National lab partnerships speed nuclear deployment

Idaho National Laboratory is a leader in the effort

By Donna Kemp Spangler and Joel Hiller

"The tools of the academic designer are a piece of paper and a pencil with an eraser. If a mistake is made, it can always be erased and changed. If the practical-reactor designer errs, he wears the mistake around his neck; it cannot be erased. Everyone sees it."

Many in the nuclear community are familiar with this sentiment from Admiral Rickover. A generation of stagnation in the industry has underscored the truth of his words. But as economies around the world put a price on carbon emissions, there's a renewed sense of urgency to deploy clean energy technologies. This shifts the global balance of economic competitiveness, and it's clear that the best path forward for nuclear requires combining the agility of private innovators with the technology and capabilities of national laboratories.

The Department of Energy's Office of Nuclear Energy has recognized this and has been funding public-private partnerships at a record pace. A series of initiatives is making it easier for nuclear developers to tap into the capabilities and resources of the national laboratory system. It's about not just technology assistance but also helping catalyze innovative partnerships, advising on technical and strategic approaches for leadership, and helping stakeholders build necessary capacity.

Idaho National Laboratory is playing a leading role in these efforts as the lab's experts interact with policymakers, government and utility regulators, and private industry.

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During a Frontiers Project meeting in Anchorage, Alaska, a panel discussion was moderated by Christi Bell of the University of Alaska. The panel featured Alaska lieutenant governor Nancy Dalhstrom, Wilson Center Polar Institute chair Michael Sfraga, and INL associate laboratory director for nuclear science and technology Jess Gehin.

Emerging energy markets

Steven Aumeier, senior advisor of strategic programs at INL, sought to develop a holistic approach to these partnerships. He brought together a diverse group with expertise in social, financial, regulatory, business, and technological innovations around clean energy transitions.

"The lab is good at developing technology, but states undergoing energy transitions—driven by market influences for low-emission products and services—need a deeper understanding of all the considerations that go into energy decisions," he said.

The Emerging Energy Markets Analysis (EMA) Initiative represents the top minds in academia providing analysis and leadership to help states and communities make value-based energy decisions. "This is incredibly important," Aumeier continued, "as decisions made today will have a cost for decades to come."

EMA partners include the University of Alaska–Anchorage Business Enterprise Institute, the University of Michigan, the University of Wyoming, Massachusetts Institute of Technology, the Energy Policy Institute at Boise State University, and, most recently, the University of Utah.

EMA focuses on providing tools and information about clean energy transitions to communities

INL representatives visited Anchorage, Alaska, to strengthen cooperative relationships and discuss potential uses for nuclear energy.

so they can better understand choices that might include nuclear. A companion effort, the Frontiers Initiative, builds partnerships that lead to broader adoption and acceptance of advanced nuclear energy. The Frontiers approach is based on helping states on the cusp of deploying advanced reactors demonstrate leadership in low-emission manufacturing, which ultimately helps advance the country's national security and economic security interests.

In the three years since these initiatives were launched, both EMA and Frontiers have been influential partners to several entities.

The WEA

In May 2022, the Wyoming Energy Authority (WEA) and INL signed a memorandum of understanding, agreeing to collaborate on the research, development, demonstration, and deployment of advanced nuclear technologies, including innovations that harness nuclear energy for industry applications.

This MOU led to INL assisting the state with capacity building and strategic development, which helped the WEA efficiently engage the nuclear energy industry and develop its Nuclear Energy Strategic Framework.

Marcio Paes Barreto, director of industrial development for the WEA, believes the resources provided by EMA were instrumental in the development of Wyoming's nuclear energy strategy. "The report and data provided by EMA helped me to stand up our strategic framework and continue [to be] an important reference to translate knowledge into practical actions," he said.

This approach is well represented by two projects that received support from the first round of investment from Wyoming's Energy Matching Funds (EMF) program, which awards funds to projects that aim to reduce the state's industrial emissions. In addition to supporting a nuclear energy–related project, the funds also will advance the University of Wyoming's CarbonSAFE Project.

Industry partnerships

Wyoming's strategic framework, with assistance of the private sector and national laboratory partners, paved the way for the state to build a strategic relationship with top microreactor vendor BWX Technologies. The Lynchburg, Va.–based company received $9.9 million from the EMF program to assess the viability of deploying small-scale nuclear reactors in Wyoming. This will be done in two phases, with BWXT leveraging its existing cost-shared partnership under the DOE's Advanced Reactor Demonstration Program (ARDP).

"BWXT sees great value in public-private partnerships," said Erik Nygaard, the company's director of product development. "The vast majority of future commercial nuclear projects that we see require collaboration. Efforts like the INL-led Frontiers Initiative are key to bringing organizations together so they can each use their strengths to develop a successful project from the very beginning."

Tata Chemicals Soda Ash Partners, a subsidiary of the multinational Tata Chemicals, has also announced a partnership with BWXT to study the use of microreactors to power its trona facility near Green River, Wyo., making it the first company in the United States to pursue small-scale industrial nuclear power.

L&H Industrial is another company working with the state of Wyoming to build a nuclear industry. "Our collaboration with INL, Frontiers WEA, and BWXT has been transformative for L&H Industrial and created Evercore Energy," said L&H Industrial president Mike Wandler. "Their expertise empowers and activates Wyoming entrepreneurs like us to confidently and responsibly venture into the nuclear energy sector."

Paes Barreto said these partnerships are important because he sees scientists and politicians differ on interest and allocation of research and development resources. "Our constant collaboration with Steve Aumeier from the INL is enabling us, via an

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INL researchers visited L&H Industrial to discuss the company's interest in nuclear energy for decarbonizing industrial processes.

evidenced-based approach, to diminish the gap between research and practical problem-solving by creating private sector–led partnerships with the public sector—government and institutions of higher education," he said.

Capacity building

Universities play a key role in providing the nuclear industry with well-qualified candidates.

This fall, the University of Wyoming began offering Fundamentals of Nuclear Energy, a new course that drew more than 30 students. Tara Righetti, codirector of the Nuclear Energy Research Center, said the course will give the future energy workforce an understanding of the basic principles of nuclear energy. Most of the workers at nuclear plants are not nuclear engineers but have other skills and training that contribute to the operation of the reactor.


Righetti

"The interest in this class has been high," Righetti said, "not just [among] engineers but students studying social sciences, environment, and other disciplines."

UW is rapidly growing its nuclear energy research portfolio with support from lab, academic, and industry partners. The Wyoming legislature, INL, and the Nuclear Regulatory Commission's Office of Nuclear Regulatory Research have partnered with the university to build capacity for the nuclear industry.

In addition, the WEA's efforts in nuclear energy industrial development involve UW's Research and Economic Development Division (REDD).

Curtis Nathan Biggs, executive director of REDD Industry & Strategic Partnerships (ISP), highlighted the recent expansion of UW's responsiveness to traditional and emerging energy industries. "UW's creation of the ISP office is timely in furthering collaboration and service with these nuclear developments in our state," he said. "These partnerships are opening doors to faculty experts, sponsored research, curricular advances, and student-applied learning and workforce experiences."


Biggs

The Wyoming Innovation Partnership (WIP) is an initiative from Wyoming Gov. Mark Gordon to modernize and focus the state's efforts to develop a resilient workforce through innovative solutions. The partnership involves UW, community colleges, the Wyoming Business Council, and the Department of Workforce Services.

Biggs explained, "Statewide, Wyoming's community colleges are instrumental in such collaborations. The WIP connects our institutions, key state agencies, and industry to help drive economic growth in core sectors of our state to include energy with nuclear [as] one of the focus areas."

Interstate collaboration

Recognizing that states can benefit from each other to learn best practices, the National Association of Regulated Utility Commissioners and the National Association of State Energy Officials kicked off the Advanced Nuclear Energy State Collaborative in February. The effort is supported by the DOE, and the national laboratories play a role in this collaboration.

Energy offices from 23 states have joined the collaborative, which also includes senior public service commission members and commerce executives focused on helping each other build capacities and outreach capabilities as they plan for the deployment of advanced nuclear energy in their states. DOE-NE is funding the collaborative for the next three years.

States looking to deploy advanced nuclear reactors—"first-mover" states, which include Idaho, Wyoming, Alaska, and Utah—turn to the Frontiers Initiative to help shape policy to secure U.S. leadership in the new economic frontier. That expertise helped the state of Alaska adopt regulations to streamline the regulatory process for communities interested in microreactors. The U.S. Air Force is seeking to pilot its first microreactor at Eielson Air Force Base near Fairbanks, anticipated to be operational in 2027.

Patrick Millin, state energy program manager from the WEA, is optimistic that the Advanced Nuclear State Collaborative will allow Wyoming to support the deployment of new nuclear generation through increased understanding of policy and regulatory considerations shared by members of the collaborative.

Advancing knowledge, facilitating innovation

INL-funded studies, conducted through a partnership with university experts and INL researchers from the EMA team, have received national attention.

Kathy Araújo, professor at Boise State University and director of the Energy Policy Institute, the policy arm for the Center for Advanced Energy Studies, collaborated with INL nuclear economist David Shropshire on the article "A Meta-Level Framework for Evaluating Resilience in Net-Zero Carbon Power Systems with

Extreme Weather Events in the United States." Published in the peer-reviewed open access journal *Energies*, it has been widely applauded in industry circles.


Araújo

"We're in a pivotal time for making choices about energy and related infrastructure. What used to be 100-year events are now happening regularly, and planning can be a game changer if approaches are used that account for local community priorities, advances in knowledge, and changing conditions," Araújo said. "The resilience framework provides a flexible way for decision makers to track information inputs alongside community engagement processes. It can be used to track any fuel or energy option that is of interest for a community, accounting for qualitative priorities and integration that may often be missed in conventional analysis."

Other collaborations with EMA have led to numerous grants funded by DOE-NE's Nuclear Energy University Program to produce white papers, such as one presented at the Arctic Circle Assembly in Iceland in October.

"Opening New Arctic Frontiers in Low-Carbon Economic Development" focuses on the latest advances in low-carbon technologies in today's marketplace and evaluates the challenges of implementation, including social acceptance and community readiness and other considerations.

Other studies include the following:

- An analysis of microreactor applications in U.S. markets by researchers from INL and university partners concluded that there is a high market potential for microreactors in states with energy-intensive industries, nuclear-friendly laws, and widespread social acceptance. (*Microreactor Applications in U.S. Markets: Evaluation of State-Level Legal, Regulatory, Economic and Technology Implications*; doi.org/10.2172/1964093)
- A University of Michigan–led study showed market advantages of charging electric heavy-duty vehicles with small modular nuclear reactors. ("A Techno-Economic Analysis of Distributed Energy Resources versus Wholesale Electricity Purchases for Fueling Decarbonized Heavy Duty Vehicles"; doi.org/10.1016/j.apenergy.2022.119460)
- A UW-led survey of 2,800 people in selected areas of Alaska and Wyoming asked people about their perception of nuclear energy and the value choices they make based on selective models.
- An MIT-EMA study on microreactor costs in Alaskan markets showed under what circumstances such systems would be competitive with existing technologies and assessed elements of value. ("The Value of Nuclear Microreactors in Providing Heat and Electricity to Alaskan Communities"; CEEPR WP-2021-018)

Public-private partnerships

The Frontiers Initiative has collaborated with the Atlantic Council's Nuclear Energy Policy Initiative, a Washington, D.C., think tank, to convene and connect major stakeholders for thought leadership, visibility, and influence.

In September, INL and the Atlantic Council executed a Frontiers project in Jackson, Wyo., which drew regional, national, and global stakeholders from the policy, finance, and energy-intense industries and the nuclear technology and regulatory arenas.

In October, another Frontiers project gathering was held in Anchorage, Alaska. One panel discussion was about the economic and national security imperatives for leadership in low-emissions industries moderated by Julia Nesheiwat, the Atlantic Council's vice president for policy and insights and former U.S. Homeland Security advisor. The EMA's Christi Bell moderated another panel about arctic energy-enabled economic development featuring corporate leaders in manufacturing.

In the three years since the EMA and Frontiers efforts launched, many important public-private partnerships have been created. "I believe we've done some very important work," Aumeier said.

GAIN an advantage

In 2015, as states were beginning to express interest in new nuclear energy, the Obama administration announced a public-private partnership between the nuclear energy industry and the nation's national laboratories to accelerate the commercialization of advanced nuclear technologies.

The Gateway for Accelerated Innovation in Nuclear (GAIN) was launched to connect the nuclear industry with access to the technical, regulatory, and financial support necessary to move innovative nuclear technologies toward commercialization. The growing interest in new nuclear innovations has led numerous states to consider nuclear energy.

State leaders have turned to GAIN for unbiased information about the applications and benefits of nuclear energy.

"As nuclear designs approach commercial markets, GAIN's audience has expanded to include the regions,

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states, and communities where these technologies will be considered and built," said Christine King, director of GAIN. "Our mission is the same, but the audience is expanding."


King

GAIN's approach is simple and direct: only go where invited, show up and listen, and commit to multiple engagements. "We aren't selling nuclear, but informing and demystifying nuclear, and sharing what we learned," King said. "Each state is at a different level of nuclear readiness."

GAIN keeps a finger on the pulse on what's happening in different regions by tracking legislation and making it available in a nuclear regulatory dashboard. This dashboard provides a one-stop resource for the public to get an understanding of what states are doing to advance nuclear energy. It does not provide any analysis.

In the past two years, 37 bills have passed in 23 states related to nuclear energy. Those bills range from removing moratoriums on nuclear power plants to creating task forces to study the feasibility of nuclear energy.

GAIN has developed resources to help states and communities learn more about nuclear power. For instance, GAIN's Milestones in Advanced Nuclear website provides a snapshot of progress made in the nuclear industry. Also available to interested stakeholders is a resource kit with links to reputable resources on advanced nuclear energy ranging from technology and regulation to policy decisions other states have made.

Partnerships with states

Kentucky: Since 2021, GAIN has worked with state officials in Kentucky to facilitate conversations with utilities, industry, and elected officials about advanced nuclear development in a largely coal-producing state. Specifically, GAIN developed a series of webinars with the Kentucky Office of Energy Policy. Those conversations sparked interest with the state's largest utility, the Kentucky Utilities Company, which is exploring advanced nuclear at its Ghent Generating Station, its largest coal-fired power plant.

"I believe our partnership with GAIN set the stage for important pathways that will result in lasting benefits for Kentuckians," said Kenya Stump, executive director of Kentucky's Office of Energy Policy.

Colorado: GAIN has been working in northwestern Colorado—including engaging with former state senator Bob Rankin—by spending the past year and a half meeting with communities, the Colorado Energy Office, county commissioners, utilities, and universities. GAIN testified before the Colorado House Energy and Environment Committee in February to explain how advanced nuclear could help the state meet its clean energy goals while also addressing job losses. That led to the first nuclear bill being introduced in the Colorado legislature earlier this year. The bill directs the Colorado Energy Office to study the feasibility and viability of various energy options, including advanced nuclear, in northwestern and southeastern Colorado.

"Thanks to GAIN, we have a bill on the books in Colorado," said Rankin. "GAIN got us started and stayed the course."

Arizona: In St. Johns, Ariz., GAIN has partnered with the Salt River Project, the utility that runs the coal-fired Coronado Generating Station, on a repurposing study. In September, that study was discussed at a community meeting that drew a large crowd.

"Overall, our work was well received by St. Johns," King said. "City officials indicated that it has been pivotal to changing the conversation with Salt River Project and resulted in a commitment from the utility to develop a repurposing plan for this site."

At the meeting, INL researchers spoke about a coal-to-nuclear study that identified 90-plus retired coal plants that qualified for potential advanced nuclear reactors based on workforce, transmission lines, access to the site, and other factors.

For the study, researchers at Idaho, Argonne, and Oak Ridge National Laboratories evaluated 157 retired coal sites and 237 operating sites and found that 80 percent have the basic characteristics needed to be considered amenable to host an advanced reactor.

"With the accelerated retirement of coal, the partnership of coal and nuclear might be the early adopter market we need to replace firm power which acts like the shock absorber in our grid," King said.


Worrall

Andy Worrall, head of the Integrated Fuel Cycle section at ORNL and deputy director of GAIN, said GAIN's success is largely due to having resources from other laboratories.

"The U.S. national laboratories have a broad set of expertise, experience, and facilities that have supported U.S. national programs for decades. Using these existing capabilities to support the U.S. industry in a timely manner, rather than having to build new capabilities

from the ground up, has been invaluable. These capabilities have supported existing utilities and vendors, as well as the supply chain and startup companies, and the end users of nuclear such as chemical companies."

Hussein Khalil, nuclear engineering research director at Argonne and GAIN senior advisor, agrees.


Khalil

"The public-private partnership GAIN has established leverages leading-edge capabilities and experimental facilities of our national labs to advance designs and technologies for innovative nuclear energy systems," he noted. "Demonstration and implementation of advanced systems is already underway and will be essential for increased availability and affordability of clean energy in the U.S. and around the world."

National Reactor Innovation Center

To foster the DOE's renewed emphasis on collaboration, DOE-NE established NRIC in 2019. Over the past four years, NRIC has engaged with developers around the country as they prepare to test their reactor designs. While other INL efforts focus on engaging nuclear-curious communities and potential stakeholders, NRIC's primary role is technology demonstrations. It maintains close relationships with multiple nuclear technology developers to provide direct support for testing.

"NRIC recognizes the unique role the national lab system can play in enabling private industry to move closer to their commercialization goals," said acting director Brad Tomer. "The sooner we can get new nuclear technologies tested, the faster our partners can build and operate, and the better it is for the world."

Central to these efforts are two new test beds for hosting fueled experiments at INL. The Demonstration of Microreactor Experiments (DOME) test bed will be in the containment dome of the decommissioned Experimental Breeder Reactor-II and will host microreactor tests generating up to 20 MWt. The Laboratory for Operation and Testing in the U.S. (LOTUS) test bed, located in the former Zero Power Physics Reactor facility, will host smaller experiments (up to 500 kWt), including those that require high-security materials.

NRIC also fills gaps in the national lab complex's experimental infrastructure by constructing the Molten Salt Thermal Physical Examination Capability, which will provide industry partners with a location to test irradiated fuel salts. The center has constructed and is operating the Helium Component Test Facility to test high-temperature gas reactor components.


The containment dome from the decommissioned Experimental Breeder Reactor-II will serve as a new test bed for experimental reactors.

In addition to the physical infrastructure, NRIC is developing a virtual test bed where industry partners can access and run modeling and simulation tools critical to moving reactor testing forward quickly.

As part of their outreach, NRIC has organized and hosted a series of webinars aimed at bringing together nuclear developers, community stakeholders, utilities, and academia. These Tech Talks have provided information on topics such as maritime nuclear, quality assurance, community support, modeling/simulation, and environmental analysis.

NRIC also engages with community leaders around the country to discuss energy needs and how advanced nuclear might help keep energy prices low while delivering abundant, carbon-free electricity and heat. A prime case is Alaska, where discussions have taken place with leaders of remote communities where diesel is the main energy source, with high transportation costs reflected in consumers' utility bills.

Advanced Reactor Demonstration Program

Under the DOE-NE's ARDP, cost-shared funding awards are helping innovators advance technology toward commercialization. NRIC supports these developers with a wide variety of technology development activities, including the following.

X-energy: In support of the Xe-100 high-temperature, gas-cooled reactor, NRIC is providing modeling and simulation work as well as safety analysis and fuel performance research.

TerraPower: To support the Natrium reactor project,

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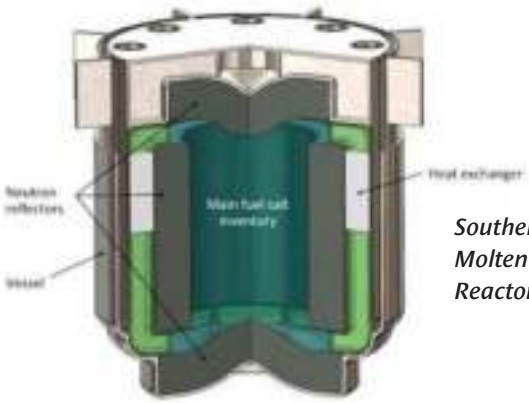
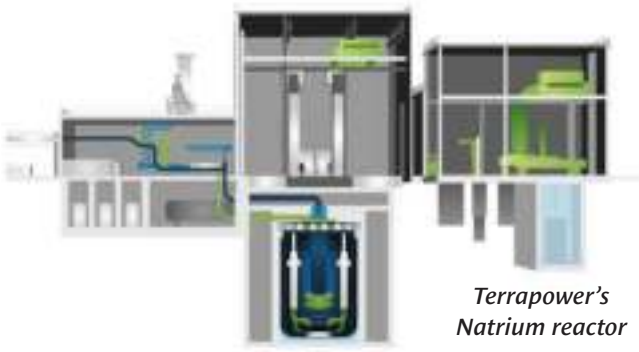
X-energy's XE-100 reactor



Southern Company's Molten Chloride Reactor Experiment



Terrapower's Natrium reactor

NRIC researchers at INL are performing fabrication and irradiation testing of the reactor's advanced fuel form and have also completed final design for fuel qualification testing.

Southern Company: The Molten Chloride Reactor Experiment, planned to be the world's first fast-spectrum fission reactor experiment, will be installed in the LOTUS test bed. INL researchers have begun synthesizing fuel salts to establish the capability to fuel the experiment.

Advanced construction

With construction timelines and costs a major concern with new nuclear builds, NRIC has partnered with GE Hitachi to demonstrate three high-impact technologies in a nuclear context:

- Vertical shaft excavation, a technique adopted from the construction industry to reduce excavation and backfill.
- Modular steel-concrete composite wall systems that provide strength and durability to streamline construction.
- Digital twins supported by embedded sensors and integrating monitoring into operations to reduce safety concerns and maintenance costs.

Nationwide efforts to expand the use of nuclear energy require not only technical know-how and successful demonstrations but also significant buy-in from stakeholders at every level of society. The unique space nuclear occupies in the public consciousness means decision makers need a frank exchange of ideas to advance understanding of nuclear energy along with other clean energy sources.

The new wave of partnerships between public and private organizations is laying the foundation for a clean energy future. As cooperation increases between the national labs, nuclear innovators, utilities, and communities, rapidly deploying new nuclear will help meet carbon reduction goals.

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About Idaho National Laboratory

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development and performs research in each of the DOE's strategic goal areas: energy, national security, science, and the environment. For more information, visit inl.gov. Follow us on social media: X (formerly Twitter), Facebook, Instagram, and LinkedIn.