# Foreword

## Special issue on the U.S. Department of Energy Microreactor Program

*Guest Editors*

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With pleasure, we introduce this *Nuclear Technology* special issue, which focuses on the U.S. Department of Energy, Office of Nuclear Energy (DOE-NE) Microreactor Program and associated research and development (R&D) activities. Led by Idaho National Laboratory, the DOE-NE Microreactor Program is one of four national advanced reactor campaigns under the Office of Nuclear Reactor Deployment's Advanced Reactor Technologies umbrella. The other three national advanced reactor campaigns focus on molten salt, high-temperature gas, and fast reactor concepts, providing a robust portfolio of national laboratory and university expertise and R&D infrastructure to enable and accelerate commercial deployment of advanced reactor (generally, non-light-water–cooled) concepts.

This special issue of *Nuclear Technology* focuses on the cross-cutting research and development and technology information generated by a variety of organizations under the DOE-NE Microreactor Program. Its publication as an open access issue is intended to allow broad access to research organizations, industry, government entities, and researchers for open discussion of the latest nuclear technology and the development of a new research direction. The scope of the issue includes the following topics: experimental thermal hydraulics, modeling, verification and validation studies, neutronics and criticality, techno-economic analysis, market analysis, advanced materials and manufacturing, advanced moderators, instrumentation and sensors, autonomous control, and industrial applications.

The DOE-NE Microreactor Program was officially established[a] in the fiscal year (FY) 2019 to support R&D for technologies related to the development, demonstration, and deployment of low-power, rapidly deployable fission reactors that can provide power and heat for decentralized generation in civilian, industrial, and defense energy sectors. The program conducts fundamental and applied R&D to de-risk the technology performance and manufacturing readiness of microreactors. R&D projects and work packages are selected to support concept-neutral technology maturation. The intent is to ensure that those concepts can be licensed and deployed by commercial entities to meet specific use case requirements. Meanwhile, the program also supports R&D that is specific to certain reactor technology groups (e.g., heat pipe reactors and gas-cooled reactors) to ensure relevancy and address the technological needs of commercial developers.

Microreactors are a class of very small modular reactors initially targeted for unconventional nuclear markets, but that could be useful in more mainstream applications as the technology matures. Such areas include remote communities, mining sites, and remote defense bases, at which locations the cost of conventional energy is high, as well as applications such as humanitarian assistance and disaster relief missions. These applications currently face economic and energy security challenges that can be uniquely addressed by this new class of innovative nuclear reactors. Microreactors are typically sized for generating approximately 20 to 30 MW(thermal), despite being defined in the Infrastructure Investment and Jobs Act of 2021 (H.R. 3684) as being capable of up to 50 MW(electric), which correlates to a thermal output of at least 150 MW(thermal). Sizes over approximately 20 to 30 MW(thermal) would face challenges in terms of fabrication, packaging, and shipping the reactor generally as a single unit—which are among the distinguishing characteristics that differentiate them from existing reactors and larger advanced reactors [e.g., small modular reactors (SMRs)]:

1. Factory fabricated. For the most part, microreactors are expected to be fully assembled in a central factory and shipped out to the operation site. This allows for shifting from large-scale, site-specific construction to repeatable factory construction, thus reducing the marginal cost of production and enabling rapid installation and subsequent operation.

[a] Some funding was also provided in FY2018 for microreactor development.

2. Transportable. Smaller designs are transportable even in their fully assembled configurations. Transportation by truck, rail, cargo ship, or air is envisioned.

3. Self-regulating. Simple design concepts can enable remote and semiautonomous microreactor operations that may significantly reduce the number of specialized operators required on-site. In addition, microreactors are designed to utilize inherent passive safety systems (e.g., natural circulation) to prevent overheating in the event of a loss of power.

Microreactor designs vary based on the coolant medium for extracting heat from the core for power conversion or process heat production. Depending on the end user and purpose of a given microreactor, various social, economic, environmental, or operational factors will influence the deployment of the reactor and, subsequently, the type of reactor chosen. Microreactor concepts currently under development include, but are not limited to, heat pipe–cooled, gas-cooled, liquid metal–cooled, and molten salt–cooled reactor technologies.

Because microreactors are novel and will possess unique technology features (e.g., autonomous operation, inherent safety, and full transportability), the need for R&D support is significant. The DOE national laboratory complex is uniquely positioned to fulfill those needs to support the industry and other stakeholders. This is why the DOE-NE Microreactor Program was established. This program performs R&D in areas specifically pertaining to civilian commercial microreactors—areas not being pursued in other government and industry technological development programs.

The vision for the Microreactor Program is that, through cross-cutting R&D and technology demonstration support, it will, by the year 2025, (a) achieve technological breakthroughs for key features of microreactors, (b) enable the successful maturation of multiple domestic commercial microreactor technologies, and (c) empower initial demonstrations of the next advanced reactor in the United States. This vision is supported by three key objectives:

1. Meet the critical cross-cutting R&D needs of existing developers that require national laboratory or university expertise/capabilities.

2. Develop R&D infrastructure to support design, development, demonstration, regulatory, and safety-related tests and collect data to validate modeling and simulation tools.

3. Develop advanced technology concepts that enable improved microreactor performance, economics, and integration.

The scope of the DOE-NE Microreactor Program encompasses the performance of R&D necessary to support the development, demonstration, and licensing of microreactors being developed by the private sector. This is accomplished through four technical focus areas, each encompassing a particular category of R&D while also retaining synergy with the other three areas to help fulfill the objectives of the Microreactor Program and realize the program's vision. High-level descriptions of the four technical focus areas are as follows:

1. *System integration and analyses*. This focus area identifies the needs, applications, and functional requirements for microreactors through market analysis, the results of which will be used to drive the future focus of the Microreactor Program toward improving the economics and viability of microreactors. It seeks to understand the microreactor design space by investigating innovative supporting concepts for microreactor technology and will perform regulatory research to help develop a regulatory basis for microreactor deployments.

2. *Technology maturation*. This focus area centers on the maturing of key technologies used for designing and developing microreactors. This includes research on advanced materials such as high-temperature moderators and structural materials, as well as on relevant legacy fuel; investigation of heat removal technologies such as heat pipes, gas cooling, heat exchangers, and power conversion; and the coupling of these components. Research into improved instrumentation and sensors and technology that supports intelligent or autonomous control is also considered.

3. *Demonstration capabilities*. This focus area centers on developing cross-cutting capabilities that can support a variety of microreactor technology demonstrations, primarily focusing on nonnuclear testing capabilities in support of thermomechanical testing, systems integration, controls testing, and applications. The program may also explore disruptive future microreactor supporting concepts and technologies within this focus area. The success of these concepts should represent significant improvements in terms of performance, safety, mobility, manufacturability, operations, deployment, and economics. Finally, within this technical focus area, the program will support investigations into the efficient fabrication and assembly of microreactors and the identification of other types of infrastructure needed to support demonstrations.

4. *Microreactor application*. This focus area centers on applied R&D supporting the evolution of fundamental technology to enhance the efficacy of microreactor operations. Examples include reactor-integrated partial or fully autonomous control systems, shielding systems, and technology associated with the factory fabrication and transportation of mobile/transportable concepts. Within this focus area, the Microreactor Program will design, construct, and operate a fully functional microreactor called the Microreactor Applications Research Validation and Evaluation (MARVEL) reactor. This project scope aims to provide a noncommercial demonstration of microreactor technology's potential. It is intended to accelerate commercial concepts' development, demonstration, and deployment through technology sharing, process development, and end user/stakeholder question resolution.

The DOE-NE Microreactor Program was created to facilitate and accelerate commercial demonstration and deployment of microreactors: small, factory-fabricated, transportable, self-regulating nuclear fission reactors. This *Nuclear Technology* special issue highlights the current R&D being conducted through this program. It is hoped that by sharing these topics, we can illuminate how the DOE complex is helping to empower this exciting and rapidly developing technology.

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