THIRD WAY

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The Global Race for Advanced Nuclear Is On

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Takeaways

- In 2021, Third Way, Pillsbury Law, ClearPath, Nuclear Innovation Alliance, and Clean Air Task Force unveiled a map of planned and active advanced nuclear demonstration projects around the world, showing clear evidence that advanced reactor technologies are not merely conceptual.

- Since the 2021 map, there has been marked progress in advanced nuclear demonstrations across the globe. Across North America and Europe, many new projects have emerged and existing projects have reached new milestones in siting, licensing, construction, and offtake arrangements. We also saw new advanced reactor projects take shape on the African continent in countries like Ghana and Rwanda.

- At the same time, China and Russia *continue to lead in terms of licensing, constructing, and operating advanced reactors*.

- It is clear that the success of advanced reactor demonstration and deployment is directly linked to government funding and support. In the United States, this means added urgency on federal support for commercializing advanced nuclear at home: expeditiously standing up fuel supply, modernizing the licensing processes, ensuring that our vanguard demonstrations are able to cross the finish line as quickly as possible, and providing financing tools to facilitate the build-out of these technologies at scale.

In 2021, a coalition of organizations—Third Way, Pillsbury Law, ClearPath, Nuclear Innovation Alliance, and Clean Air Task Force—released an interactive map of advanced nuclear demonstration projects around the world at various stages of completion. Under the title, "Turning the Corner," the map and narrative descriptions of progress on global deployment were intended to show that advanced nuclear technologies are very real—that we are now at the cusp of witnessing the commercialization of advanced reactors worldwide.

In just a few short years, there has been considerable progress on this front, with new projects emerging and ongoing projects either advancing towards or reaching completion. And more recently, commercial deals and offtake agreements for these technologies are starting to emerge (see the Google-Kairos agreement and the Amazon deal with X-energy). These developments have

prompted the coalition to update the map, revealing both growing interest and movement in advanced reactor technologies globally.

Key Takeaways from this Update

The original 2021 map showed more than 30 commercial-scale demonstrations internationally, including details on technology types, vendors, sites, and estimated completion dates. The 2024 update tracks nearly 80 advanced nuclear demonstration projects, but these numbers do not tell the full story.

There has been significant progress in North America on advanced nuclear projects.

Although developments on advanced nuclear projects are occurring around the world, there has been pronounced progress in North American projects that is now resulting in *landmark commercial deals* to spur advanced reactor deployment, such as the Google-Kairos agreement and Amazon's $500 million investment into X-energy. New advanced reactor demonstrations have been proposed and announced in both the United States and Canada over the last few years, and a number of ongoing projects identified back in 2021 have steadily advanced in maturity—achieving new milestones in development and licensing as they move towards construction, operation, and commercial entry. In late December 2023, the US Nuclear Regulatory Commission (NRC) approved a construction permit for Kairos Power's Hermes Demonstration Reactor in Oak Ridge, Tennessee—the first non-light water reactor approved for construction in the US in over half a century—with Kairos starting construction activities in July 2024. Additionally, in September 2024, Natura Resources also received its construction permit for its research reactor project at Abilene Christian University. Since 2021, TerraPower has sited its Natrium demonstration in Kemmerer, Wyoming, submitted its construction permit application in March 2024, and broke ground months later. There has been similar progress in Canadian advanced nuclear projects: Ontario Power Generation (OPG) selected the GE-Hitachi BWRX-300 design for its Darlington new build project, with the first phase of site preparation activities completed in June 2024 and current plans to begin construction activities as early as next year.

China and Russia are leading in constructing and operating advanced reactors.

The most advanced demonstrations globally are in Russia and China. These projects are the result of long-term government support and funding in both countries for the commercialization and deployment of advanced nuclear technologies.

Russia has long been a global leader in fast reactor technologies, having operated both commercial and test fast reactor units for decades. There is continuing progress on Russia's next generation fast neutron research reactor, MBIR, and Russia has new plans to deploy additional floating nuclear power plants (FNPP) to power mining and industrial operations in remote regions. Russia is also using domestic deployment to secure advanced reactor export opportunities in countries like Uzbekistan.

China has witnessed remarkable progress across a range of advanced nuclear technologies in just the last few years. Arguably, the headliner of these developments is China's high-temperature gas-cooled reactor project in Shidao Bay, which completed construction and started commercial operation *almost a year ago* in December 2023. This significant achievement may soon be followed up by entry into commercial service of China's sodium-cooled fast reactor project, which according to recent reports, began low-power operations in late 2023 with connection to the grid pending.

It is increasingly urgent that the US maintain robust federal support to build advanced nuclear projects to completion.

The intensifying global race to build and deploy advanced nuclear has not been lost to observers and experts. The Information Technology & Innovation Foundation (ITIF) released a landmark report in June 2024, *How Innovative is China in Nuclear Power?* In the ITIF report, it is estimated "that China likely stands *10 to 15 years ahead* of the United States in its ability to deploy fourth-generation nuclear reactors at scale." This is in no small part due to the Chinese government's consistent support and funding of advanced reactor deployment.

For the United States, the advanced nuclear competition has more than just commercial and clean energy implications, but massive significance for the country's geopolitical and national security interests. Therefore, despite recent wins to secure fuel supply and modernize regulatory pathways, if the United States wants to be competitive in the advanced reactor space, it is absolutely vital that the federal government keeps its "foot on the pedal" and continues robust support for advanced nuclear commercialization. This means expeditious execution of federal fuel programs, maximizing efficiencies in the licensing processes, meeting the needs of the leading advanced reactor demonstrations to completion, and proactively seeking strategies to deploy these technologies at fleet scale. In light of the US Department of Energy's projections that the US will need 200 GW of additional nuclear capacity by 2050, these actions are critical.

The interactive map below shows locations and details of projects underway globally. These details can also be viewed in this chart.

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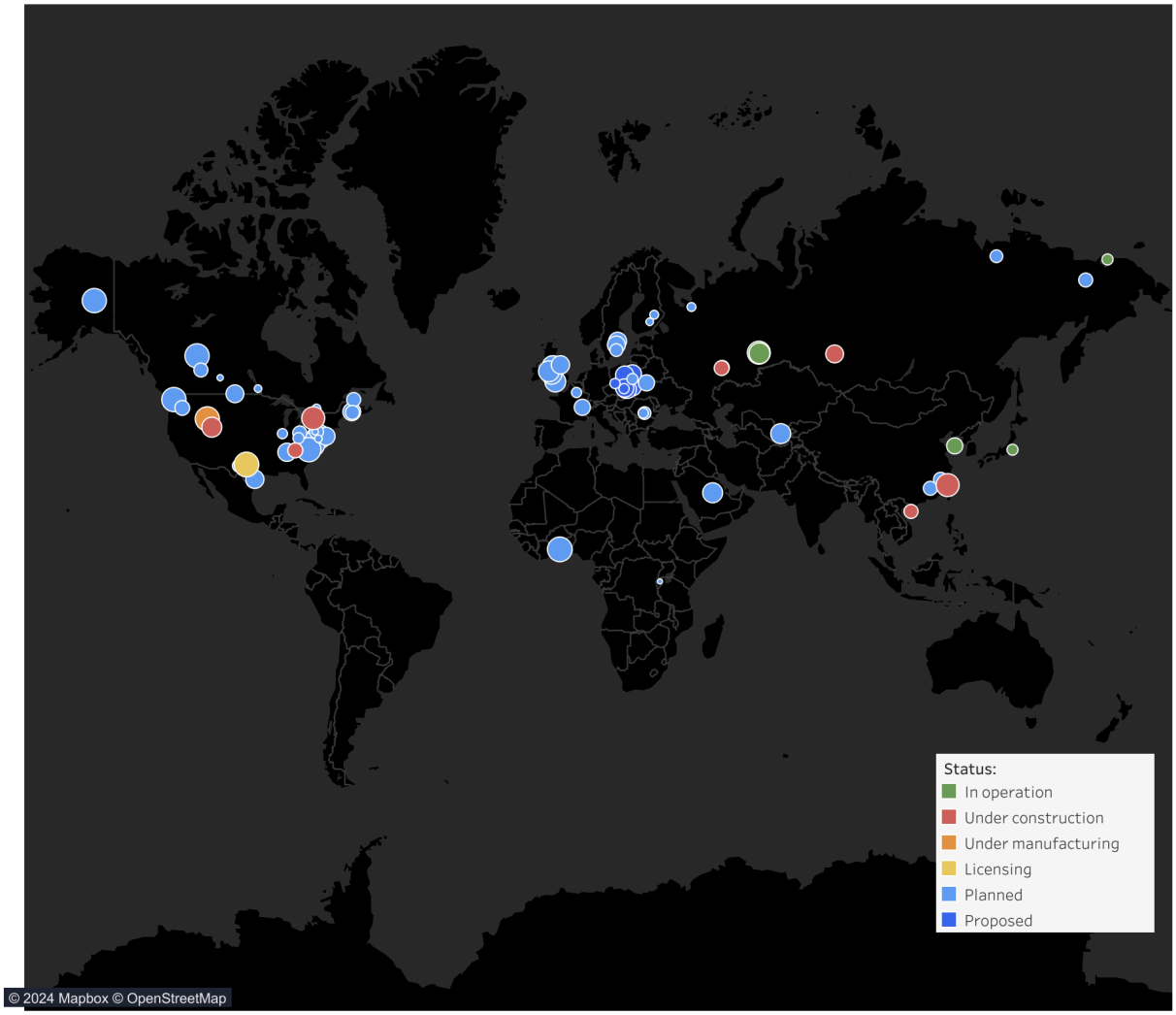
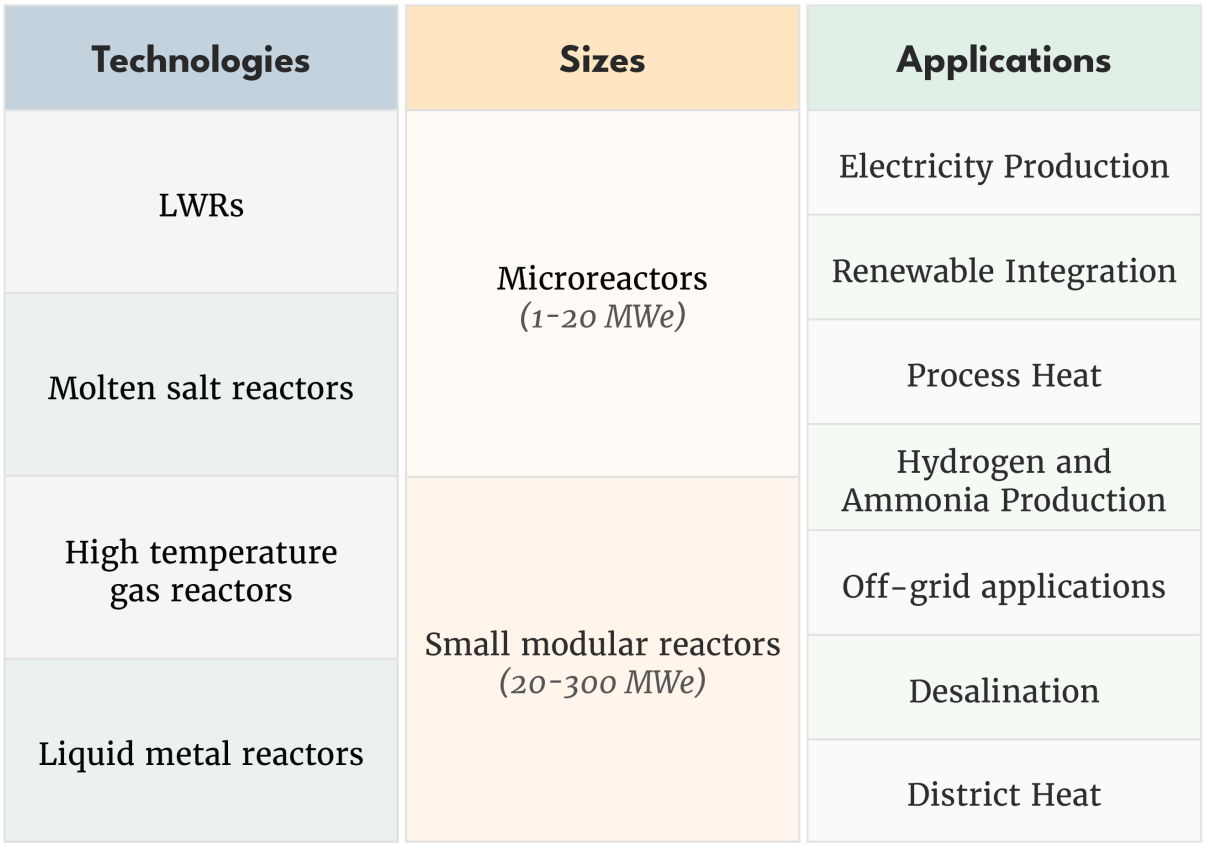
2024 Global Advanced Nuclear Demonstrations Map



Notable Updates Since 2021

The next generation of reactors, collectively referred to here as "advanced reactors," represent a diversity of sizes, technologies, and potential applications. Nevertheless, within this broad spectrum, there are common profiles and characteristics: enhanced passive safety, uses beyond electricity generation, smaller footprints, and flexibility in deployment. Perhaps most importantly, these reactors are designed to be mass deployed and help minimize construction risk through modularity, design simplifications, and significant manufactured content. By minimizing construction risk and lowering timeframes for deployment, advanced reactors can quickly achieve cost reductions and facilitate progress through learning curves.

Advanced Reactor Types, Sizes, and Applications



Source: Pillsbury Winthrop Shaw Pittman

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The following is an outline of notable updates and developments in advanced reactor projects around the world since the 2021 map:

United States

In a span of a few years, there has been significant progress in advanced reactor demonstration projects in the US, including those projects initiated by the US Department of Energy's (DOE) Advanced Reactor Demonstration Program (ARDP), authorized under the Energy Act of 2020 and launched by DOE in May 2020. For example, TerraPower's Natrium reactor, an ARDP Pathway 1 demonstration, was officially sited in Kemmerer, Wyoming in November 2021. More recently, TerraPower submitted its construction permit application for the Kemmerer project in May 2024, to be followed by a formal groundbreaking for the reactor demonstration in June 2024. X-energy, the other ARDP Pathway 1 awardee, similarly broke ground on its Oak Ridge fuel fabrication facility in October 2022. X-energy also entered into a commercial partnership with Dow Chemical Company, signing a joint development agreement in March 2023 and a few months later, announcing Dow's

Seadrift, Texas site as the location to install its Xe-100 high-temperature gas-cooled reactor design. In October 2024, Amazon announced a $500 million investment in X-energy and signed an agreement with Energy Northwest to advance the deployment of the Xe-100 in the Pacific Northwest.

Kairos Power, also the recipient of an ARDP Risk Reduction award, received its construction permit from the NRC and started construction of its Hermes reactor in Oak Ridge. In addition, they also are expected to receive their construction permit for their "Hermes 2" test reactors, which will demonstrate electricity production. Due to these projects and their Manufacturing Development Campus in Albuquerque, NM, Kairos recently announced a partnership with Google for up to 500 MW of Kairos reactors by 2035, which accelerates Kairos' first commercial facility to 2030.

There has been significant progress in other US advanced reactor projects, including DoD's mobile microreactor prototype (under Project Pele) which is being manufactured at BWXT's Lynchburg, Virginia facility and will be deployed at Idaho National Lab, where they have already broken ground at the test site. Abilene Christian University's Nuclear Energy eXperimental Testing (NEXT) Lab submitted an application for a construction permit for its molten salt research reactor project in 2022, and the construction permit was formally issued by the NRC in September 2024.

On top of progress in projects since 2021, plans and proposals for new demonstrations have emerged throughout the US. Below is a non-exhaustive list of new proposed and planned advanced nuclear demonstrations in the US that have been announced since the 2021 map:

- Besides the new Seadrift project in collaboration with Dow, X-energy also concluded an agreement with the Maryland Energy Administration to explore the viability of "repurposing a specific Maryland coal-fired electric generating facility with X-energy's Xe-100" in 2022.

- In addition to its Idaho National Laboratory demonstration project, Oklo signed an agreement with the Southern Ohio Diversification Initiative to deploy two Oklo plants in Southern Ohio and a letter of intent (LOI) with Diamondback Energy to provide power to Diamondback's operations in the Permian Basin. Moreover, in May 2024, Oklo signed an LOI with Wyoming Hyperscale to deliver up to 100 MWe to its data centers, as well as a pre-agreement with the data center colocation company, Equinix, to provide up to 500 MWe.

- In late 2023, Holtec International announced plans to develop and build two SMR units at the Palisades Nuclear Power Plant site, targeting 2026 for submission of its construction permit application and mid-2030 for commissioning.

- Penn State University and Westinghouse announced plans in 2022 to jointly explore siting of Westinghouse's eVinci microreactor "to address sustainable power needs from immediate use in large communities to decentralized remote applications."

- In September 2023, BWX Technologies began a two-year, two-phase contract with the Wyoming Energy Authority to explore the viability of its BWXT Advanced Nuclear Reactor (BANR)—developed in partnership with DOE through ARDP—to meet heat and power needs of industrial/mining activities within the state. In June 2024, BWXT announced that it was awarded the second phase of this contract.

- Major US utilities such as Duke and Dominion announced plans to develop SMRs on existing sites, with a proposed deployment of an SMR at the Belews Creek coal plant site and issuance of a request for proposals (RFP) for an SMR at the North Anna Power Station, respectively.

Canada

Arguably the most significant advanced nuclear development in Canada since the 2021 map was Ontario Power Generation's (OPG) decision to select GE-Hitachi's BWRX-300 for its SMR new build project at its Darlington site. According to reports, the first phase of site preparation activities concluded in June 2024, and OPG expects construction activities to start in 2025, and a target construction completion date for the first of four BWRX-300 units in 2028.

GE-Hitachi has also made headway in prospective markets elsewhere in Canada: in January 2024, GEH signed an agreement with SaskPower to advance SMR deployment in Saskatchewan using its BWRX-300 design. Months later in May 2024, possible locations for this SMR project were narrowed down to two sites near the city of Estevan.

Other US advanced nuclear vendors have also made progress in advancing projects throughout Canada. X-energy concluded an agreement with TransAlta to partner in a study to determine the feasibility of the Xe-100 as a solution to repurpose a fossil fuel power generation site in Alberta. In May 2022, Westinghouse signed an MOU with the Saskatchewan Research Council for the joint development of the eVinci microreactor for commercial and research applications in Saskatchewan. Approximately a year later in 2023, the Government of Saskatchewan announced $80 million in government funding to "support licensing and other work for the project, which is scheduled to be completed in 2029, subject to licensing and regulatory processes." ARC Clean Energy, with an ongoing project with New Brunswick Power to build its ARC-100 reactor at Point Lepreau, now has proposed projects to build its design at a planned green energy hub in the Port of Belledune and potential sites in Alberta through an MOU with Invest Alberta Corporation.

United Kingdom

Since the 2021 map, the Sunak Conservative Government reconstituted British Nuclear Fuels Limited (BNFL) under the moniker, Great British Nuclear (GBN). GBN announced a Small Modular Reactor (SMR) Competition—through which it would award billions of dollars in both public and

private investment to advance innovative reactor designs, and in October 2023, shortlisted six vendors to proceed to the next phase of this competition. In September 2024, GBN narrowed the list to four vendors—GE-Hitachi, Holtec, Rolls Royce SMR, and Westinghouse—to negotiate with GBN for contracts. The final investment decision is expected in 2029.

Following its victory in the July 2024 elections, the new Labour government remains openly committed to nuclear as part of its ambitions for the UK to become a clean energy superpower, stating its plans to complete Hinkley Point C and add new nuclear capacity through Sizewell C and SMRs.

There has been demonstrable progress in the UK's advanced nuclear development over the last few years, including completion of a site assessment review by Rolls-Royce SMR in 2022, narrowing a broader list of candidate sites down to four sites either on UK Nuclear Decommissioning Authority (NDA) land or land leased by NDA to a third party: Trawsfynydd, Sellafield, Wylfa, and Oldbury. In February 2024, an agreement was reached between Community Nuclear Power, Ltd. and Westinghouse Electric Company to deploy Westinghouse's AP300 design on a proposed green industrial hub site in North Tees near Stockton.

Russia

Russia is continuing its current global leadership in fast neutron reactors, leveraging its considerable experience in constructing and operating a range of fast reactor types. Russia's MBIR test reactor project, under construction at the Research Institute of Atomic Reactors (RIAR) site in Dimitrovgrad, has achieved notable milestones in the last few years: MBIR's block roof was completed in October 2023 and pilot fuel elements for the test reactor have been fabricated and approved for use as of August 2024. The MBIR, once completed, will accelerate advancement of Russia's fast reactor program through its ability to conduct fast neutron testing using a variety of coolants: sodium, lead, lead-bismuth, and gas.

Russia has also taken additional steps following its initial deployments of floating nuclear power plants (FNPP). Following the commissioning of the *Akademik Lomonosov* in 2019, Russia has made progress in plans to deploy additional FNPP units in remote industrial and mining operations in Russia's Far East: in July 2021, Rosatom signed an agreement to supply power to the Baimsky mining and processing plant (Baimsky GOK) in Chukotka, proposing floating power units to provide electricity to the facility. Reportedly, the first two floating units will be in their offshore positions and connected to the Baimsky plant via power lines by the end of 2026.

China

China has the fastest growing civil nuclear fleet in the world, having more than doubled its nuclear generating capacity in the last decade (from around 20 GW to now over 53 GW) and with 23 additional units now under construction. While much of these capacity additions are from large conventional reactor builds, China is now rapidly diversifying the technological composition of its commercial nuclear fleet to include SMRs, fast reactors, high temperature reactors, etc.

As previously noted, arguably the most significant development in China's efforts to develop innovative reactor types is its placement into commercial operation of its high-temperature gas-cooled reactor, the HTR-PM. Back in 2021, the HTR-PM in Shidao Bay entered hot functional testing, and in December 2023, the plant officially entered into commercial service. China is presently seeking to add new HTR-PM units at the Shidao Bay site, and scaled up versions of the design are in development.

Similar to Russia, China has also been heavily investing in fast neutron reactor development as part of a larger effort to recycle spent nuclear fuel and close the fuel cycle. Back in 2021, the Xiapu fast reactor demonstration project was still under construction. According to reports, the Xiapu demonstration began low-power operations in December 2023, although exact timelines on the start of grid connection and commercial service remain uncertain.

Beyond non-light water designs, China has also made considerable advancements in light water SMR technologies. As in 2021, the ACP-100 SMR remains under construction at China's Changjiang Nuclear Power Plant site. However, there has been marked progress in the Changjiang SMR project —the internal reactor building structures were completed in 2023 and the control room was commissioned approximately a year later in May 2024—and more ACP-100 projects are being contemplated at other sites throughout China, including China National Nuclear Corporation (CNNC) agreements for ACP-100 projects in Shangrao and Ganzhou.

France

With France's longtime fast reactor program now on hold, French efforts on the development of advanced nuclear technologies have primarily been focused on NUWARD, a light-water SMR design announced by the French Alternative Energies and Atomic Energy Commission (CEA) in 2019, and a number of advanced reactor start-ups which have received funding under the France 2030 program, such as Jimmy Energy, Newcleo, Stellaria, Thorizon, NAAREA, Hexana, Calogena, Otrera Nuclear Energy and Blue Capsule.

According to CEA's previously announced roadmap, the goal was to begin construction of a NUWARD reference plant at one of EDF's 18 licensed sites by 2030. However, in June 2024, EDF

announced that it would modify the NUWARD design based upon feedback from prospective customers and longer-term commercialization considerations.

Jimmy Energy reached a milestone in April 2024 by filing a request for authorization with the ASN, the French regulator, to install a project based on its thermal generator technology at Cristal Union's sugar and ethanol factory in Bazancourt, Marne province.

Poland

Poland's commitment to nuclear energy is perhaps most evident through its large nuclear build plans—in 2022, Poland officially announced its selection of Westinghouse's AP1000 for its first nuclear energy project. Nevertheless, interest and progress in advanced nuclear projects has also been apparent, primarily driven by the needs of Poland's energy-intensive industrial sector. ORLEN Synthos Green Energy (OSGE) has been at the vanguard of this movement on advanced nuclear: OSGE is a joint venture between Poland's multinational oil refiner ORLEN and chemicals firm Synthos Green Energy, which is now pursuing development and deployment of GEH's BWRX-300 at industrial sites throughout Poland. In an April 2023 press release, OSGE announced seven potential sites for SMRs in Ostrołęka, Włocławek, Stawy Monowskie, Dąbrowa Górnicza, Nowa Huta, Tarnobrzeg Special Economic Zone and Warsaw. This announcement was shortly thereafter followed up with positive responses from the Polish nuclear regulator, the National Atomic Energy Agency (PAA). PAA issued a general positive opinion on the BWRX-300's compliance with its safety and radiological standards in May 2023, and later in December 2023, granted a decision-in-principle to approve construction of the SMRs at the announced sites.

There has also been progress in Poland on non-light water technologies. In June 2023, Poland's National Centre for Nuclear Research (NCBJ) announced the design of its 30 MWth high-temperature gas-cooled reactor demonstration, the HTGR-POLA, which it developed in partnership with the Japan Atomic Energy Agency (JAEA).

Romania

Romania formally announced its entry into the advanced nuclear space at COP26, where Romania's Nuclearelectrica and NuScale Power jointly announced an agreement to build NuScale's six-unit VOYGR SMR plant in Romania. There was a subsequent agreement to conduct engineering studies and technical reviews at a retired coal plant site in Doicesti, and later in 2022, the formation of the joint venture, RoPower (between Nuclearelectrica and Nova Power & Gas), to develop SMR projects in Romania (with the Doicesti site as the first proposed project).

The US Trade and Development Agency (USTDA) awarded RoPower grant funding to conduct a front-end engineering and design (FEED) study for the Doicesti project in October 2022. The first

phase of the FEED study was completed in late 2023, followed by a contract between Fluor Corporation and RoPower in July 2024 to commence phase two and US Export-Import Bank (EXIM) approving a final loan commitment of $98 million for pre-project services. Based on reports, Nuclearelectrica anticipates that a final investment decision (FID) on the Doicesti project will be made sometime in 2025.

Finland

Present plans to add nuclear capacity in Finland revolve around proposals to deploy an indigenous SMR design by the Finnish developer, Steady Energy. Steady Energy is reportedly planning on starting construction of its SMR pilot facility by 2025 at a number of prospective sites: Salmisaari caves near Helsinki, Huuhanmäki caves near Kuopio, and power plant sites in Kymijärvi and Teivaanmäki in Lahti. Steady Energy has also concluded agreements with Finnish utilities, Helen Oy and Kuopion Energia, to study the potential use of its SMR technology for district heating uses. Steady Energy's special focus on district heating applications allows its design to operate at lower temperatures/pressures and without connection to a turbine island.

Sweden

Swedish advanced nuclear developer, Blykalla, is presently developing an indigenous lead-cooled reactor design: the Swedish Advanced Lead Reactor (SEALER). Blykalla has entered into an agreement with Uniper Energy and the Swedish Royal Institute of Technology (KTH) to build a demonstration of SEALER at the Oskarshamn nuclear plant site by 2030. The SEALER design uses innovative steel alloys that allow for the use of lead coolant, resulting in enhanced passive safety characteristics that make the technology attractive for co-location and non-power applications such as desalination, industrial process heat, etc.

At the same time, Swedish developer Kärnfull Next is advancing a program to build SMR parks across several locations in Sweden seeking clean, firm capacity. The first of these is Studsvik's industrial site at Nyköping in the east of the country and the second is Valdemarsvik in the southeast region. The latter is to host four to six reactors. Kärnfull Next has selected the BWXR-300 as a candidate technology for these projects.

Ghana

In August 2024, Nuclear Power Ghana (NPG), established to be the owner/operator of Ghana's first nuclear power plant, signed a commercial agreement with Regnum Technology Group, a US project developer for the first SMR in Ghana, which will be based on NuScale's technology. Earlier, in 2023, the US government provided support to in Ghana an SMR Regional Training Hub with $1.75M of funding from the U.S. State Department's Foundational Infrastructure for Responsible Use of Small

Modular Reactor Technology (FIRST) capacity building program. The funding included the provision of an SMR control room simulator.

Rwanda

In September 2023, the Rwanda Atomic Energy Board (RAEB) signed an agreement with Dual Fluid, a German-Canadian nuclear company that is proposing an innovative reactor technology that incorporates design characteristics from both molten salt reactors (MSRs) and metal-cooled fast reactors. According to Dual Fluid's press release, the "demonstration reactor is expected to be operational by 2026 and the subsequent testing of the technology is to be completed by 2028."

Uzbekistan

In May 2024, UzAtom, Uzbekistan's government agency responsible for development of nuclear power plants in the country, signed an agreement with Russia's Rosatom for the construction of a 330MWe nuclear power plant based on Rosatom's RITM-200 technology in Uzbekistan's Jizzakh province. The plant is planned to reach criticality in 2029. Rosatom is also currently exploring the potential to build a similar project in neighboring Kyrgyzstan.

Conclusion

Although the progress in North American advanced nuclear projects is undeniable, equally as evident is the growing lead that China and Russia presently enjoy in terms of building, completing, and operating nuclear plants. In a time of surging international interest in nuclear generally and advanced nuclear specifically, this state of affairs should create a heightened sense of urgency for policymakers in other countries to take proactive steps to ensure influence and presence in a global market that is projected to grow exponentially.

For the US, the goal should be clear: get advanced nuclear projects across the finish line and better position these technologies to scale up rapidly. Although new agreements, proposed plans, and licensing milestones are positive developments and should be celebrated, there must absolutely be a concerted push to ensure that projects are completed and can be deployed at scale commercially, lest the US fall further behind in a race that it cannot afford to lose.

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