MICROGRID KNOWLEDGE™

Nuclear Microgrids: Prospects for a Small, Modular and Reactive Future

Coverage and analysis of how nuclear energy can relate to future expansion of data centers, AI and mission critical electrification.

NUCLEAR MICROGRIDS: PROSPECTS FOR A SMALL, MODULAR AND REACTIVE FUTURE

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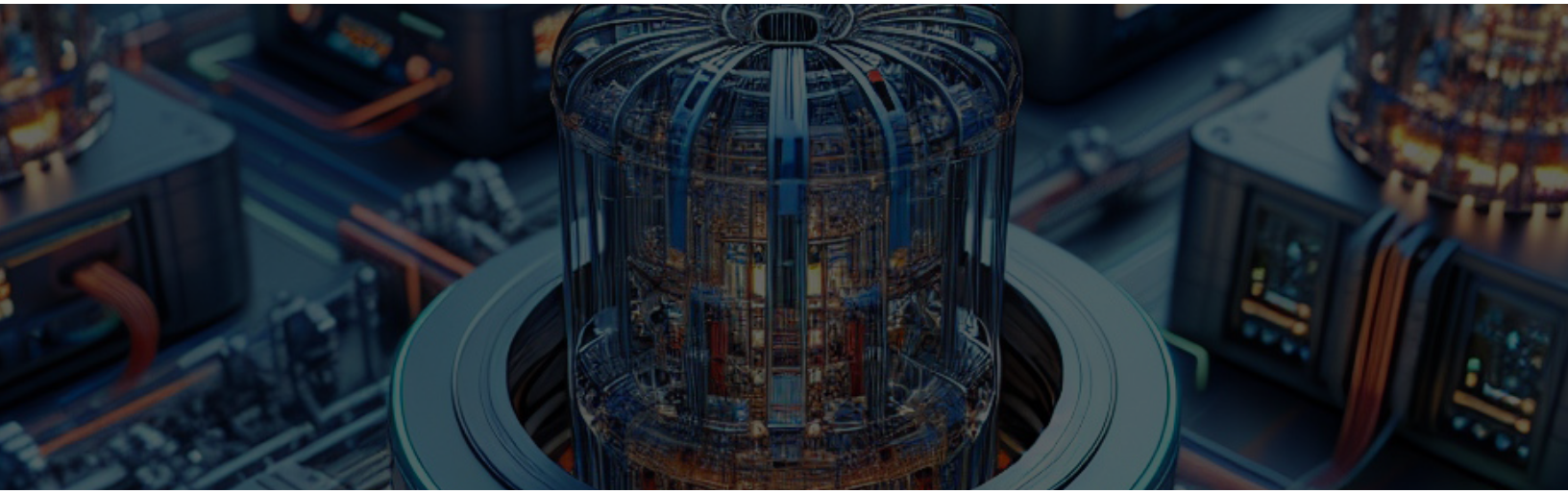
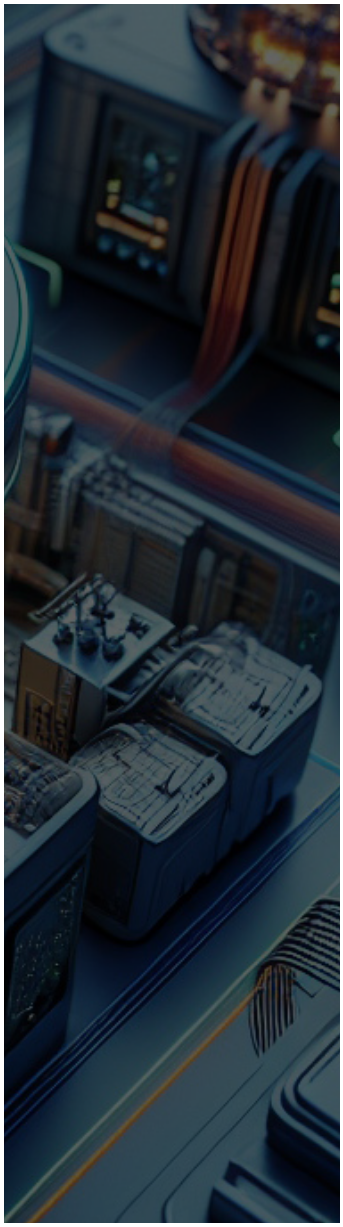
TABLE OF CONTENTS



EXECUTIVE SUMMARY

BY ROD WALTON, MANAGING EDITOR



It's not overreactive to say that nuclear fission has changed the world of energy generation and propulsion since the 1950s, when EBR-1 and the USS Nautilus proved they could deliver.

During the intervening 70 years, hundreds of nuclear generation plants and military vessels have been commissioned utilizing reactors for their power. In the U.S. even today, nuclear power generates nearly 20% of the electricity produced in the U.S. and even higher portions in some other developed countries.

Nuclear comes with its own safety concerns, but it also accounts for close to half of all carbon-free electricity generated. Many believe that the world cannot achieve net-zero emissions goals by 2050 without maintaining and growing the nuclear energy mix.

The sector is long taken for granted as a giant, utility-scale power resource, but increasingly nuclear microgrids are becoming a topic of interest in the commercial, industrial and mission-critical sectors such as military bases. The advancement of small modular reactor designs toward future construction means that demonstration projects and small nuclear power plants could be operational and commercialized by the early 2030s.

Microgrid Knowledge covers the spectrum of nuclear power as it relates to small energy applications. Tech giants such as Amazon Web Services and Microsoft are exploring nuclear microgrid options as the data center capacity grows exponentially.

The concept of nuclear microgrids currently is just that—a concept working toward reality. But the twin challenges of decarbonization goals and electrification throughout the economy are pushing optimism forward.

Microgrid Knowledge is agnostic about resources except to support all that helps interconnect power resiliency and sustainability goals. In addition to renewable energy, nuclear could very well achieve that feat. For that reason, we will continue to cover it intently and fairly.

NATURA, ABILENE CHRISTIAN CLOSER TO NRC APPROVALS TO BUILD 1-MW DEMONSTRATION REACTOR AT CAMPUS LAB

Small modular (SMR) and advanced next-gen nuclear energy is viewed by many as a solution for the twin challenges of decarbonization and exponential load growth. Many tech firms such as Microsoft are exploring the future potential of SMR nuclear microgrids.

BY ROD WALTON, MANAGING EDITOR — ORIGINALLY PUBLISHED JUNE 24, 2024

What could be a huge move forward for a type of advanced nuclear reactor technology, and possibly nuclear-powered microgrids of the future, is closer to starting its journey at a small private university in a historic Texas cattle drive hub community.

The U.S. Nuclear Regulatory Commission (NRC) informed Natura Resources that it expects to complete a safety assessment and issue a construction permit early this fall for the company's first deployed project. Natura Resources plans to locate the advanced and unique molten salt reactor at Abilene Christian University (ACU).

The campus is home to the newly opened Nuclear Energy eXperimental Testing (NEXT) Laboratory. Once completed and if commissioned, the Natura reactor project would be operated at low power for research purposes.

The NRC could issue the permit by Sept. 30, according to reports. The commission oversees non-power research reactors as well as all of the 90-plus commercial reactors in operation across the U.S.

"The environmental assessment and upcoming completion of the safety evaluation for a construction permit are significant steps forward in the first deployment of the Natura MSR-1 system," Doug Robison, company founder and president, said in a statement. "This deployment at ACU will not only demonstrate successful licensure of a liquid-fueled molten salt reactor but will provide critical operational data that will help us meet the world's growing energy needs."

Small modular reactor (SMR) and advanced next-gen nuclear energy is viewed by many as a solution for the twin challenges of decarbonization and exponential load growth from data center expansion and electrification of the transportation and building sectors. Many tech firms such as Microsoft are exploring the

Photo Credit: Natura Resources

potential of SMR nuclear microgrids to someday power data centers.

Nuclear fission does not emit greenhouse gasses when generating power for electricity. Gaining permitting, financing and public support for nuclear projects, however, is a key challenge going forward.

Private and relatively small Abilene Christian University has claimed molten salt reactor research as one of its key energy specialties. ACU professor and NEXT Lab Director Rusty Towell and the campus team have been working on flowing salt research for close to seven years.

Graphite-moderated, fluoride salt flowing fluid may be a safer option in nuclear energy compared to a water-cooled reactor, proponents say. If a system fails, theoretically the salt solidifies around the reactive uranium and preventing overheating, according to reports.

ACU's research is working to advance technical readiness levels of critical equipment needed in molten salt reactor operation,

including flow meters, flanges, seals, level sensors, salt monitors, instrumentation and other hardware, Towell said.

Natura Resources was started only five years ago. With NRC permitting, the company will use the ACU research to continue developing its small modular MSR system to be fabricated on an assembly line and shipped to future customer sites via truck or rail.

Nuclear energy is carbon-free, but conventional, utility-scale projects are proving to be difficult to permit and supremely expensive to build. Georgia Power's expansion to add two new Vogtle nuclear reactor units (3 and 4) took close to a decade and upward of $32 billion.

SMR nuclear reactors might be built at a fraction of that cost and with a much smaller footprint from 10 MW all the way to 300 MW, still far below Vogtle 3 and 4's 1-GW capacity for each Westinghouse AP1000 reactor. The Abilene Christian research reactor will be only 1 MW and not connected to power any load, according to reports.

Abilene Christian University's total enrollment is about 5,000 undergraduate and graduate students, according to U.S. News and World Report. Once revered as a critical hub of a historic cattle drive trail, the city of Abilene is now home to 125,000 residents, home to three universities, an Air Force base and several major facilities in the health care and insurance sectors.

Other small modular and advanced reactor startups trying to progress to an operational project include TerraPower, NuScale, X-energy and Oklo. The U.S. Department of Energy recently announced funding of up to $900 million for applications working on SMR projects.

Current U.S. nuclear energy power plants account for close to 18% of the utility-scale electricity mix and about half of the nation's carbon-free generation, according to federal statistics from the Energy Information Administration.

U.S. ARMY SEEKS MICROREACTOR NUCLEAR POWER PLANT SOLUTIONS FOR MILITARY BASES

The Army intends to deploy the prototype microreactor nuclear power plant at an installation in the continental U.S. by 2030. If successful, the technology could be used at bases around the globe.

BY KATHY HITCHENS — ORIGINALLY PUBLISHED JUNE 20, 2024

Photo Credit: Dragos Asaftei Shutterstock

The U.S. Army is looking to leverage the recent advancements in nuclear technology to shore up the energy resilience of its bases. As such, the Department of Defense's (DOD) Defense Innovation Unit (DIU) and the U.S. Army are now accepting proposals to prototype on-site microreactor nuclear power plants at military installations.

The Army, through the Advanced Nuclear Power for Installations program, aims to deploy the technology to ensure its bases have

the energy resilience needed to maintain operational readiness at all times.

"Modular advanced nuclear power is a joint and global need. DIU energy's effort will help bolster and protect critical energy infrastructure by providing a supply of carbon-free energy for emerging, future mission and facility needs within the DOD, allowing for installation energy resilience," said Andrew Higier, energy portfolio director at the DIU.

In March, the Senate Intelligence Committee sent a letter to Christine Wormuth, secretary of the Army, urging the exploration of advanced nuclear power technologies as a source of safe, secure, clean and reliable power on military bases.

The letter stated, in part, "It is critical that the United States lead in the development and deployment of advanced nuclear reactors to secure our own critical infrastructure with resilient, continuous power, especially for DOD mission-critical operations in remote and austere environments."

Not only could the technology ensure military mission continuity, it could also help the Army achieve its goal of 99.9% reliable energy by 2030.

PROTOTYPE CAPABILITIES OUTLINED

The Army intends to deploy the prototype microreactor nuclear power plant at an installation in the continental U.S. by 2030. If successful, the technology could be used at bases around the globe.

According to the solicitation notice, submitted briefs must address "all stages of a microreactor's life cycle, including design, construction, operation, deconstruction and returning the site to an unrestricted release status."

Proposed solutions must be capable of local control and dispatch and must meet 100% of all critical loads, which are anticipated to be between 3 MW and 10 MW.

The Army is also looking for the solutions to integrate with existing infrastructure and operations systems at the military installation.

Full details of the desired capabilities and features can be found in the solicitation notice.

ARMY INVESTING IN MULTIPLE ENERGY RESILIENCE TECHNOLOGIES

The Army is largely reliant on off-site providers to deliver the electricity its installations need to support critical missions around the world. Recognizing that this dependence on outside sources could put operations at risk during severe weather, cyberattacks or other outage-inducing events, the Army is investing in multiple types of on-site energy resilience technologies to ensure mission readiness.

Among those solutions are a growing number of microgrids. In 2022, the Army announced it would build microgrids at each of its 130 bases worldwide by 2035.

At U.S. Army Garrison-Fort Cavazos in Texas, for example, the Army has installed a microgrid to power critical services and infrastructure during outages and to reduce energy costs during ERCOT peak demand periods.

Fort Campbell in Kentucky, broke ground last year on a natural gas powered microgrid that will allow the base to maintain 100% mission capability for up to two weeks in the event of a grid failure.

NEXT-GEN NUCLEAR: TERRAPOWER BREAKS GROUND ON 345-MW NATRIUM REACTOR PROJECT

Nuclear safety concerns persist, yet more and more environmentally minded tech giants such as Microsoft and Amazon Web Services are becoming nuclear-friendly as they fear a conventional and renewable utility grid is not ready for the sheer capacity of data center expansion.

BY ROD WALTON, MANAGING EDITOR — ORIGINALLY PUBLISHED JUNE 12, 2024

Photo Credit: TerraPower

Some recent setbacks may have impeded small, advanced nuclear as a pathway to baseload, carbon-free power temporarily, but the industry celebrated a future-forward moment this week with a tech icon to cheer it on.

Next-gen nuclear startup TerraPower broke ground, ceremonially, Monday on its planned Natrium reactor demonstration project in Wyoming. The milestone is important as the first advanced reactor project to move from design to construction, although it's five years away from completion.

The ultimate goal is a 345-MW sodium-cooled fast reactor with a molten salt-based energy

storage system. Liquid sodium's boiling point is eight times higher than water, according to the demonstration project site.

TerraPower, which was founded by Microsoft co-founder and former CEO Bill Gates, would operate the plant as a commercial power generator once commissioned. The demonstration plant will be developed and operated in partnership with the U.S. Department of Energy.

Nuclear energy does not emit greenhouse gasses in generating electricity. Conventional-scale projects, however, have faced public opposition over radioactivity concerns and are extremely expensive to build, as evidenced by Georgia Power's Vogtle 3 and 4 expansion totaling more than $32 billion.

Smaller nuclear innovators such as TerraPower, X-Energy and NuScale hope to reduce the time and expense by focusing on smaller footprints and becoming valuable in meeting the future GWs of capacity needed for data center and artificial intelligence facility growth.

"I believe that TerraPower's next-generation nuclear energy will power the future of our nation—and the world," Gates said in a statement released for the Monday groundbreaking. He attended and participated in the ceremonial event.

The headwinds vs. advanced nuclear are not much easier than conventional nuclear, either. NuScale Power gained federal design approval for its small modular reactor design and demonstration with the Idaho National Laboratory, but the project was scrapped when the municipal utility partner found it didn't have enough subscribers to match revenue to costs.

Lingering memories of past nuclear disasters such as Chernobyl and Fukushima also surface repeatedly in public opposition.

Photo Credit: TerraPower

Nonetheless, more and more environmentally minded tech giants such as Microsoft and Amazon Web Services are becoming nuclear-friendly as they see a conventional and renewable utility grid not ready for the sheer capacity of data center expansion. Some 21 GW of needed data center capacity is under construction with about 47 GW expected by the end of the decade, according to a recent report by Goldman Sachs.

This puts pressure on the commercial and industrial sector trying to connect environmental emissions goals with power resiliency requirements. Many are considering the possibility of nuclear-powered or nuclear-connected microgrids to power data centers.

"This groundbreaking represents the beginning of the next era of nuclear energy," TerraPower President and CEO Chris Levesque said in a statement. "The natrium reactor is more than a design; it's a plant coming to life that will support both the clean energy transition and our historic energy communities."

The construction site in Kemmerer, Wyoming, is located near a retiring coal-fired power plant and is touted by the company as the only coal-to-nuclear project under development. The builders expect to employ about 1,500 construction jobs on the site.

Coal-fired electricity generation is the worst-emitting utility-scale resource currently in the power portfolio of the U.S. Nuclear energy, meanwhile, represents almost 20 percent of the mix and more than half of the carbon-free electricity generation, according to the federal Energy Information Administration.

SMALL NUCLEAR'S BIG MOMENT: DOE FUNDING $900M FOR SMR PROJECTS

An expanding array of potential future microgrid customers, particularly those in information technology and data center industries, are favoring development of advanced and small modular nuclear (SMR) reactors to connect sustainability and power reliability goals.

BY ROD WALTON, MANAGING EDITOR — ORIGINALLY PUBLISHED JUNE 20, 2024

Photo Credit: TerraPower

Digital transformation is driving the future of the economy, and that driver needs fuel.

An expanding array of potential future microgrid customers, particularly those in information technology and data center industries, are favoring development of advanced and small modular nuclear (SMR) reactors to connect sustainability and power reliability goals.

The U.S. Department of Energy (DOE) is giving nearly a billion other reasons to prove that it's on board with that.

The DOE announced a notice of intent this week to fund up to $900 million to support deployment of new SMR technologies. The funding, made possible by the Bipartisan Infrastructure Law, will incentivize growth of smaller, advanced nuclear reactor projects.

The current U.S. fleet of more than 90 larger, utility-scale nuclear reactors, mainly owned and operated by the private sector, produces close to 19% of total electric power and more than half of the carbon-free energy generated nationwide. The costs and safety concerns around utility-scale nuclear projects, however, has impeded recent growth of the sector.

Many believe that the nation will not reach its net zero goals without future nuclear power as a flexible, baseload resource. SMR and advanced nuclear with smaller footprints are seen as less costly and more easily deployed opportunities; that is not to say they are inexpensive or uncomplicated.

INTEREST IN SMRS INCREASING: What's Their Role in Microgrids?

"President Biden is determined to ensure nuclear power—the nation's single largest source of carbon-free electricity—continues to serve as

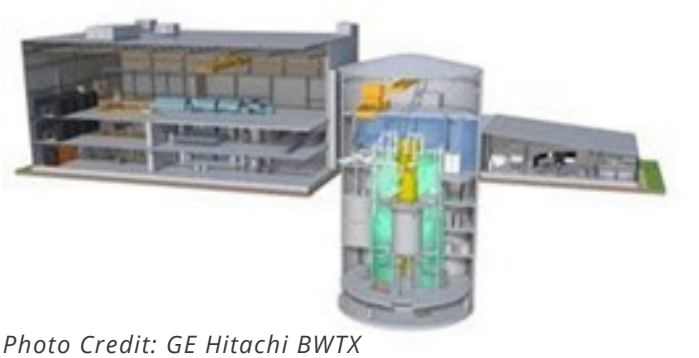


Photo Credit: GE Hitachi BWTX

a key pillar of our nation's transition to a safe and secure clean energy future," Secretary of Energy Jennifer Granholm said in a DOE statement. "Today's announcement will support early movers in the nuclear sector as we seek to scale up nuclear power and reassert American leadership in this critical energy industry."

The DOE estimates that the U.S. will need approximately 700 GW to 900 GW of additional carbon-free and firm electricity capacity to reach net-zero emissions by 2050. Solar and wind are intermittent resources, while battery storage is limited by short duration and its own safety and supply chain concerns.

The funding solicitation for this SMR nuclear investment could be released by late summer or fall. The DOE's Gen III+ Small Modular Reactor Program is part of the Office of Clean Energy Demonstrations and its website can be found here.

Next-gen nuclear projects are underway at various stages nationwide. Earlier this month, Bill Gates-founded startup TerraPower celebrated a groundbreaking ceremony for its planned 345-MW Natrium Reactor Project in Wyoming. Natrium is the first advanced reactor project to move into the construction stage and

is an expected five years away from completion. Other companies such as Oklo, NuScale Power, Westinghouse, X-energy, BWTX and Kairos Power are among those working on SMR designs and possible future demonstrations. NuScale Power received federal Nuclear Regulatory Commission approval for its reactor design. However, the company's planned partnership with electric cooperative Utah Associated Municipal Power Systems was terminated late last year because of a shortfall in customer subscriptions that could have made the Idaho National Lab-sited SMR plant economical. The exponential and sudden rise in anticipated future load from data center and artificial intelligence expansion is fueling consideration of dependable and carbon-free nuclear energy. Tech giants such as Microsoft, Amazon Web Services (AWS) and others are increasingly committed to adopting nuclear as a means of bridging sustainability and resource adequacy goals.

AWS, for instance, recently acquired a data center site that is directly linked to the nearby Susquehanna Nuclear Generation facility in Pennsylvania.

Track small modular nuclear's future role in microgrids and data centers via our free MGK newsletter

OKLO, DIAMONDBACK ENERGY MULLING 20-YEAR PPA ON NUCLEAR TO ELECTRIFY PERMIAN BASIN OIL AND GAS OPERATIONS

A series of 50-MW Aurora powerhouses could act as nuclear-powered microgrids to provide carbon-free electricity to counter the emissions involved in production from the shale plays. The agreement between Oklo and Diamondback is tentative and non-binding as both sides work out the logistics

BY ROD WALTON, MANAGING EDITOR — ORIGINALLY PUBLISHED APRIL 10, 2024

Photo Credit: Oklo

Oil and gas producer Diamondback Energy has signed a non-binding letter of intent (LOI) exploring a power purchase agreement for advanced, small reactor nuclear to potential electrify much of its operations in the shale oil-rich Permian Basin of west Texas.

Next-gen nuclear reactor developer Oklo announced the 20-year LOI with Diamondback. Under the proposed deal,

Oklo's future Aurora powerhouses would supply electric power to Diamondback's E&P subsidiary in the region near Midland, Texas.

A series of 50-MW Aurora powerhouses could act as nuclear-powered microgrids to provide carbon-free electricity to counter the emissions involved in production from the shale plays. The agreement between Oklo and Diamondback is tentative and non-binding as both sides work out the logistics and, of course, the nuclear developer gaining regulatory approval, additional future financing and building the projects.

"By developing and providing a low-cost, high-reliability and emission-free energy source, Oklo is poised to help meet the growing energy requirements of operators like Diamondback," Oklo co-founder and CEO Jacob DeWitte said in a statement.

Oklo has received a site use permit from the U.S. Department of Energy, fuel material award from the Idaho National Laboratory and made its license application to the U.S. Nuclear Regulatory Commission. Last year, Oklo announced a merger with AltC Acquisition Corp. to create a publicly traded company and generate up to $500 million in capital for accelerating Oklo's business plan and fund deployment of the first Aurora powerhouse.

Other early supporters of Oklo include OpenAI CEO Sam Altman, one of the data sector leaders who is bullish on next-gen nuclear power to help meet the needs of future data center development and net zero goals.

Interest in nuclear energy to help meet net zero goals is increasing, although some microgrid developers are skeptical on whether advanced, small modular reactors can be safe, cost-effective or even socially accepted as on-site or nearby power resources.

Diamondback Energy is focused entirely on the Permian Basin with a reported 1.8 billion barrels of oil equivalent proved reserves. Last month, news reports indicated that Diamondback and rival producer Endeavor Energy Resources were in final talks over a possible $50 billion merger.

AWS ACQUIRING HYPERSCALE DATA CENTER DIRECTLY CONNECTED TO NUCLEAR PLANT

Cumulus data center campus owner and nuclear power plant owner Talen Energy agreed to sell the facility to AWS for approximately $650 million. It is directly connected to the Susquehanna Nuclear Station.

BY ROD WALTON, MANAGING EDITOR — ORIGINALLY PUBLISHED MARCH 5, 2024

Photo Credit: Talen Energy-Cumulus

Amazon Web Services (AWS) is acquiring a 960-MW data center campus in Pennsylvania which will be directly powered with nearby nuclear energy.

Talen Energy, which owns both the Cumulus data center project as well as the Susquehanna nuclear power plant, agreed to sell the facility to AWS for approximately $650 million, according to reports. The deal also includes a provision in which Talen will receive additional revenue from AWS related to the dispatch of carbon-free power back into the grid.

Cloud data service provider AWS will install its hyperscale data center at the site. Talen will supply direct-connect nuclear power from its Susquehanna power plant to the future AWS campus under a long-term power purchase agreement.

"This transaction provides an attractive return on Talen's investment and vision in building Cumulus, and creates value through the sale of clean carbon-free power from the our Susquehanna nuclear plant," Talen Energy CEO Mac McFarland said in a statement.

The project does have some opposition from the utility sector. AEP and Exelon , on behalf of their subsidiary utilities, filed protests with the Federal Energy Regulatory Commission in June 2024, alleging that some $140 million in transmission costs will be borne by customers while AWS gets the benefits.

Domestic nuclear energy, generated from more than 90 utility-scale plants in the U.S., provides close to 20% of the nation's electricity resources and more than half of its carbon-free power, according to the federal Energy Information Administration.

Susquehanna, located in Luzerne County, Pennsylvania, can generate close to 2.5 GW of power capacity through its two units. The first unit went online in 1983 and unit 2 was commissioned two years later.

Utility company PPL owned and operated Susquehanna until June 2015 when Talen Energy was formed out of PPL's competitive supply business to take that business over. The plant has two General Electric boiling water reactors.

Talen subsidiary Cumulus Data was formed to begin developing and building the hyperscale

Photo Credit: WIkimedia Commons

center to attract a tenant or buyer. The 1,200-acre campus facility completed several construction milestones over the past year.

The boom in artificial intelligence capacity will add to the energy demand as more hyperscale data centers are being planned. Synergy Research Group has forecasted that hyperscale data center capacity will nearly triple over the next five years.

Data center firms, meanwhile, are focused on emissions reduction goals and seeking carbon-free microgrid-type energy connections such as renewable natural gas, solar and storage, and nuclear. In fact, Microsoft announced it is hiring for a new job to seek potential connection of its data centers to advanced and small modular reactor (SMR) nuclear technologies.

"This senior position is tasked with leading the technical assessment for the integration of SMRs and microreactors to power the data centers the Microsoft Cloud and AI reside on," read a company release in announcing the job and future focus on small nuclear.

Studies by Xendee, the Idaho National Laboratory and others are exploring the potential for microgrids of the future to utilize SMR nuclear, although many industry insiders are skeptical of the idea due to safety, location and cost concerns.

The SMR industry also suffered a recent blow when reactor designer Nuclear Power and electric cooperative Utah Associated Municipal Power Systems terminated the planned Carbon Free Power Project pilot in Idaho. The NuScale small reactor design had gained federal approval, but a shortfall in subscriptions from potential off-takers made the project uneconomical.

Nonetheless, small nuclear technology firms like X-energy, NuScale and others are pursuing future goals to build the projects. Proponents say nuclear energy is currently the only carbon-free energy resource that can produce at a higher efficiency and capacity factor than renewables such as solar, wind and battery storage.

Others dispute that contention and say that over the long haul solar and other renewables are better at truly reducing greenhouse gas emissions.

RESOURCES

ROD WALTON
MANAGING EDITOR

I've spent the last 15 years covering the energy industry as a newspaper and trade journalist. I was an energy writer and business editor at the Tulsa World before moving to business-to-business media at PennWell Publishing, which later became Clarion Events, where I covered the electric power industry. I joined Endeavor Business Media in November 2021 to help launch EnergyTech, one of the company's newest media brands. I joined Microgrid Knowledge in July 2023.

I earned my Bachelors degree in journalism from the University of Oklahoma. My career stops include the Moore American, Bartlesville Examiner-Enterprise, Wagoner Tribune and Tulsa World, all in Oklahoma . I have been married to Laura for the past 33-plus years and we have four children and one adorable granddaughter. We want the energy transition to make their lives better in the future.

Microgrid Knowledge and EnergyTech are focused on the mission critical and large-scale energy users and their sustainability and resiliency goals. These include the commercial and industrial sectors, as well as the military, universities, data centers and microgrids. The C&I sectors together account for close to 30 percent of greenhouse gas emissions in the U.S.

Many large-scale energy users such as Fortune 500 companies, and mission-critical users such as military bases, universities, healthcare facilities, public safety and data centers, shifting their energy priorities to reach net-zero carbon goals within the coming decades. These include plans for renewable energy power purchase agreements, but also on-site resiliency projects such as microgrids, combined heat and power, rooftop solar, energy storage, digitalization and building efficiency upgrades.

For Microgrid Knowledge editorial inquiries, please contact Managing Editor Rod Walton at rwalton@endeavorb2b.com.

KATHY HITCHENS
SPECIAL PROJECTS EDITOR

I work as a writer and special projects editor for Microgrid Knowledge. I have over 30 years of writing experience, working with a variety of companies in the renewable energy, electric vehicle and utility sector, as well as those in the entertainment, education, and financial industries. I have a BFA in Media Arts from the University of Arizona and a MBA from the University of Denver.