates new elements, some of which act as neutron poisons that absorb neutrons and halt the chain reaction, requiring long-term observation to understand these processes.
   - New fuel must safely conduct heat away from the core; testing must ensure the fuel will not melt or degrade under the extreme thermal and pressure gradients.

7.2 Key Testing and Validation Infrastructure Gaps

7.2.1 Expand Access to High-Temperature, Coolant-Specific Test Loops for Gen IV Reactors

Many Gen IV designs operate in environments fundamentally different from LWRs, requiring specialized loops for materials, fuels, and components. Critical gaps include:

- Sodium loops (SFR) for corrosion testing, thermal-hydraulics validation, and sodium–water/air reaction behavior
- Helium loops (HTGR) for ceramic matrix composites, graphite testing, and high-temperature heat exchanger validation

Existing U.S. facilities cannot meet the increased energy demand projected over the next 5 years, and many developers rely on foreign infrastructure for FOAK component testing because long queues limit access to domestic facilities. The specialized sodium, helium, and molten salt test facilities that do exist in the U.S. are largely located at national laboratories. Some universities have also invested in test loops and facilities to test the effects of radiation, such as Oregon State University's (OSU) Glovebox for Experimental Liquid Sodium Facility or the Massachusetts Institute of Technology's (MIT) Molten-Salt Forced Circulation Loop.

NNL has two primary sites in New York State to conduct research, develop, design, test, and train operators, in addition to providing fleet support for naval reactor designs. This may offer opportunities to collaborate where additional testing infrastructure capacity in New York State also supports their mission if the facility meets technical and classified information requirements. The City College of New York has a high-pressure helium flow test loop for HTGRs.[37] Some private companies test components, including in the Northeastern U.S.

New York State could alleviate the facility bottleneck and help address the R&D needs for advanced materials and corrosion identified in Section 4 by exploring a Memorandum of Agreement with NNL to coordinate on testing facilities and information protection requirements for classified and other sensitive information. Continued outreach with NYS companies and institutions, as has begun under the R&D-TWG, could identify additional opportunities for access to testing facilities.

Reactor Relevance: HTGRs, sodium-cooled

Risk to Deployment: Moderate

7.2.2 Increase Irradiation Testing Capacity for Fuels and Structural Materials

Fuel qualification is one of the most significant timeline drivers for advanced reactors. TRISO, metallic fuels, and new claddings require multiple cycles. According to interviews with DOE researchers, a single irradiation campaign often takes 2–4 years, followed by 18–24 months of PIE. Improving testing timelines through increased capacity is an important R&D priority.

Two existing LWR-spectrum loops are located at national laboratories: the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory and the ATR at Idaho National Laboratory. Recent improvements at HFIR have increased the neutron-beam brightness and expanded the range of instruments available for testing. Brightness measures how densely packed the neutron stream is as it travels out of a beam; a brighter beam keeps the particles moving closely together in a tight path, illuminating a sample more effectively. ATR is the only facility in the U.S. capable of producing the large volume, high-flux neutron irradiation needed to test nuclear fuels; the facility began operation in 1967 and is nearing end of life. DOE is currently planning an approximately $1.3B investment over 20 years to maintain and improve reliability of the facility[38]. This may include routine overhauls of the key internal reactor components and the transition from analog instrumentation systems to digital control systems. Despite these improvements, queue congestion continues to slow progress, even for Gen III+ R&D.

Fast-spectrum testing is required for reactor designs that operate with a higher energy neutron spectrum than existing LWRs. Fast-spectrum test facilities must provide unmoderated high-energy neutrons and sufficient controlled testing volume to accommodate multiple fuel and materials samples.

The Experimental Breeder Reactor II (EBR-II) was a sodium-cooled fast neutron test reactor located at the former Argonne National Laboratory-West site at the Idaho National Laboratory. Operations began in 1964, but the U.S. shut down EBR-II in 1994. Developers of sodium-cooled fast reactors (SFRs) (e.g., Natrium) currently rely on limited infrastructure in other countries.

Expanding fast-spectrum and high-temperature irradiation capabilities is essential to advance R&D topics on materials, components, and fuels.

Even with perfect infrastructure, irradiation and PIE cycles take years. R&D could focus on:

- Accelerating sample throughput
- Improving modeling-to-testing integration
- Validating non-destructive evaluation methods to reduce reliance on destructive PIE when possible

Reactor Relevance: All Gen IV designs; some Gen III+ fuels
Risk to Deployment: Moderate

7.2.3 Increase Irradiation Testing Capacity for Materials and Coatings

Testing and validation of fuel requires evaluations of heat transfer, fission product behavior, and gas accumulation. Materials and coatings testing requires evaluating microstructural degradation that may occur under harsh conditions. Materials and coatings testing focuses on void swelling and embrittlement of cladding and structural components. While both require access to irradiation facilities, the testing infrastructure needed for materials and components differs from that needed for fuel testing. For example, materials testing requires equipment to replicate extreme environmental or mechanical loads such as earthquakes, vibration, and high-pressure steam loops, rather than containing fission. Additionally, tested specimens are less radioactive than used fuel, allowing nondestructive evaluation using advanced imaging. NYS institutions, including Brookhaven National Laboratory and some private facilities such as the GE Vernova Advanced Research Center, can support materials testing more directly than fuel testing.

Reactor Relevance: All Gen IV designs
Risk to Deployment: Moderate

7.2.4 Scale Post-Irradiation Examination Capacity

The testing facilities used for fuel and materials validation are PIE labs or hot cells. A PIE lab is a highly shielded facility that uses remote-controlled robotics in heavily walled hot cells to study how radiation and extreme heat affect the properties of the fuel or materials. The PIE lab consists of a complex or building containing multiple hot cells, support rooms, and ventilation systems. A hot cell is a single, heavily shielded containment chamber that provides the physical isolation and shielding needed to handle the radiation required. Even when irradiation facilities

are available, insufficient PIE lab capacity in other states and hot cells create multiyear backlogs. Investing in additional PIE lab capacity would support:

- Modern hot-cell and radiochemical labs, which use modular designs, automated robotics, and digital control systems
- High-resolution microscopy and mechanical testing gear for advanced ceramics, alloys, TRISO
- Shared PIE infrastructure with standardized workflows for different fuel forms

Hot cells currently exist in Missouri, North Carolina, and Pennsylvania; these other states could expand their existing capacity. In New York State, Stony Brook University has Post-irradiation Examination and Research Laboratory, and other institutions have chambers used for nuclear medicine, radiopharmacy, and naval nuclear testing.

Reactor Relevance: All technologies
Risk to Deployment: Low

7.2.5 Establish Integrated Component-Scale Testbeds

Developers highlighted that U.S. infrastructure is insufficient to test the following:[39]

- High-temperature heat exchangers (printed-channel heat exchangers, compact heat exchangers)
- Sodium or molten-salt primary pumps
- Digital instrumentation and control systems under reactor-relevant conditions

Integrated component scale testbeds are facilities designed to simulate, monitor, and validate the performance of specific reactor parts such as heat exchangers, pumps, or control mechanisms under extreme scaled-down operational conditions using high-fidelity sensors, thermocouples, and strain gauges. These testbeds bridge the gap between small-scale material coupon testing and full-scale reactor operations and provide data needed for both NRC qualification and commercial bankability. National laboratories or vendors typically develop large-scale component testbeds for high-temperature heat exchangers, pumps, and reactor systems through demonstration programs.

Reactor Relevance: Gen IV primarily; some Gen III+ for new instrumentation and control (I&C)
Risk to Deployment: Low

7.2.6 Create Shared Test Infrastructure for Multiunit Control Room Demonstrations

As SMRs and microreactors propose multi-module configurations (e.g., NuScale, up to 12 units), shared test infrastructure is needed to allow developers to evaluate advanced digital twins and remote operations at a fraction of the cost of physical prototypes. Several factors drive this need. Many SMR and microreactor concepts propose operating several independent modules from a single centralized control room. Shared infrastructure enables researchers to simulate how an operational event in one reactor impacts adjacent modules and shared safety systems. It also provides the empirical data required for licensing, eliminating the need for every developer to build a testing facility from scratch. Because advanced SMR and microreactor control rooms are expected to rely heavily on automated systems and centralized data dashboards, shared testing will help the industry address key questions, such as whether a single operator can safely and effectively monitor and manage multiple microreactor modules simultaneously. NNL is developing simulations for naval training. If there is a way to collaborate while protecting classified or sensitive information, collaboration may be beneficial. For example, if there is a key challenge with training simulation development that NNL encounters and is independent of the technology specifics, generic development that would help both NNPP and commercial nuclear could fill the gap. Key areas for R&D include:

- Developing multi-reactor control algorithms, including high-fidelity simulators and digital twins to assist operators with real-time diagnostic tools
- Researching hardware and software isolation strategies to ensure that a compromise in one module does not impact the safety systems or communication interfaces of another
- Use of AI to design, license, manufacture, construct, and operate nuclear reactors with human-in-the-loop workflows (see Section 2 on DOE Genesis Mission)
- Validating novel staffing models

These efforts ensure regulatory confidence and reduce licensing friction.

Reactor Relevance: LWRs
Risk to Deployment: Moderate

7.3 New York State Strengths Assessment

This section maps New York State's existing testing and validation capabilities against the six infrastructure gaps identified in Section 7 and against the R&D topics from Sections 3 through 6 that depend on addressing the gaps.

New York State has multiple testing facilities unique in the country that support the development and characterization of new materials and components for the nuclear industry. These capabilities complement those available at other national laboratories and research entities and can address specific needs. Table 14 lists key identified facilities, including PIE facilities, ion beam laboratories, and material characterization facilities, and Appendix D provides a more extensive list of U.S. test infrastructure, along with additional details.

Table 14. Testing and Validation Infrastructure Located in New York State with Capabilities Relevant to the Nuclear Industry

Institution	Testing and Validation Infrastructure	Application for Nuclear R&D	Relevant For
RPI	Gaerttner LINAC Center	Neutron interaction with materials	• Irradiation testing and lifetime data (C3) • Nuclear data supporting advanced fuel qualification (F5)
BNL	NSLS-II	Characterization of materials and components under extreme environments of radiation, temperature, corrosive media, and strain	• Qualification of advanced high-temperature alloys and coatings (C1) • Coolant capability, and corrosion performance (C2)
NNL*	Radioactive materials laboratory Nuclear materials testing and qualification Corrosion testing	Extensive capability dedicated to Naval Nuclear applications	• NDE & inspection techniques (M5) • Coolant compatibility and corrosion (C2) • Irradiation testing (C3)
Stony Brook University	• Post-irradiation Examination and Research Laboratory • Fracture and Creep at Elevated Temperatures Lab	Analysis and qualification of alloys, ceramics, composites, and surrogate fuels following irradiation	• Irradiation testing and lifetime data (C3) • Spent fuel management and disposal pathways (F6)
University at Albany	Ion Beam Lab	Elemental and structural analysis of materials Irradiation of material samples	• Sample-scale irradiation of coatings and surfaces (C1) • Radiation-hardened sensors and instrumentation (C8)
City College of New York (CCNY)	HTGR helium/nitrogen gas flow loop	Thermal-hydraulic behaviors of HTGRs	• Coolant compatibility and corrosion (C2) • Qualification of high-temperature passive safety systems (C7)

* Collaboration would require classified capabilities to serve both naval and commercial nuclear industries

Table 15 summarizes 12 R&D topics across the manufacturing and project delivery, materials and components, and fuel and fuel cycle categories that depend on access to specialized testing and validation infrastructure. While the existing capabilities listed are complementary to, or address an aspect of, the identified gap, the State identified no reactor-scale test loops, test reactors, hot-cell PIE capacity, testbeds, or multiunit control room demonstration facilities.

Table 15. Crosswalk of Testing and Validation Infrastructure Gaps to Dependent R&D Topics and New York State Capabilities

Infrastructure Gap (7.1)	Dependent R&D Topics (Sections 3–6)	Available in NYS	Resulting Gap
Expand access to high-temperature, coolant-specific test loops	Coolant compatibility and corrosion performance; qualification of high-temperature passive safety systems; radiation-hardened sensors and instrumentation (Sec. 4)	CCNY HTGR helium/ nitrogen flow loop (sample and component scale)	No sodium or molten-salt loop capability; no reactor-scale loop capacity in State
Increase irradiation testing capacity for fuels and structural materials	Alloy and coating qualification; irradiation testing and lifetime data; PM-HIP component qualification (Sec. 4); TRISO, metallic fast-reactor fuel, ATF/LEU+, and accelerated fuel qualification (Sec. 5)	RPI Gaerttner LINAC Center, University at Albany Ion Beam Lab, BNL NSLS-II (sample scale)	No test reactor in State
Scale PIE capacity	Irradiation lifetime data (Sec. 4); spent fuel management, long-term reprocessing options, TRISO and ATF qualification (Sec. 5)	Stony Brook University laboratories (bench scale)	No hot-cell PIE capacity at scale in State for commercial nuclear development
Establish integrated component-scale testbeds	Qualification of high-temperature passive safety systems (Sec. 4); modularization and factory fabrication, NDE and inspection techniques (Sec. 3)	None identified	Full gap; nearest capability is component testing within federal testbeds
Create shared test infrastructure for multiunit control room demonstrations	Improve constructability and modernize product delivery models (Sec. 3); construction and manufacturing workforce development (Sec. 3)	None identified	Full gap

Two of the R&D topics listed in Table 15 are high priority because of their relevance to deployment and New York State's role: improving constructability and product delivery models, and workforce development, both of which can be supported through investment in shared test infrastructure for multiunit control room demonstrations. Moderate-priority R&D topics on materials and fuel cycle depend on irradiation facilities and PIE lab capacity. This indicates investments, either by upgrading and expanding existing facilities or building new facilities, to address those gaps would be most beneficial for the New York State nuclear innovation ecosystem. This conclusion was validated through discussions with the R&D-TWG.[40]

7.4 Options for Closing the Infrastructure Gap

To address the nationwide testing and validation infrastructure gap, existing facilities would need to be expanded or new facilities constructed. Options to expand existing capabilities are generally an order of magnitude less than building new facilities.

As shown by the NYS strengths assessments throughout this study, RPI, Brookhaven National Laboratory, and the Naval Nuclear Laboratory are an important part of the nuclear innovation ecosystem in New York State and have existing facilities. They were therefore identified as possible candidates for expanding testing and validation infrastructure in the State and were selected for further assessment.

At BNL, expansion options could include a materials irradiation and testing laboratory and expanded nuclear data measurement capabilities, which would directly serve the irradiation testing and qualification topics rated high priority in Sections 4 and 5.

The RPI expansion options could build on their existing expertise, operating Gaerttner LINAC Center, Waltenhousen Reactor Critical Facility, and recently installed NuScale E2 Center for SMR simulation training, rather than creating a new facility. Accelerator modernization and extended flight paths strengthen the nuclear data and radiation effects capabilities that support fuel qualification (Section 5) and materials lifetime data (Section 4), while a subcritical or critical assembly would restore hands-on reactor physics capability for testing and training.

The Naval Nuclear Laboratory is another potential site to consider. However, R&D-TWG members noted that concerns over confidential information have limited collaboration and partnerships to date. Collaborative work between the Naval Nuclear Laboratory and universities in other states including PSU ARL and JHU APL indicates that this type of work may be possible

in New York if the infrastructure to protect classified information is implemented and there is a compelling case for collaboration.

New infrastructure, including PIE and hot cells, would be needed to comprehensively support the identified R&D needs and close the identified testing and infrastructure gaps. For example, a testbed at the microreactor would bring fuels-scale testing capability, and at the component level could support innovations in the supply chain. These capabilities currently exist only at out-of-state federal sites. A university-scale research and test reactor with an associated hot cell facility would close the in-state irradiation and PIE gap and could anchor an innovation campus for New York State's nuclear industry, supporting workforce development, early-stage research, and institutional hosting functions.

7.5 Potential Role for New York State

The State should focus on facilitating and building partnerships between universities, private industry, the Naval Nuclear Laboratory, Brookhaven National Laboratory, and other DOE national labs to expand access to critical testing and validation facilities for NYS innovators and increase collaboration.

Beyond that, increasing irradiation testing capacity and scaling PIE could begin through incremental expansion at Brookhaven National Laboratory and RPI, enabling pursuit of the largest number of high-priority materials and fuels topics from Sections 4 and 5. In the long term, developing a university-scale research and test reactor with hot cells represents a comprehensive path to fully closing both gaps.

Shared multiunit control room infrastructure rates high on reactor relevance, given the expected multiunit facilities being considered by the technology developers and the high priority of the R&D topics it would support. Development of this infrastructure is expected to be less costly than options for new infrastructure for many materials and fuels R&D topics.

The State has multiple options to help address these gaps, by expanding access to existing facilities, upgrading or expanding existing capabilities in the State, or investing in new facilities that could help address these gaps. Additional evaluation into the cost and benefits of those options and others is needed. If the State decides to pursue a project with a significant capital cost, it will likely require coordination and partnerships across State regulatory and funding entities, institutions, elected officials, and private developers.

8. Fusion Energy R&D

Fusion is the process by which two light atomic nuclei combine to form a single heavier nucleus, releasing energy. Fusion energy has long been viewed as a potential source of abundant, low-carbon electricity, but for seven decades it remained primarily a scientific endeavor rather than a near-term energy option and has been the subject of extensive R&D efforts. The current state of fusion energy development is assessed in the Master Plan Fusion Energy study, while the Master Plan Supply Chain study identifies areas in which the state may have comparative supply chain advantages and emerging capabilities. The objective of this analysis is to identify technical challenges to deployment, identify strengths within New York's research institutions, and consider what role New York State could play in the emerging ecosystem.

8.1 Background Information

Most fusion concepts under development rely on the deuterium-tritium reaction. This reaction uses two isotopes of hydrogen—deuterium and tritium—as fuel, with lithium playing a supporting role in sustaining the fuel cycle (Table 16). When deuterium and tritium fuse at high energy, they produce helium and a high-energy neutron, which carriers more of the energy released in the reaction. In many fusion power plant designs, this neutron energy is absorbed by surrounding blanket materials, generating heat that can be used to produce steam and drive turbines for electricity generation.

Table 16. Overview of Fuel Components for a Fusion Machine

Material	Characteristics	Role in Fusion Systems
Deuterium	Stable, non-radioactive hydrogen isotope; abundant in seawater	Primary fuel component
Tritium	Radioactive hydrogen isotope (12.3-year half-life); scarce and mobile	Primary fuel component
Lithium	Light metal; reacts with neutrons to produce tritium	Enables in-situ tritium production (fuel breeding)

Fusion development is currently being pursued through several distinct technological approaches, which differ in how they create and maintain the conditions required to achieve fusion reactions. They can be broadly categorized into three groups:

- magnetic confinement fusion (MCF),
- inertial confinement fusion (ICF), and
- magneto-inertial fusion (MIF).

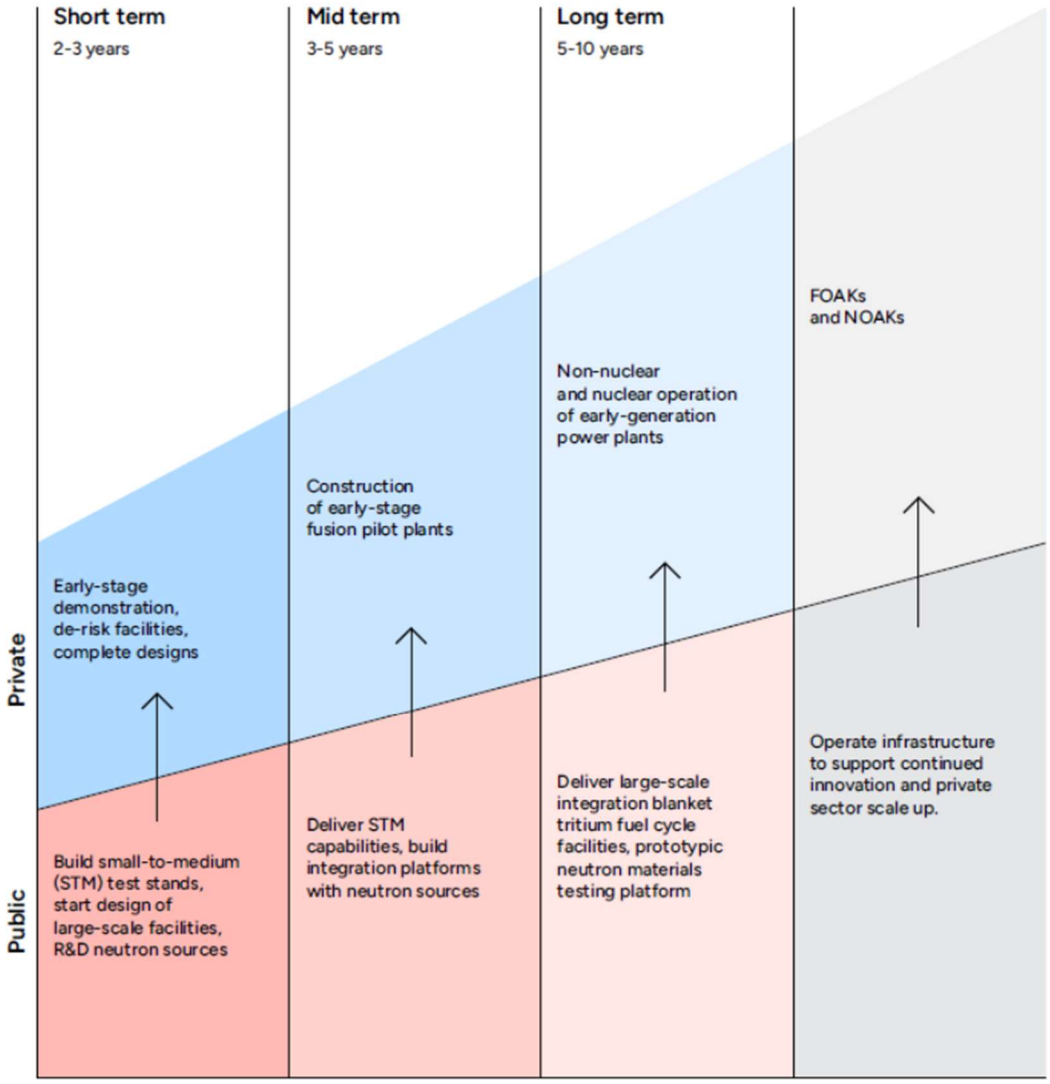
MCF systems use powerful magnetic fields to confine high-temperature plasma within a vacuum chamber in two primary configurations: tokamaks and stellarators. ICF systems rapidly compress a small fuel pellet to extremely high densities, but for very short times and typically use high-powered lasers to do so. MIF is a hybrid approach that combines aspects of both MCF and ICF systems.

The DOE's Fusion Science and Technology Roadmap outlines coordinated activities across near-, mid-, and long-term horizons, aligning public research programs, private-sector development, and pilot plant goals (Figure 5). In the near-term, DOE has identified goals to build small-to-medium test stands, to design large-scale facilities, and to build R&D neutron sources. This provides opportunities for the State to consider filling gaps that leverage the State's research institutions, industrial capabilities, and supply chain to capture benefits for New York State.

As fusion technologies continue to advance, their role within future energy systems will depend on the pace at which key commercialization and R&D challenges are addressed. This will ultimately determine the timing and scale of fusion's transition from demonstration systems to commercially deployed energy infrastructure though external factors, including supply chain disruptions, the availability and cost of key materials, and continued access to private and public financing will also play a role.

Figure 5. DOE Fusion Science and Technology Roadmap

Source: U.S. Department of Energy. Fusion Science and Technology Roadmap. June 2026.



8.2 Key R&D Topics

To bridge the gap between experimental proof-of-concept and a commercial fusion machine, there are technical and engineering challenges that must be overcome across several domains, including plasma physics, materials science, fuel cycle management, and systems engineering. Several critical components specific to fusion remain underdeveloped with limited analogs in other industries and will require dedicated development, testing, and manufacturing capacity. Some challenges are common across all fusion approaches, while others are specific to confinement method.

For deuterium-tritium fusion systems, the most important cross-cutting issues include integrating the full plant around the fusion core, breeding and managing tritium, developing materials that can withstand neutron and heat loads, extracting fusion energy as usable power, and achieving sufficient reliability and availability to justify high capital costs.[41] The key R&D topics identified below are by no means exhaustive, and should be viewed as the most essential challenges to address in the near term. The challenges identified here were presented to and validated by the Technical Stakeholder Working Group on fusion convened throughout the Master Plan development process.

8.2.1 System Integration and Net Plant Performance (N1)

Commercial fusion requires a complete plant that integrates the fusion core with fuel handling, heat extraction, power conversion, controls, safety systems, maintenance systems, and other balance-of-plant infrastructure, all of which represent a significant portion of total energy consumption. A key commercialization challenge is proving that these subsystems can operate together under power-plant-relevant conditions while achieving net energy gain.

Status: Integrated plant performance has not yet been demonstrated. Developers are advancing designs and pilot-scale concepts, but whole-plant integration remains a challenge.

Reactor Relevance: Fusion – cross-cutting

8.2.2 Tritium Fuel Cycle and Fuel Self-Sufficiency (N2)

Fusion plants will require systems to produce, recover, process, store, account for, and recycle tritium while minimizing inventory and releases. Because tritium is scarce and radioactive, fuel-cycle performance is directly tied to plant operability, safety, licensing, and scalability.

Status: Tritium breeding has been demonstrated experimentally, but a fully integrated system capable of breeding, extracting, and recycling tritium at commercial scale has not yet been demonstrated.

Reactor Relevance: Fusion – cross-cutting

8.2.3 Materials Performance in Fusion Environments (N3)

Fusion plant materials must withstand high neutron flux, thermal loads, mechanical stress, corrosion, tritium exposure, and other extreme operating conditions. Structural materials, first-wall components, blanket materials, and in-vessel supports must retain strength and functionality over useful operating lifetimes.

A dedicated high-flux neutron irradiation infrastructure—such as ORNL's or INL's ATR—is required to fully replicate fusion-relevant neutron environments and support end-to-end materials qualification, just as with materials testing for fission environments.[42] As discussed in the Testing and Validation section, this infrastructure is not located in New York, and thus New York State-based researchers and manufacturers rely on partnerships with national laboratories and international programs for irradiation testing and qualification to advance this R&D topic.

Status: Candidate materials and testing programs are advancing, but qualification data under integrated fusion-relevant conditions remain limited. Long-duration exposure data, fusion-spectrum neutron testing, component lifetime validation, and manufacturing qualification remain key gaps.

Reactor Relevance: Fusion – cross-cutting

8.2.4 Energy Capture, Blanket Systems, and Power Conversion (N4)

Fusion plants must capture neutron energy and convert it into usable electricity or heat. This generally requires blanket systems that convert neutron energy into heat, breed tritium, shield sensitive components, and interface with coolant and power-conversion systems. Integrating these functions into a system that can operate continuously at plant scale is central to both fuel self-sufficiency and electricity generation.

Status: Blanket and power-conversion concepts are under development, but no integrated blanket and energy-conversion system has been validated for a fusion power plant.

Reactor Relevance: Fusion – cross-cutting

8.2.5 Plant Reliability, Maintainability, and Operations (N5)

Commercial fusion plants will need high availability and capacity factors to justify their high capital costs. However, fusion systems are complex, highly integrated facilities that operate in extreme environments and may require remote handling or robotics for maintenance due to neutron-induced activation of structural materials. Reducing capital costs while maintaining durability, limiting maintenance downtime, and supporting efficient inspection and component replacement will be critical to long-term commercialization.

Status: Reliability, availability, and maintenance are increasingly recognized as a core design requirement, but fusion-specific operating experience is limited

Reactor Relevance: Fusion – cross-cutting

8.2.6 Long-Duration Plasma Stability and Confinement (N6)

Magnetic confinement systems must sustain stable plasma conditions over extended operating periods. Toroidal systems can experience instabilities, including tearing modes, edge-localized modes, and major disruptions, that can release stored energy and damage in-vessel components.

Status: Plasma control tools and disruption mitigation systems are improving, but long-duration stable operation at pilot-plant-relevant performance levels has not yet been demonstrated.

Reactor Relevance: Fusion – MCF, MIF

8.2.7 Plasma-Facing Components and Divertor Operations (N7)

Plasma-facing components, including the first wall, divertor, and high-heat-flux cooling structures, must tolerate intense heat and particle fluxes while limiting erosion, cracking, fuel retention, impurity generation, and material degradation. Divertors must dissipate exhaust power, remove helium ash and impurities, and maintain plasma detachment without degrading confinement.

Status: Precision target fabrication has been demonstrated for experimental use, but high-volume, low-cost manufacturing and reliable injection at plant cadence have not yet been demonstrated.

Reactor Relevance: Fusion – MCF

8.2.8 Fuel Target Fabrication and Injection (N8)

Inertial fusion systems require precision fuel targets that can be manufactured at very high volumes, delivered into the chamber, tracked, and engaged accurately at commercial repetition rates. Target quality, cost, and injection reliability are central to plant economics and operability.

Status: Remains an active design challenge

Reactor Relevance: Fusion – ICF

8.2.9 Optics and Component Survivability (N9)

The optical systems used to focus and deliver laser energy onto the target must withstand debris, radiation, and mechanical stress generated by repeated fusion micro-explosions.

Commercial systems must be able to clear the chamber and protect sensitive components between repeated shots.

Status: Remains an active design challenge

Reactor Relevance: Fusion – ICF

8.2.10 Repetitive Driver and Pulsed-System Performance (N10)

ICF and MIF systems rely on drivers or pulsed compression systems that must operate repeatedly with high precision, efficiency, and reliability. For ICF, this includes lasers, pulsed-power systems, or other drivers capable of high repetition rates and sufficient wall-plug efficiency. For MIF, this may include mechanical, electromagnetic, plasma-liner, or liquid-metal compression systems that must repeatedly deliver precise compression under high-stress conditions.

Status: Current experimental systems are not yet configured for commercial repetition rates, efficiencies, or duty cycles. High-repetition-rate drivers, pulsed-power systems, compression hardware, and related power-delivery technologies remain major development priorities.

Reactor Relevance: Fusion – ICF, MIF

8.2.11 Synchronized Magnetization, Compression, and Control (N11)

MIF systems must coordinate plasma formation, magnetization, compression, and energy delivery within a tightly timed operating cycle. Small deviations in timing, alignment, confinement, or compression symmetry can significantly reduce performance, creating additional integration and control complexity relative to MCF or ICF alone.

Status: MIF concepts are being pursued by several developers, but repeatable integrated demonstrations of magnetization-compression performance remain at relatively early stages. Control and synchronization requirements remain highly concept-specific and a key uncertainty for scale-up.

Reactor Relevance: Fusion – MIF

8.2.12 High-Temperature Superconducting Wire and Magnet Systems (N12)

MCF systems use powerful magnetic fields to confine high-temperature plasma within a vacuum chamber. The development of high-temperature superconductors (HTS) has led to stronger magnetic fields, improving plasma confinement, and enabling compact, high-field reactor designs. There are few U.S. based producers of commercial-scale HTS conductors, creating dependencies on limited foreign suppliers.

Status: HTS magnets currently used in research devices and technology demonstration units, but manufacturing scale-up, quality assurance, and testing infrastructure remain gaps.

Reactor Relevance: Fusion – MCF, MIF

8.3 New York State Strengths Assessment

There are a number of New York State-based university research programs in addition to LLE that provide extensive expertise with plasma physics, materials science, and modeling; these programs actively contribute to advancing fusion research. Select New York State-based university fusion research programs are summarized in Table 17.

Table 17. Select New York State-Based University Fusion Research Programs

University	Department or Laboratory	Focus & Achievements
Columbia University	Columbia Fusion Research Center	MCF on tokamaks and ICF Multiple research devices located on site Fusion Center of Excellence established in 2025 collaborates with fusion startups
Cornell University	Laboratory of Plasma Studies	High-density plasma physics in operation for over 50 years MIF research with simulations and two pulsed power test machines Member of DOE-established hub to advance fusion
Rensselaer Polytechnic Institute	Nuclear Science & Engineering Plasma Dynamics Laboratory	Develops heavy-ion beam diagnostics for magnetically confined fusion plasmas. Computational modeling of fusion systems Nuclear materials & fuel cycle R&D
University of Rochester	Laboratory for Laser Energetics	Laser-driven fusion research Operates OMEGA laser facilities Leading DOE-established multi-disciplinary/multi-institute hub to advance ICF Tritium handling Plasma diagnostics

Table 17. (Continued)

University	Department or Laboratory	Focus & Achievements
RIT		Optics, photonics, imaging Precision manufacturing
Stony Brook University	Department of Materials Science & Chemical Engineering	Recipient of multiple DOE awards on materials for fusion machines Advanced structural materials and radiation-effects research; materials characterization

New York State is nationally and internationally competitive in high-power laser and optical systems, anchored by the University of Rochester's LLE. LLE operates the OMEGA laser facilities and conducts research in high-energy-density physics, laser–plasma interactions, and advanced fusion diagnostics.[vi] They are leading one of three multi-institutional and multi-disciplinary hubs established by DOE in 2023 to advance inertial fusion energy.[43] LLE has spun startups out and participated in public-private partnerships – they recently entered into a partnership with Focused Energy Inc., a private fusion startup, studying laser-plasma instabilities. This collaboration was awarded a $6.9 million DOE INFUSE grant.

Brookhaven National Laboratory conducts research in superconducting materials, magnet science, material behavior under extreme conditions, and accelerator-based systems that are directly relevant to high-field magnet and materials development for fusion applications. This work leverages BNL's NSLS-II and BLIP to study radiation effects in materials and participates in collaborative research efforts focused on extreme environments.[44] These capabilities support the key challenges in plasma confinement, high-field magnet performance, radiation-tolerant materials, high-performance alloys, and structural components relevant to fusion energy systems.[45]

Stony Brook University has significant research focused on the development and performance of structural materials for extreme irradiation and high-temperature environments characteristic of MCF systems. Faculty in the Department of Materials Science and Chemical Engineering investigate radiation-induced defect evolution, embrittlement, and microstructural stability in advanced metallic alloys, with an emphasis on designing radiation-tolerant microstructures for first wall and blanket applications.[46] The university's work also includes experimental characterization of materials under irradiation-mimicking conditions and advanced processing techniques to engineer structural alloys capable of sustaining prolonged neutron exposure and high thermal loads in fusion reactors.

Many of RPI's strengths in nuclear engineering, materials science, and mechanical engineering, including research in radiation effects in materials, advanced alloys, ceramics, and computational materials modeling, are also applicable for fusion. For example, RPI researchers conduct work on radiation effects and aging of structural materials used in nuclear environments, as well as neutron interaction and cross-section measurement experiments using the Gaerttner Linear Accelerator Center, both of which are directly relevant to fusion challenges such as neutron-induced degradation of structural materials and validation of nuclear data for fusion blanket and shielding design.[47]

Targeted state investment could help address these gaps by supporting expanded materials R&D collaborations between universities and industry, funding pilot-scale materials processing and qualification facilities, or facilitating cost-shared access to national laboratory irradiation infrastructure.

8.4 Potential Role for New York State

Overall, New York State is well positioned to play a significant role in the emerging fusion energy ecosystem by leveraging its existing industrial base, research institutions, and national laboratory infrastructure. While the state is not a vertically integrated fusion hub with reactor developers and breeding test facilities, it has meaningful strengths in several high-value enabling domains that are critical across multiple fusion technology pathways and create strong opportunities for the state to contribute. As identified in the Master Plan Supply Chain Study, the State also has a base of relevant manufacturers in optics, superconductors, vacuum systems, precision fabrication, controls, and advanced materials that could contribute to applied R&D efforts.

In particular, these strengths are well positioned to address R&D topics such as materials performance in fusion environments (N3), plasma-facing components and divertor operations (N7), fuel target fabrication and injections (N8), optics and component survivability (N9), repetitive driver and pulsed-system performance (N10), and high-temperature superconducting wire and magnet systems (N12).

The Master Plan Fusion Energy Study concludes that fusion remains in a pre-commercial phase, with significant commercialization challenges to be addressed before it can be deployed as a reliable source of electricity. There is no clear indicator which approach could ultimately result in a commercial fusion machine. Therefore, cross-cutting challenges across fusion technology approaches and solutions with applications beyond the fusion industry or that also support fission, represent the lowest risk investment pathways. The most immediate opportunity is to

strengthen the enabling research, testing, and manufacturing ecosystem that fusion commercialization will require.

The state has multiple opportunities to build upon in-state expertise and consider facilities that could align with the goals outlined in the DOE Roadmap. DOE has explicitly identified public-private partnerships and shared R&D infrastructure as mechanisms to close remaining science and technology gaps, like the ones identified in this section. It has pointed to regional hub structures as a way to align state and local funding with private-sector roadmaps and critical supply-chain needs. In its 2025 report, *State Policy Options for Fusion Energy Development* the Clean Air Task Force (CATF) also identified establishing innovation hubs as a policy option for state's looking to support fusion energy development.[48]

Establishing an operating vehicle to coordinate R&D and facilitate public-, private-, and university-partnerships such as an advanced nuclear R&D consortium, could encourage development of the fusion ecosystem. In practice, this could support applied fusion materials testing, component prototyping, magnet and cryogenic system development, diagnostics, digital engineering, and coordinated partnerships with private developers. Fusion developers locating in or partnering with the region would have access to nearby R&D infrastructure, specialized workforce talent, prototyping facilities, and in the case of optical components, established suppliers. The co-location of academic research institutions and industrial manufacturing capability in the State creates opportunities for collaborative development, rapid iteration, and technology transfer.

9. Findings and Conclusions

9.1 Working with New York State's Research Institutions

New York State universities and research institutions represent valuable assets for accelerating the deployment of advanced nuclear technologies, as well as maintaining and building on State expertise on nuclear energy issues. Strategic investment into the priority areas outlined in this report will require ongoing collaboration with institutions that possess the relevant facilities, expertise, and technical infrastructure. Some institutions within NY currently support the R&D topics identified in this report, while others have adjacent capabilities that could be leveraged to support nuclear R&D topics.

Table 18 identifies, at a high level, intersections between these institutions and the R&D categories discussed in the prior sections. A check indicates directly relevant ongoing work or potential for subsequent work to develop a work scope. A more detailed assessment of the relevant expertise at these institutions is provided in the NYS strengths assessment table provided in each category-specific section. Appendix E provides a more detailed list of the expertise and relevant facilities.

Most of the organizations identified in Table 18 were invited to or actively participated in the R&D-TWG or FUS-TWG to provide insight and feedback on the R&D needs and capabilities within New York State. However, two gaps remain in this assessment. First, the U.S. Military Academy (USMA) at West Point and NNL focus on national defense and nuclear propulsion, but additional outreach is needed to better understand partnership opportunities on technology-agnostic topics, such as testing and validation, qualification pathways, and manufacturing. For example, Project JANUS, focused on nuclear deployment to U.S. Army facilities, may offer an opportunity to bring the U.S. Military Academy into NYS-focused R&D in support of Fort Drum (see Section 2.2).

Second, this assessment of NYS strengths did not include private industry capabilities. Further analysis of the industries and companies in New York State that would or could participate in the supply chain may identify additional strengths. This is particularly relevant to the manufacturing and project delivery category of R&D topics. Members of the R&D-TWG provided some information on private facilities that might help fill gaps, especially with local State fabrication shops.

Table 18. Summary of New York State's Existing R&D Ecosystem

Resource	Manufacturing & Project Delivery	Materials & Components	Fuel & Fuel Cycle	Site Characterization & Preparation	Testing & Validation	Fusion Energy
University at Buffalo	✓	✓		✓		
Rensselaer Polytechnic Institute (RPI)	✓	✓	✓		✓	✓
Naval Nuclear Laboratory	✓	✓	✓		✓	
USMA (West Point)			✓			
City University of New York CUNY)				✓	✓	
Columbia University						✓
New York University (NYU)				✓		
Cornell University		✓				✓
Brookhaven National Laboratory (BNL)	✓	✓			✓	✓
RIT	✓			✓		✓
University at Albany				✓	✓	
University of Rochester					✓	✓
Stony Brook University		✓	✓		✓	✓

New York State's robust research expertise can be strengthened through coordination, and building a cohesive nuclear innovation ecosystem with an emphasis on partnerships is a priority. TWG members identified that a centralized hub to connect and coordinate researchers, facilitate partnerships with industry and national laboratories, and promote knowledge sharing is needed and would be valuable to build a durable foundation for nuclear innovation in New York State. Such coordination is needed to avoid fragmented testing and duplicative efforts, and to achieve measurable progress on high-priority R&D topics. Entities such as the New York Battery and Energy Storage Technology Consortium, the National Offshore Wind Research and Development Consortium, and NY Creates were provided by R&D-TWG members as models that have fostered innovation and growth in New York State for the energy storage, offshore wind, and semiconductor industries.

9.2 Fission R&D Findings

Deployment of advanced nuclear will be best served by meeting several R&D challenges across both Gen III+ and Gen IV technologies. While Gen III+ systems mostly require targeted improvements to manufacturing, project delivery, and component qualification, Gen IV systems introduce additional needs in materials, fuels, and specialized testing infrastructure. This report identifies the major R&D areas where advances are needed to help strengthen readiness, reduce uncertainty, and therefore support reliable deployment pathways for advanced nuclear across various reactor technologies.

Opportunities for innovation:

Supply chain and project-delivery performance can be strengthened with targeted R&D. NYS institutions have strong construction management, advanced manufacturing, and engineering programs as well as expertise with sustainable manufacturing, digital twin development, and AI/ML decision-making. This will advance the pipeline for new reactor deployment in New York State and beyond. Priority R&D topics include:

- Improving non-destructive evaluation and inspection techniques (M5) by developing radiographic, ultrasonic, and AI-assisted inspection approaches,
- Modernizing constructability and delivery models through digital-twin planning tools, improved sequencing, and integrated project delivery frameworks (M7)
- Strengthening the construction and manufacturing workforce with novel staffing models, human factors R&D, and advanced simulators (M8).

Site characterization processes that are faster, more standardized, and more predictive than the current paradigm, which were designed for gigawatt-scale LLWRs, are necessary to accelerate advanced nuclear deployment. While many foundational requirements remain the same (e.g., hydrology, seismology, environmental baselines), targeted R&D to streamline the time and cost of these steps is essential for achieving growth and cost reduction in new nuclear deployment. New York State's strengths lie in civil, structural, and environmental engineering departments at universities with specific expertise in dispersion modeling, environmental monitoring and sensing, geotechnical analyses, and simulations for environmental and site characterization. Priority R&D topics include:

- Developing modular, reactor-specific site templates to reduce redundant and unnecessary data collection (S1)
- Developing predictive modelling tools for environmental and geotechnical impacts (S2)

- Generating robust data on offsite consequences under credible accident scenarios to streamline data requirements for EPZs (S3)
- Improving early-phase environmental baselining methods with drone and remote-sensing technologies (S6)

Fuel-cycle preparation remains essential for Gen IV systems, particularly the development of HALEU, TRISO, and metallic fuel capabilities needed to enable advanced reactor deployment at scale. Enrichment and large-scale fabrication infrastructure are nationally concentrated and capital-intensive. The federal government leads coordination of this research and has dedicated programs to address the gaps. While states can contribute meaningfully through fuel cycle analysis, environmental modeling, materials performance research, and policy-support work, coordinating or executing research at the state level is not a priority.

Advances in reprocessing and recycling SNF present opportunities to address the long-standing issue associated with a lack of a geologic disposal facility location in the U.S. Renewed interest in reprocessing and recycling SNF also presents opportunities to address long-standing disposal challenges and support broader deployment readiness.

Materials qualification continues to require sustained investment. Qualifying advanced materials will allow designers to remove constraints imposed by current materials, improving the performance and cost of nuclear designs while ensuring safe operation over expected lifetimes of 60–80 years. This is important for reducing costs for Gen III+ reactors and enabling deployment of Gen IV reactors that require high-temperature alloys, graphite, and sodium- or helium-compatible components. NYS institutions have extensive expertise in developing advanced materials that could ultimately be qualified, as well as in simulations and modeling to support qualification pathways. However, to have a significant impact in this category, they require collaboration with, and increased access to, specialized testing and validation infrastructure at national labs and other universities. New York State is best positioned to contribute on topics that do not require irradiation testing or can leverage sample-size material characterization techniques. One high-priority R&D topic is:

- Identifying alternative sources and validating alternatives for critical reactor materials (C6)

Nationwide constraints in testing and validation infrastructure are delaying commercial readiness of nuclear innovations. Innovators need access to specialized testing and validation facilities to examine and test materials and parts. To address this, existing facilities would need to be expanded or new facilities constructed. Shared multiunit control room infrastructure, irradiation facilities, and PIE laboratories were identified as the most impactful for the NYS innovation ecosystem. Additional analysis is needed to evaluate the benefits, costs, and

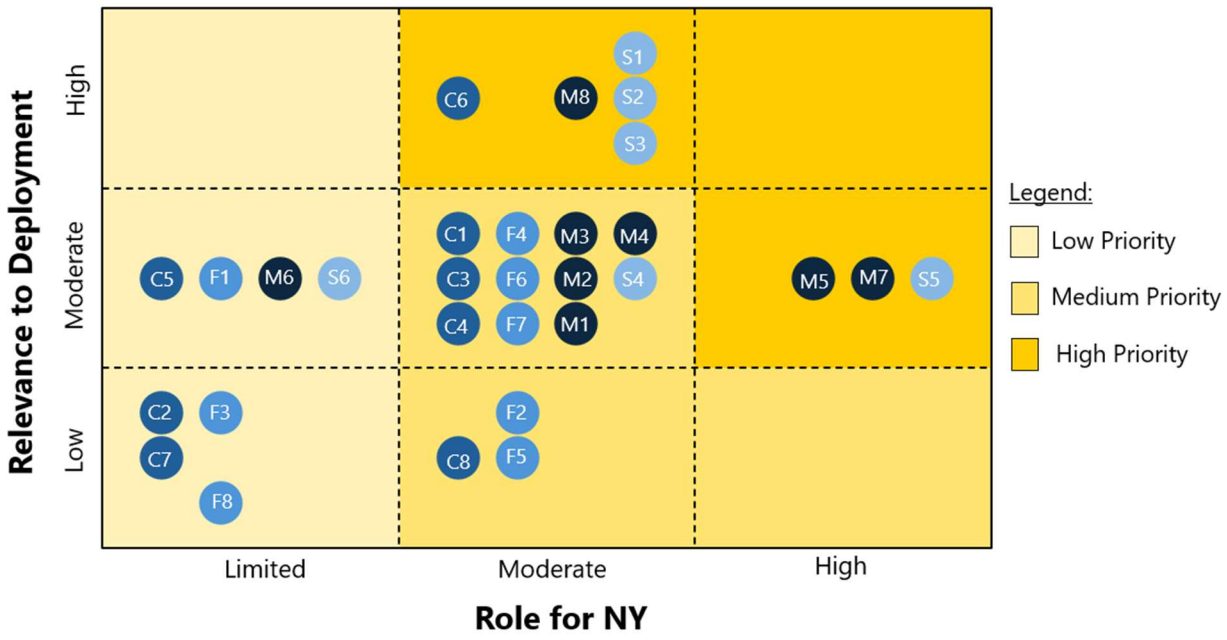
opportunities of building new facilities or upgrading and expanding existing testing capabilities to bridge this gap. Facilities identified as the most potentially impactful for the State, listed from lowest to highest cost, are:

- Upgrading existing nuclear-relevant testing capabilities
- Building a shared multiunit control room testing facility
- Building a new microreactor or component testbed
- Building a university-scale research reactor in the State

9.3 Fission R&D Prioritization

As New York State considers how to move forward on various options to address the R&D topics, consideration should include the priority of the need, its impact on enhancing deployment of new nuclear, and the associated cost. Fission R&D topics were color-coded by category and organized based on the Role for New York State, which evaluates New York State's strengths and potential for independent impact, and the Relevance to Deployment, which evaluates the relevance to prioritized reactor types and the overall risk to deployment from failing to advance the R&D topic (Figure 6). Eight R&D topics are high priority for investment in the near term because of their potential to affect the speed and cost of Gen III+ deployments. Many topics are clustered in the moderate-priority category, with a moderate Role for New York State and moderate Relevance to Deployment. Moderate-priority indicates R&D topics where New York State should build capability to develop innovations and preserve optionality. If New York State selects a particular reactor technology type or identifies necessary characteristics of a reactor type, this group could yield additional high-priority R&D topics.

Figure 6. Summary of R&D Priorities



Manufacturing & Project Delivery	
M1	Streamline qualification pathways
M2	Reduce cost and complexity of NQA-1
M3	Capital investment barriers
M4	Modularization and factory fabrication
M5	NDE and inspection techniques
M6	Mitigating liability barriers
M7	Constructability and delivery model modernization
M8	Construction and manufacturing workforce

Fuel & Fuel Cycle	
F1	Establish reliable HALEU supply chain
F2	Scale TRISO fuel fabrication and qualification
F3	Metallic fast reactor fuel development
F4	Gen III+ fuel lifetime
F5	Fuel qualification acceleration and simulation
F6	Used-fuel management and disposal pathways
F7	Reprocessing options and safeguards
F8	Thorium as fuel

Materials & Components	
C1	Qualification adv. high-T alloys and coatings
C2	Coolant compatibility and corrosion performance
C3	Irradiation testing & lifetime data
C4	PM-HIP & AM
C5	Validated methods for advanced manufacturing
C6	Supply chains for critical reactor materials
C7	Qualification of high-T passive safety systems
C8	Radiation and high-T instrumentation

Site Characterization & Preparation	
S1	Modular, reactor-specific site templates
S2	Predictive modeling tools
S3	Streamlining data requirements for EPZ
S4	Integrating reactors at existing nonnuclear sites
S5	Early-phase environmental baselining methods
S6	Standard geotech and subsurface protocols

Table 19 summarizes each of these priorities, along with their associated costs and constraints, grouped by topic area and drawing on the cost information presented in Section 7.

Table 19. Summary of the Priority for Deployment for Each R&D Area, and Options for New York State with Cost Ranges

Category	NYS Options (Low to High Investment)	Cost Range	Key Constraints
Manufacturing & Project Delivery	• Fund university R&D on digital engineering, modularization, project delivery • Support DOE-matched workforce training programs • Targeted supply chain and large-forge capability investments	$2M–$340M	• N-stamp supplier decline; workforce shortages; no dedicated nuclear manufacturing R&D center in NYS • Range reflects spectrum from DOE matched workforce training grants to domestic ultra-large forge press capability
Materials & Components	• Fund material characterization at NY universities • Partner with BNL, ANL, and ORNL for irradiation campaigns • Build materials testing lab at BNL • Support supply chain development for critical reactor materials	$1M–$50M	• No in-state irradiation facilities; qualification timelines are 4–6+ years minimum • Range reflects spectrum from NEUP scale university research awards to building a full materials testing lab at BNL
Fuel & Fuel Cycle and SNF	• Partner with INL fuel cycle R&D • Fund BNL radiochemistry program • Explore reprocessing and waste form research at NYS institutions	$1M–$50M	• Fuel fabrication concentrated outside NYS; reprocessing politically sensitive; HALEU supply is federally led • Range reflects spectrum from university fuel cycle research grants to a dedicated radiochemistry or waste form program at BNL
Site Characterization & Preparation	• Commission site studies for NYS candidate locations • Develop standardized siting templates • Fund environmental monitoring program at BNL and universities • Advance predictive modeling tools and streamlined EPZ data approaches	$1M–$4M	• Strongest NYS alignment; existing agency, authority and university expertise directly applicable at University at Buffalo and CUNY
Testing & Validation	• Partner with INL and ORNL for queue access • Fund BNL neutron and materials program • Explore naval lab testing • Build testbed or research reactor in NYS	$3M–$700M	• No in-state irradiation or hot-cell facilities; multiyear NRC licensing for new builds • Range reflects spectrum from joining existing DOE test programs to building a full research reactor with hot cells at BNL

9.4 Fusion Energy R&D Findings

New York State has a strong fusion energy R&D ecosystem. LLE provides world-class inertial-fusion and high-energy-density physics capabilities; BNL offers superconducting magnet expertise, materials characterization, and accelerator-based irradiation capabilities; and universities including Columbia, Cornell, RPI, Stony Brook provide complementary expertise in plasma physics, materials, nuclear engineering, diagnostics, and modeling. In addition, the State has a base of relevant manufacturers in optics, superconductors, precision fabrication, controls, and advanced materials that could partner in applied R&D. Brookhaven National Laboratory's strengths in advanced characterization, accelerator-based irradiation, and materials science could position New York State to play a critical upstream and midstream role in the fusion materials ecosystem, complementing national facilities that specialize in high-flux testing. These strengths are in several areas that are critical across multiple fusion technology approaches and create opportunities for the state to contribute to fusion development.

9.5 Conclusions

NYS research institutions will play an essential role in accelerating the deployment of advanced nuclear technologies, while maintaining and increasing State expertise on nuclear energy issues. Innovations developed through expanded R&D support would enable the State to become a meaningful contributor to the national and international advanced-nuclear landscape.

Conclusions:

- **Establish an advanced nuclear fission and fusion R&D consortium to serve as a centralized support hub for innovation by facilitating knowledge sharing, public–private partnerships, and coordinated research efforts.**
    - This operating vehicle could serve as the coordinator and facilitator of R&D around a shared advanced nuclear R&D agenda by coordinating research activities and knowledge sharing in priority topics.
    - The consortium could also facilitate academic–industry–government collaboration and public–private partnerships. Building partnership opportunities between national laboratories, such as Idaho National Laboratory, Oak Ridge National Laboratory, and Brookhaven National Laboratory, and New York State universities would increase collaboration with New York State innovators and expand access to specialized testing facilities and tools.
    - Additional detail on the advanced nuclear consortium should be developed as reactor technology, siting, and other aspects of the Nuclear Reliability Backbone

Initiative continue to advance. The purpose of this study is a gap analysis; detailed planning of the consortium would occur at a later phase.

- **Evaluate NYSERDA's advanced nuclear R&D funding priorities based on the near-term opportunities for manufacturing, project delivery, site characterization and preparation identified in this study, as well as further stakeholder input.**

Acronyms and Abbreviations

AGN	Aerojet-General Nucleonics
AI	artificial intelligence
AI/ML	artificial intelligence/machine learning
AM	additive manufacturing
ANS	American Nuclear Society
ARDP	Advanced Reactor Development Program
ARPA-E	Advanced Research Projects Agency—Energy
ASME	American Society of Mechanical Engineers
ATF	accident-tolerant fuel
ATR	Advanced Test Reactor
BLIP	Brookhaven Linac Isotope Producer
COLEX	column exchange
CSCMS	Center for Smart Convergent Manufacturing Systems
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE NE	U.S. Department of Energy, Office of Nuclear Energy
DOME	Demonstration of Microreactor Experiments
DPS	New York State Department of Public Service
EBR-II	Experimental Breeder Reactor II
EIC	Electron-Ion Collider
EPC	engineering, procurement, and construction
EPRI	Electric Power Research Institute
EPZ	emergency planning zone
ESP	Early Site Permit
FES	Fusion Energy Sciences
FLiBe	lithium fluoride–beryllium fluoride ($LiF–BeF_2$) molten salt
FOAK	first-of-a-kind
FUS–TWG	Fusion Energy Technical Working Group
GELS	Glovebox for Experimental Liquid Sodium
Gen III+	Generation III+ Light Water Reactors

Gen IV	Generation IV non- Light Water Reactors
HALEU	high-assay low-enriched uranium
HEU	highly enriched uranium
HFIR	High Flux Isotope Reactor
HTGR	High-Temperature Gas Reactor
HIP	hot isostatic pressing
HPC	Hinkley Point C
HT-9	HT9 ferritic/martensitic steel alloy
I&C	instrumentation and control
ICF	inertial confinement fusion
ILPM	Intelligent Lab of Power and Manufacturing
INFUSE	Innovation Network for Fusion Energy
IRA	Inflation Reduction Act of 2022
LEU	low-enriched uranium
LINAC	Linear Accelerator
LLWR	large light-water reactor
LOTUS	Laboratory for Operations and Testing in the United States
LWR	light-water reactor
MARVEL	Microreactor Applications Research Validation and Evaluation
MASLWR	Multi-Application Small Light Water Reactor
Master Plan	"Master Plan for Responsible Advanced Nuclear Development in New York"
MCF	magnetic confinement fusion
MHTGR	Modular High-Temperature Gas-Cooled Reactor
MIF	magneto-inertial fusion
MOU	Memorandum of Understanding
MSR	molten salt reactors
MSRR	Molten Salt Research Reactor
NASEO	National Association of State Energy Officials
NDE	non-destructive evaluation
NEI	Nuclear Energy Institute
NEUP	Nuclear Energy University Program

NNSA	National Nuclear Security Administration
NOAK	Nth-of-a-kind
NQA-1	Nuclear Quality Assurance-1
NRC	U.S. Nuclear Regulatory Commission
NRIC	National Reactor Innovation Center
NSLS-II	National Synchrotron Light Source II
NSUF	Nuclear Science User Facilities
NYPA	New York Power Authority
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
OR-SAGE	Oak Ridge—Siting Analysis for Power Generation Exploration
OSTP	U.S. DOE Office of Science, Technology and Policy
PHWR	pressurized heavy-water reactor
PIE	post-irradiation examination
PM-HIP	powder metallurgy—hot isostatic pressing
PPA	power purchase agreement
PULSTAR	Pulstar Nuclear Reactor
PWR	pressurized water reactor
QA	quality assurance
R&D	research and development
R&D–TWG	Research and Development Technical Working Group
S8G	Submarine 8th Generation
SBIR	Small Business Innovation Research
SFR	sodium-cooled fast reactor
SMR	small modular reactor
SNF	spent nuclear fuel
STAND	Siting Tool for Advanced Nuclear Development
TCF	Technology Commercialization Fund
TOF	time-of-flight
TRIGA	Training, Research, Isotopes, General Atomics
TRISO	tristructural isotropic

Federal Laboratories

ANL	Argonne National Laboratory
INL	Idaho National Laboratory
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory
LLNL	Lawrence Livermore National Laboratory
NNL	Naval Nuclear Laboratory
ORNL	Oak Ridge National Laboratory
PNNL	Pacific Northwest National Laboratory
SNL	Sandia National Laboratory
SRNL	Savannah River National Laboratory
BNL	Brookhaven National Laboratory

Universities

CUNY	City University of New York
MIT	Massachusetts Institute of Technology
NC State	North Carolina State University
OSU	Oregon State University
Penn State	Pennsylvania State University
RIT	Rochester Institute of Technology
RPI	Rensselaer Polytechnic Institute
SUNY	State University of New York
UIUC	University of Illinois at Urbana-Champaign
USMA	U.S. Military Academy
VCU	Virginia Commonwealth University

Appendix A. Methodology Details

This appendix provides further details on the study approach to fission Research and Development (R&D) as summarized in Section 2.

Assessment of Risk to Deployment

For each identified R&D topic, the risk to deployment is identified. Consistent with the approach described earlier, reactor relevance is applied as a qualifier to this rating: where the importance of a topic differs materially by reactor class, the risk rating is stated separately for the relevant technologies (e.g., High for Generation IV; Low for Generation III+), and the rating for a topic relevant to only one technology type reflects the risk to deployment of that technology alone.

To determine the risk to deployment, a literature review was conducted to identify factors where R&D progress is particularly important for successful deployment. Sources reviewed include evaluations from the Electric Power Research Institute (EPRI), studies from INL, and documents from original equipment manufacturers (OEMs) and reactor design companies.[49] It is categorized as High, Moderate, or Low, as follows:

- High: Lack of R&D to address the issue will be detrimental to technology deployment
- Moderate: This area of R&D has not been documented as critical to deployment but is recognized as important.
- Low: This R&D area has not been documented as critical to deployment, but may help accelerate deployment timelines

Where possible, references to reports or events are included, along with qualifiers and expected changes to the risk over time.

Potential for Independent Impact

Each R&D topic was evaluated based on the degree to which R&D execution would depend on access to specialized testing infrastructure located outside the State, overlap with efforts led by national laboratories, or the impact of a solution would depend on adoption by a national regulatory body, such as the U.S. Nuclear Regulatory Commission (NRC). The degree of overlap with national laboratories considers both the level of federal investment in a topic and the need for coordination.

- High: New York State (NYS) institutions, companies, or accessible regional facilities can both execute the R&D and capture its impact largely without external gatekeepers.

- Moderate: The R&D uses or expands existing external facilities or federally led programs, or benefits materially from national coordination, while NYS institutions can still execute meaningful portions independently.
- Low: Progress depends on external factors. Executing the R&D requires access to specialized facilities located outside New York State (e.g., licensed test reactors), or the solution's impact hinges on adoption by a national regulatory or standards body such as the NRC or American Society of Mechanical Engineers (ASME).

The capabilities of other states were considered at a high level in the testing and validation infrastructure category. However, the strengths of other states and their investments in these R&D topics were beyond the scope of this study.

New York State Strengths Assessment

Within each category, a NYS strengths assessment identifies existing facilities, programs, or curricula at NYS institutions with direct or relevant expertise on the R&D topics. The degree of strength is categorized as High, Moderate, or Low as follows:

- High: Existing facilities, programs, or curricula at NYS institutions have a direct correlation to the R&D topic
- Moderate: Facilities or programs have relevant expertise, including in other focus areas, that can be modified or adapted to address the R&D topic
- Low: Very limited overlap exists between the R&D topic and existing programs, curricula, and facilities

Summary Prioritization of R&D Topics

The specific R&D topics within each category were then prioritized based on the four factors listed earlier, which were grouped into two dimensions. The first dimension, the Role for New York State, evaluates both New York State's strengths in the topic area and its potential to make an independent impact. Where both factors scored the same (e.g., high), that score was assigned to the dimension. If the scores differed, the lower score was used (e.g., a combination of high and moderate resulted in a moderate overall score). The second dimension, Relevance to Deployment, assesses both the relevance of the topic to various reactor types and the overall risk to deployment if the R&D topic is not advanced. The same approach was used to combine the two factors within this dimension.

Finally, using these two dimensions, the summary plot shown in Figures S-1 and Figure 6 categorizes each research topic in one of three priority levels:

- High: Indicates R&D topics most likely to impact deployment of near-term projects. Role for New York State is moderate or high, and Relevance to Deployment is high.
- Moderate: Indicates R&D topics where New York State has strength, but risk to deployment may be moderate, or a moderate to high dependency on external factors limits the potential for New York State to have an independent impact. Role for New York State is moderate, and Relevance to Deployment is low or moderate.
- Low: Indicates limited strength for New York State, low risk to deployment, lack of relevance to Generation III+, or high dependency on external factors. Role for New York State is limited.

Appendix B. R&D Investments by Reactor Technology

The cost ranges shown in the following three reactor technology tables do not represent specific project cost estimates. Rather, they reflect the typical scale of funding committed to Research and Development (R&D) activities of each type by comparable federal programs, benchmark facilities, and supplier investments. Lower bounds generally correspond to academic research grant scales, and upper bounds correspond to facility-scale or manufacturing-scale investments. These ranges should be interpreted as order-of-magnitude indicators of the investment scale typically associated with each R&D area, not as precise cost estimates for any specific New York State (NYS) project.

B.1 Generation III+ Light-Water Reactors

Technology status: Commercially proven. AP1000 operational at Vogtle. Primary deployment barriers are cost, supply chain, and project execution—not fundamental technology gaps.

Table B-1. Gen III+ Light-Water Reactors

R&D Topic	Cost Range	What It Takes
Construction productivity and project delivery	$1M–$6M	• Digital twins • Modular construction sequencing • Lean project management adaptation for nuclear
Fuel optimization and long-term performance	$1M–$6M	• Extended burnup qualification • ATF development • Fuel cycle economics optimization
Multi-unit control room and human factors	$1M–$6M	• Simulator-based R&D for multi-module SMR operations • Staffing model validation
Site characterization for new and brownfield sites	$1M–$5M	• Site-specific geological, environmental, and seismic surveys for NYS candidate locations

B.2 Generation IV: Sodium- and Metal-Cooled Fast Reactors

Technology status: Natrium (TerraPower) under construction. Sodium fast reactor technology has been demonstrated historically, but no U.S. commercial prototype is currently operating. Significant R&D is required for fuel qualification, sodium handling, and materials under fast-neutron irradiation.

Table B-2. Sodium- and Metal-Cooled Fast Reactors

R&D Area	Cost Range	What It Takes
Sodium test loops and thermal-hydraulics validation	$20M–$100M	• Corrosion testing • Sodium-water- and air-reaction studies • Component qualification in flowing sodium
Metallic fuel qualification under fast-spectrum irradiation	$1M–$7M	• Multiyear irradiation campaigns and PIE • No fast-spectrum test reactor in the U.S. since EBR-II (1994)
Structural materials qualification (fast-neutron environment)	$5M–$20M	• Creep, fatigue, and irradiation embrittlement data for HT-9, Alloy 709, and other candidate steels
Sodium component manufacturing (pumps, heat exchanger, valves)	$80M–$200M	• Qualify sodium-compatible components • Electromagnetic pump development • Inspection methods
Spent metallic fuel handling and storage	$1M–$6M	• Pyroprocessing R&D • Sodium-bonded fuel storage and transport qualification

B.3 Gen IV: High-Temperature Gas-Cooled Reactors

Technology status: Xe-100 (X-energy) is the leading U.S. HTGR design, supported by DOE Advanced Reactor Development Program (ARDP) funding. Tristructural isotropic (TRISO) fuel has an extensive testing history but requires qualification for commercial deployment. The graphite moderator and helium coolant introduce unique materials challenges.

Table B-3. High-Temperature Gas-Cooled Reactors

R&D Area	Cost Range	What It Takes
TRISO fuel qualification and manufacturing scale-up	$50M–$150M	• Full-scale TRISO production line • Irradiation qualification • Fission product release testing
Nuclear-grade graphite qualification	$5M–$20M	• Irradiation behavior of candidate graphite grades • Dimensional change, creep, and oxidation data
Helium test loops and high-temperature component validation	$20M–$100M	• Printed-circuit heat exchangers • Ceramic matrix composites • Helium circulator testing at >700^{0}C
High-temperature alloy and CMC qualification	$5M–$20M	• Creep-fatigue data for Alloy 800H, Inconel 617 • CMC performance under irradiation and high temperature
TRISO spent fuel storage and disposal pathway	$1M–$6M	• Long-term integrity of TRISO particles • Waste form qualification • Disposal concept development

Appendix C. Nuclear R&D Funding Detail

Table C-1. National Laboratory Nuclear R&D Funding

National Laboratory	FY2025 Enacted ($ in billions)	FY2026 Request ($in billions)	State	Nuclear Focus
Idaho National Laboratory (INL)	1.6	1.5	Idaho	• Lead nuclear energy lab • Reactor testing, fuels, DOME and LOTUS
Oak Ridge National Laboratory (ORNL)	2.1	1.7	Tennessee	• Nuclear science, neutrons, isotopes, Hinkley Point C (HPC)
Argonne National Laboratory (ANL)	0.9	0.7	Illinois	• Reactor engineering, nuclear materials
Brookhaven National Laboratory (BNL)	0.6	0.6	New York	• Nuclear physics, radioisotopes • Electron Ion Collider (EIC) • National Synchrotron Light Source II • Superconducting Magnet Division
Pacific Northwest National Laboratory (PNNL)	0.8	0.6	Washington	• Nuclear security, materials, environmental
Savannah River Nuclear Solutions (SRNS)	0.2	0.2	South Carolina	• Nuclear materials management, tritium
Sandia National Laboratory (SNL)	3.5	3.5	New Mexico	• Nuclear weapons safety, security analysis • High energy density plasma and magnetized liner inertial fusion
Los Alamos National Laboratory (LANL)	4.9	5.8	New Mexico	• Weapons science, plutonium pit production
Lawrence Livermore National Laboratory (LLNL)	0.9	0.7	California	• National Ignition Facility for ICF fusion
Princeton Plasma Physics Laboratory	0.1	0.1	New Jersey	• NSTX-U • Confinement and plasma physics research • Spherical tokamak

Appendix D. State and University R&D Catalog

Table D-1. American Nuclear Society Top 10 States (Ranked) identified as Tier 1 (Ranked 1-5) and Tier 2 (Ranked 6-10)

No.	State	Key Activities, Fleet, and Pipeline
1	Tennessee	• 4 operating reactors (4,743 MWe) • TVA BWRX-300 at Clinch River (construction permit filed) • Kairos Hermes demo at ORNL (under construction) • Entra1/NuScale 12-module plan. $50M SMR grant fund + $10M workforce • ORNL ($2.6B budget) • Centrus, TRISO-X, Orano USA, Oklo, LIS Technologies fuel facilities • Radiant microreactor factory planned
2	Texas	• 4 reactors (4,926 MWe) • $350M nuclear fund + TX Advanced Nuclear Energy Office • X-energy/Dow Long Mott HTGR (ARDP) • Fermi America 4× AP1000 + 4× SMR • Natura Resources 100 MWe MSR • Last Energy 30 microreactors • Texas A&M University RELLIS Energy Proving Ground (multi-developer) • Abilene Christian University MSR under construction • 3 university research reactors.
3	Idaho	• No commercial fleet; 50+ reactors tested historically • INL ($1.7B R&D) • DOME (<$77.5M), LOTUS, MARVEL testbeds • Reactor Pilot Program: Aalo, Antares, Atomic Alchemy, Deep Fission, Last Energy, Natura, Oklo, Radiant, Terrestrial, Valar • Project Pele (DOD/BWXT) • ATR • Regional compact with Utah and Wyoming

No.	State	Key Activities, Fleet, and Pipeline
4	Virginia	• 4 reactors (3,694 MWe) • North Anna Early Site Permit (ESP) + Combined License (COL) • Amazon/X-energy 5 GW MOU • VA Nuclear Energy Consortium 5-yr plan • 20+ nuclear companies (Bechtel, BWXT, Dominion, Framatome) • Virginia Tech, Virginia Commonwealth University (VCU), George Mason University (NuScale sim)
5	Washington	• 1 reactor (Columbia, 1,207 MWe + 186 MW uprate) • Energy NW/Amazon/X-energy up to 12 Xe-100 SMRs • PNNL • Framatome fuel fab (Richland) • TerraPower headquarters • Hanford site
6	North Carolina	• 5 reactors (5,341 MWe, #6 nationally) • Duke Energy evaluating SMRs/LWRs at Belews Creek • NCSU PULSTAR (1 MW, 2 MW upgrade pending) – NSUF partner • Proposed new mixed-spectrum research reactor ($504M est.) • GE Vernova/TerraPower $200M+ HALEU fuel at Wilmington • GE Vernova Hitachi HQ • Orano cask manufacturing
7	Illinois	• 11 reactors (11,864 MWe, no. 1 nationally) • Constellation operates all • Full moratorium repealed January 2026 • Meta/Constellation Clinton Power Purchase Agreement (PPA) • Nano Nuclear/ University of Illinois at Urbana-Champaign (UIUC) test reactor • ANL, 30 test reactors built historically • Honeywell Metropolis Works (only U.S. uranium conversion plant)

No.	State	Key Activities, Fleet, and Pipeline
8	South Carolina	• 7 reactors (6,837 MWe, #3 nationally) • Duke Energy holds 2 COLs for AP1000s at Lee site • Santee Cooper/Brookfield MOU for Summer AP1000 restart • Westinghouse PWR fuel fab (Hopkins) • SRNL • SRNL plutonium and uranium feedstocks.
9	Pennsylvania	• 8 reactors (9,346 MWe, #2 nationally) • Crane Clean Energy Center (TMI-1 restart, Microsoft PPA, target 2027) • Westinghouse eVinci research reactor at Penn State • Amazon/Talen PPA + SMR exploration • Westinghouse committed to 10 AP1000s • Penn State Breazeale (oldest U.S. university reactor). Westinghouse headquarters
10	Michigan	• 3 reactors (3,501 MWe) + Palisades restart in progress (passivation completed March 2026; fuel loading next; first-ever U.S. restart of decommissioned plant) • $1.52B DOE loan guarantee for Palisades restart; $400M DOE grant for new SMR-300 Pioneer Units 1 & 2 (Holtec/Hyundai) • DTE Fermi holds COL for Unit 2 • University of Michigan Nuclear Engineering and Radiological Sciences program

Table D-2. Additional Active States identified as Tier 3 (states with active investment or deployment commitments) and Tier 4 (states with policy actions, operating fleets, or emerging nuclear programs)

Tier	State	Key Activities
3	Georgia	• Vogtle Units 3 and 4 operational (2,228 MWe) • No near-term new prospects but robust workforce and supply chain
3	Indiana	• SMR partnership pilot • 20% SMR manufacturing tax credit • Cost recovery for preconstruction authorized
3	New York	• Gov. Hochul directed NYPA to develop 1 GW of advanced nuclear and another 4 GW of advanced nuclear to establish a nuclear backbone • $105M for EIC at BNL • BNL $676M DOE budget • University of Rochester Laboratory for Laser Energetics $111M DOE budget
3	Ohio	• $100M Energy Opportunity Initiative (nuclear eligible) • HALEU enrichment at Piketon
3	Utah	• Gov. Cox Operation Gigawatt • $20M nuclear infrastructure budget • Manufacturing/training hub at Brigham City • Regional compact with Idaho and Wyoming • EnergySolutions headquarters
3	Wyoming	• TerraPower Natrium 345 MWe at Kemmerer (under construction, ARDP) • BWXT microreactor assessment • Regional compact with Idaho and Utah
3	Vermont	• Legislation enacted to study feasibility of new nuclear construction

Table D-2. (continued)

Tier	State	Key Activities
4	California	• Diablo Canyon license extension through 2030 • AB bill to exempt advanced reactors from moratorium (February 2026) • LLNL and the National Ignition Facility • Lawrence Berkeley National Laboratory (LBNL)
4	Colorado	• Bipartisan bill recognizing nuclear as clean energy passed
4	Florida	• HB 1645 directed regulator study on SMR feasibility • Report delivered Q1 2025.
4	Kentucky	• SB 198 nuclear development authority established • Site suitability study directed
4	Maryland	• HB 1035 (May 2025) includes provisions supporting nuclear development
4	Mississippi	• Entergy secured site permit for potential new reactor
4	Missouri	• PUC allowed cost recovery for nuclear investments
4	Nebraska	• 16 potential SMR sites announced (July 2025) • Cooper Nuclear Station license renewal underway
4	New Hampshire	• "Nuclear is clean" measure passed after years of debate

Table D-2. (Continued)

Tier	State	Key Activities
4	New Mexico	• LANL (~$4.9B DOE) and SNL (~$3.5B DOE) • ~1/3 of U.S. reactor uranium enriched in state • No commercial reactors • Z Pulsed Power Facility focused on defense applications and magnetized linear inertial fusion with high energy density plasma
4	Oregon	• OSU: TRIGA reactor (1.1 MW), high-temperature test facility (1/4 scale MHTGR), MASLWR, Hydro-Mechanical Fuel Test Facility, NuScale prototype, glovebox capabilities
4	Wisconsin	• AB 472 nuclear tax credit bill • Gov. Evers nuclear siting study (February 2026) • Kewaunee restart planned (EnergySolutions) • SHINE Technologies, UW-Madison

Table D-3. Key University Nuclear R&D Infrastructure

Institution	State	Key Nuclear R&D Facilities and Capabilities
Abilene Christian University	Texas	• NEXT Lab Molten Salt Test Loop: a flexible, nonnuclear flowing salt test system designed to evaluate advanced instrumentation, measure fundamental salt properties, and conduct hardware testing in support of the university's Molten Salt Research Reactor (MSRR) deployment
Massachusetts Institute of Technology (MIT)	Massachusetts	• Forced-Flow Salt Loops: dual-loop system at MIT reactor featuring a non-radioactive loop for baseline testing and a highly instrumented neutron irradiation loop to duplicate salt reactor conditions under active irradiation. This reactor can also assess new fuel concepts on a small scale. • Plasma Science and Fusion Center – Alcator C-Mod, concluded in 2016 was a high-field tokamak that informs modern HTS designs
North Carolina State University (NC State)	North Carolina	• PULSTAR reactor (1 MW, 2 MW upgrade pending) • NSUF partner • Neutron imaging, positron beam, diffraction, irradiation testing • Proposed new mixed-spectrum research reactor ($504M est.) • Oldest nuclear engineering program in the U.S.
Oregon State University (OSU)	Oregon	• OSTR TRIGA reactor (1.1 MW, pulsable to 3000 MW peak) • High-temperature test facility (1/4 scale MHTGR, 600 kW) • MASLWR thermal-hydraulics • Hydro-mechanical fuel test facility • NuScale E2 simulator • Glovebox for Experimental Liquid Sodium (GELS)
Pennsylvania State University	Pennsylvania	• Breazeale reactor (oldest U.S. university reactor, 70+ years) • Westinghouse eVinci research reactor planned for campus • Top-ranked nuclear engineering program

Table D-3. (Continued)

Institution	State	Key Nuclear R&D Facilities and Capabilities
Rensselaer Polytechnic Institute (RPI)	New York	• Gaerttner LINAC Center (100 MeV, 4×10^{13} n/sec) • Nuclear data for reactor design • TOF at 25 m/100 m • Lead slowing-down spectrometer (66 MT) • Walthousen Reactor Critical Facility • NuScale E2 Center • Radiation effects testing
University of Rochester	New York	• Laboratory for Laser Energetics • OMEGA lasers facility
Texas A&M University	Texas	• TRIGA and AGN reactors • RELLIS Energy Proving Ground (multi-developer test site) • MSR partnership with Abilene Christian University
University of Wisconsin	Wisconsin	• Spawned SHINE Technologies • Strong plasma physics and fusion research program

Appendix E. New York R&D Capabilities

The following table provides an initial list of the nuclear-relevant test facilities and areas of expertise at NYS institutions that are pertinent to advanced nuclear R&D. The information was obtained from publicly available sources, responses to the New York State Research and Development Authority's (NYSERDA) Request for Information, and discussions with the Technical Working Group.

Table E-1. New York State R&D Capabilities

Institution Name	Institution Type	Test Facilities	Nuclear Relevant Expertise Areas
Binghamton University	University	N/A	• Nonnuclear digital twins • AI
University at Buffalo	University	• Structural and Earthquake Simulator • Center of Excellence in Materials Informatics	• Numerical modeling and simulation for environmental and site characterization • Digital twin development • AI • Civil & structural engineering • Environmental engineering • Geotechnical analyses • Materials informatics • Advanced manufacturing
Brookhaven National Laboratory	DOE National Laboratory	• National Synchrotron Light Source (NSLS-II) • Electron-Ion Collider (EIC) (under construction) • Data library for neutronics modeling and U.S. Nuclear Data Program	• Characterization of materials and components under extreme environments (radiation, temperature, corrosive media, and strain) • Nuclear data measurements and evaluations of nuclear reactions, structure, and decay • Performance evaluation of advanced fuels • Reactor physics modeling • Reactor design and safety analysis • Thermal-hydraulic modeling • Safeguard evaluations • Techno-economic assessments
City College of NY (CCNY)	University	• HTGR flow loop	• HTGR flow and circulation • Microreactor transport

Table E-1. (continued)

Institution Name	Institution Type	Test Facilities	Nuclear Relevant Expertise Areas
Columbia University	University	• Fusion Research Center	• Center for Global Energy Policy, nuclear regulatory pathways and policies, including risk analysis and qualification requirements • Fusion Center of Excellence
Cornell University	University	• Cornell Center for Materials Research • Laboratory of Plasma Studies	• Materials science and engineering • High-density plasma physics, • Advanced diagnostics, • Computer simulation
GE Vernova	Private	• Advanced Research Center	• R&D for GE's technologies, including nuclear • Materials testing and characterization • Nuclear materials development • Power generation equipment design optimization and technology advancement
Naval Nuclear Laboratory – Knolls and Kesselring sites	NNPP Laboratory	• Knolls Site: Laboratory facilities including Radioactive Materials Laboratory, testing, design, and remote fleet support • Kesselring Site: Submarine 8th Generation (S8G) nuclear-powered submarine prototype for technology development and naval training	• Materials performance testing and characterization for design and production • Corrosion assessment • Post-irradiation examination • Robotics for PIE • Failure Analysis • Thermal hydraulic experiments • Fuel and poison development • Cladding testing • Design optimization to improve safety and capability • Nondestructive testing development for manufacturing • Fleet support • Operator training simulation development

Table E-1. (continued)

Institution Name	Institution Type	Test Facilities	Nuclear Relevant Expertise Areas
Rensselaer Polytechnic Institute	University	• RPI's Gaerttner LINAC Center • Center for Smart Convergent Manufacturing Systems (CSCMS) • 3D printing • Nano-Nuclear and Energy Materials Laboratory • AI Multiprocessing Optimized Systems • Environmentally controlled glovebox for corrosion testing • Plasma Dynamics Laboratory	• AI/ML for anomaly detection, predictive analytics, process monitoring, manufacturing • Manufacturing ceramic and metallic fuels for Gen II+ and Gen IV • Digital twins • Robotics and automation • Additive manufacturing • Simulation-driven analysis of radiation effects and component performance • Multiphysics modeling tools • Radiation effects on structural materials, shielding systems, and electronic components • Thermal-mechanical property characterization of nuclear materials • Fuel cycle and fabrication • Source-term analysis
Rochester Institute of Technology	University	• Brinkman Machine Tools and Manufacturing Laboratory • Intelligent Lab of Power and Manufacturing (ILPM) • AMPrint Center Lab (3D printing, including metals) • Construction Materials Laboratory • Center for Imaging Science	• Advanced manufacturing • 3D Printing, including metals • Intelligent manufacturing • Sustainable manufacturing • Modeling and simulation of materials and component behavior • Drone and remote sensing for site characterization • Optics and photonics
State University of New York at Oswego	University	• N/A	• Software engineering focused on control and safety systems in nuclear facility management • Local industry integration with nuclear power plants

Table E-1. (continued)

Institution Name	Institution Type	Test Facilities	Nuclear Relevant Expertise Areas
Stony Brook University	University	• Engineered Microstructures and Radiation Effects Laboratory • Post-irradiation Examination and Research Laboratory • Quantitative Analysis and Refractory Fabrication Laboratory • Fracture and Creep at Elevated Temperatures Laboratory • Engineered Metallic Nanostructures Laboratory	• High-temperature alloys, ceramics and composites • Materials for extreme environments (i.e., fission and fusion) • Nuclear fuels • Societal and environmental impacts of waste
University at Albany	University	• Ion Beam Lab	• Atmospheric and plume modeling • Water and air quality monitoring • Simulating natural radiation damage of materials • Radiation hardening
USMA (West Point)	Military Academy	• Photonics Research Center	• National security • Applied radiation physics

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Audrey Zibelman, Chair | Doreen M. Harris, President and CEO

New York State Department of Public Service
Rory M. Christian, Chair and CEO