Modeling-Enhanced Innovations Trailblazing Nuclear Energy Reinvigoration (MEITNER)

Nuclear reactors generate about one-fifth of the electricity consumed in the United States. These plants are all conventional light water reactors (LWRs), a technology first deployed in the 1950's and improved upon steadily over time. The future of nuclear power in the United States is unclear; high costs and a rapidly changing grid—including growing renewable resources like wind and solar—present new challenges for existing and new nuclear plants.

For nuclear energy to contribute in the coming decades, the next generation of nuclear plants need to simultaneously achieve substantially lower capital costs, "walkaway" safe and secure operation, and dramatically shorter construction times. There are multiple new advanced reactor designs at various stages of development that may be able to attain these goals. For the potential of these reactors to be realized, a collection of new, innovative, technologies is needed.

The projects that comprise ARPA-E's MEITNER (Modeling-Enhanced Innovations Trailblazing Nuclear Energy Reinvigoration) program seek to develop innovative technologies that can help ensure advanced reactors have a path to commercial viability. These enabling technologies can establish the basis for a modern, domestic supply chain supporting nuclear technology. Projects will be improved and validated with advanced modeling and simulation tools, and project teams will have access to subject matter experts from nuclear and non-nuclear disciplines.

PROJECT DESCRIPTIONS

General Atomics – San Diego, CA

Improved Load Following in an Advanced Nuclear Plant Using a High-efficiency Brayton Cycle with Variable-speed Generator – $1,455,762

The General Atomics team seeks to develop a detailed and dynamic model of a nuclear power system using a helium-driven Brayton cycle engine (a type of heat engine). The team will use a variable-speed turbo-generator that will allow operators to control the plant temperature, as well as power electronics to connect the plant to the grid and provide rapid load-following, the important ability to increase or decrease power output based on demand. A quantitative assessment will be done on the "continuous" load following capability of the proposed system that would be capable of sharing the grid with substantial renewable resources like wind and solar.

General Atomics – San Diego, CA

Reducing Nuclear Plant Capital Costs Using Pre-cast Fiber-reinforced Concrete – $1,532,752

The General Atomics team seeks to develop a new construction method for concrete components used to build nuclear power plants. The team's approach will reduce cost by using pre-cast modules made of ultra-high-strength concrete in the factory before delivering to the building site. This saves time and allows quality control to be conducted in a standardized, efficient environment, creating significant opportunities for reducing construction time and capital cost.

HolosGen, LLC – Manassas Park, VA

Transportable Modular Reactor by Balance of Plant Elimination – $2,278,200

The HolosGen team seeks to develop a transportable, gas-cooled nuclear reactor with load following ability. By using a closed Brayton cycle engine with components connected directly to the reactor core, the team expects to simplify plant construction, leading to lower costs and shorter commissioning times. The reactor can be packaged in a standard shipping container, making it highly portable and reducing cost. The team aims to demonstrate the viability of this concept using multi-physics modeling and simulation tools validated by testing a non-nuclear prototype.

North Carolina State University – Raleigh, NC

Development of a Nearly Autonomous Management and Control System for Advanced Reactors – $3,386,834

The North Carolina State University team seeks to develop a highly automated management and control system for advanced nuclear reactors. The system will provide recommendations to plant operators and will use artificial intelligence and continuous data monitoring to predict future plant status through machine learning. Ultimately, the team seeks to enable a significantly smaller operational staff to manage the plant, assisted by instrumentation, operator training, and smart procedures, reducing overall operational cost.

State University of New York at Buffalo – Amherst, NY

Reducing Overnight Capital Cost of Advanced Reactors Using Equipment-based Seismic Protective Technologies – $1,443,635

The State University of New York at Buffalo team seeks to reduce nuclear power plant complexity and cost by integrating seismic protection systems into the development of advanced reactor buildings and their supporting structures. All nuclear power plants require seismic protection against earthquakes, made of large components that are typically custom-produced for each new plant construction. The team's approach aims to simplify plant design while enabling the use of standardized equipment that can be optimized for individual projects.

Terrestrial Energy USA, Inc. – New York, NY

Magnetically Suspended Canned Rotor Pumps for the Integral Molten Salt Reactor – $3,150,000

The Terrestrial Energy USA team will develop a novel, magnetically suspended circulation pump for molten salt reactors to improve plant performance, increase pump lifetime, and reduce cost. Compared to state-of-the-art cantilever type pumps that are used today in harsh environments, the team's next-generation molten salt pump is self-contained, does not require vulnerable mechanical seals, and is sturdy enough to meet the requirements set by the reactor core's seven-year operating lifetime. The project team will conduct extensive fabrication and performance testing of the pump during its ARPA-E project term.

Ultra Safe Nuclear Corporation – Seattle, WA

Technology Enabling Zero-EPZ Micro Modular Reactors – $2,350,000

The Ultra Safe Nuclear Corporation team will develop advanced technologies for gas-cooled reactors to increase their power density, thus allowing them to be smaller. Specifically, the team seeks to develop a high-performance moderator—which slows down neutrons so they can cause fission—to enable a compact reactor with enhanced safety features. Shrinking the reactor size enables greater versatility in deployment and reduced construction times and costs, both of which are especially important for smaller modular reactor systems that may be constructed wherever heat and power are needed.

University of Illinois at Urbana-Champaign – Champaign, IL

Enabling Load Following Capability in the Transatomic Power MSR – $774,879

The University of Illinois at Urbana-Champaign team seeks to develop a fuel processing system for molten salt reactors that allows these reactors to lower their output during times of reduced electricity demand. To enable this load following capability, the team will conduct simulations to determine how to remove unwanted fission by-products that slow reaction rates and, thus, energy production. By establishing a design for reprocessing the reactor's molten salt fuel, the team hopes to remove a major barrier to commercialization for molten salt reactors.

Westinghouse Electric Company, LLC – Cranberry Township, PA

Self-regulating, Solid Core Block "SCB" for an Inherently Safe Heat Pipe Reactor – $5,000,000

The Westinghouse Electric Company team will develop a self-regulating "solid core block" that employs solid materials (instead of bulk liquid flow or moving parts) to inherently regulate the reaction rate in a nuclear reactor. The nature of the design will allow the reactor to achieve safe shutdown without the need for additional controls, external power source, or operator intervention, enabling highly autonomous operation. The team will conduct modeling and simulation to demonstrate the SCB's self-regulating ability, with additional testing to validate modeling & simulation tools and confirm manufacturability.

Yellowstone Energy – Knoxville, TN

Reactivity Control Device for Advanced Reactors – $2,599,185

The Yellowstone Energy team seeks to develop a new reactor control technology to enhance passive safety and reduce costs for its molten salt reactor and other designs. Materials embedded in the control rods will vaporize at elevated temperatures, producing a vapor that captures neutrons and slows reaction rates, even in the absence of external controls. The team will use simulation tools to determine the effectiveness of the control device and conduct a techno-economic analysis at the plant level to determine cost effectiveness.