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GROUNDBREAKERS SPECIAL REPORT

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SPECIAL REPORT:

ON THE COVER

An aerial view captures engineers reviewing plans at a graded project site—a fitting image for this issue's look at the people and projects breaking new ground in the power industry. Source: Envato

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From the Manhattan Project to Fusion: The History of DOE's National Labs

Aaron Larson

The U.S. Department of Energy (DOE) maintains one of the richest and most diverse histories in the federal government. Although the department itself has only existed since 1977, its lineage traces back to the Manhattan Project—the massive scientific effort that developed the atomic bomb during World War II—and to various energy-related programs that were previously dispersed throughout multiple federal agencies. Today, the department oversees 17 National Laboratories that collectively represent the world's preeminent network for scientific research and technological innovation.

Manhattan Project Origins

The story begins in 1939, when Albert Einstein wrote to President Franklin D. Roosevelt alerting him to the importance of nuclear research and the possibility that it might lead to the development of powerful weapons. Einstein noted that Germany had stopped the sale of uranium and that German physicists were actively engaged in uranium research. This letter set in motion a chain of events that would reshape both science and geopolitics.

In 1942, the Army Corps of Engineers established the Manhattan Engineer District to develop and build the atomic bomb. Uranium isotope separation facilities were constructed at Oak Ridge, Tennessee; plutonium production reactors were built at Hanford, Washington; and a weapons laboratory was established at Los Alamos, New Mexico, under the direction of physicist Robert Oppenheimer. Reactor research at the University of Chicago's Metallurgical Laboratory after the first controlled chain reaction led to the creation of Argonne National Laboratory.

The wartime laboratories were originally conceived as temporary creations. However, after the war's conclusion and the atomic bomb's decisive role in ending the conflict, the newly created Atomic Energy Commission (AEC) took over the management of these facilities, extending their lives indefinitely and establishing the foundation for what would become the national laboratory system.

From Atomic Energy to Energy Security

The AEC governed atomic research and development from 1946 until 1974, overseeing both the weapons complex and the development of civilian nuclear power. In 1954, President Eisenhower signed the Atomic Energy Act, which opened the way for civilian nuclear power programs. The laboratories' mission began to expand beyond weapons to include fundamental research in physics, chemistry, materials science, and biology.

The 1973 oil embargo and subsequent energy crisis fundamentally changed America's approach to energy policy. On Oct. 17, 1973, the Organization of Arab Petroleum Exporting Countries (OAPEC) declared an oil embargo that exacerbated what became known as the first "energy crisis." This event catalyzed the formation of the Energy Research and Development Administration (ERDA) in 1975, which consolidated energy-related programs from across the federal government.

In 1977, President Jimmy Carter signed the Department of Energy Organization Act, establishing the DOE and consolidating ERDA, the Federal Energy Administration, and several other agencies. The new department inherited not only the national laboratories but also responsibility for the Strategic Petroleum Reserve, energy conservation programs, and the power marketing administrations.

The National Laboratories Today

Today's 17 National Laboratories constitute the backbone of American scientific leadership. These institutions tackle critical challenges ranging from combating climate change to discovering the origins of the universe, and they possess unique instruments and facilities found nowhere else in the world. The laboratories employ a multidisciplinary approach that emphasizes translating basic science into practical innovation.

The scientific achievements flowing from these laboratories are extraordinary. The DOE has recorded 118 Nobel Laureates affiliated with its programs and facilities. In December 2022, scientists at Lawrence Livermore National Laboratory achieved fusion ignition—a major scientific breakthrough decades in the making. This milestone demonstrated that more energy could be released from a fusion reaction than was used to initiate it, marking a pivotal moment in the quest for clean, abundant energy.

The National Laboratories' contributions extend far beyond pure science. A 2021 economic impact study of Sandia National Laboratories' technology transfer activities revealed that the lab had generated more than $95 billion in economic impact from 2000 to 2020, supporting approximately 21,000 jobs per year. The study documented $53.7 billion in total sales of new products and services resulting from Sandia's innovations.

Technology transfer brings knowledge, intellectual property, and capabilities developed within the laboratories to private industry, academia, and government agencies. The spectrum of breakthroughs is astonishing—from basic science discoveries to applied research that has unleashed an American energy renaissance, improved grid resiliency, and launched the LED lighting revolution.

Looking Forward

Today, the National Laboratories continue to address the nation's most pressing challenges—from advancing supercomputing and artificial intelligence to pursuing the promise of fusion energy. For more than 75 years, they have offered unparalleled scientific service, spawning industries, saving lives, and strengthening national security. As the challenges facing the nation evolve—from climate change to energy security to emerging technologies—the laboratories remain positioned at the forefront of discovery, continuing a tradition of excellence that began in wartime urgency and has grown into an enduring national asset. ■

*—**Aaron Larson** is POWER's executive editor.*

Empowering Communities with Proven Energy Solutions

Communities across the nation are at a crossroads, facing the challenge of meeting growing energy needs from advanced manufacturing, data centers, and heavy industries.

Without reliable, scalable energy solutions to meet this demand, utility leaders face tough choices in balancing community priorities with economic growth and grid resiliency. They need energy technologies that can deliver cost-effectiveness, reliability, and flexibility—not just for today, but for decades to come.

TerraPower is answering this call with transformative, proven technologies. At the forefront is the Natrium® reactor, a 345-megawatt sodium fast reactor paired with a molten salt energy storage system. This breakthrough design combines gigawatt-scale energy storage with unmatched flexibility, enabling rapid response when renewables falter, and ensuring 24/7 reliability for utilities to support communities and modern industries.

What sets the Natrium technology apart is its streamlined, cost-efficient construction process. By reducing nuclear-grade safety equipment and materials, TerraPower has made deployment faster, simpler, and more affordable than traditional reactors—all while adhering to the highest standards of safety and performance.

The first Natrium reactor, under construction in Wyoming, is already delivering tangible benefits: creating local jobs, bolstering grid infrastructure, and demonstrating the potential of nuclear innovation to strengthen communities.

At TerraPower, we believe energy solutions should empower communities and enable economic development. Our technologies are here to meet the energy challenges of today and the opportunities of tomorrow—real, disruptive, and deployment-ready. Together, we can build a more flexible and reliable energy future.

www.terrapower.com

TerraPower®

With the separation of major structures into a nuclear island and energy island, the Natrium plant is designed to utilize construction material quantities that are comparable to a combined cycle plant and significantly less than other reactor designs.

With construction of our first Natrium project already underway and a 2030 completion timeline, our offerings are implementation ready.

Powering Tomorrow: A Multi-Technology Roadmap for the Global Energy Transition

As global electricity demand surges 40% by 2035 and warming projections worsen, nuclear, geothermal, gas, offshore wind, storage, and fusion must all advance—along with the workforce to build them.

Aaron Larson

The global energy landscape is undergoing its most significant transformation since the Industrial Revolution. Electricity demand is surging at unprecedented rates while the imperative to decarbonize intensifies. According to the International Energy Agency's (IEA's) *World Energy Outlook 2025 (WEO)*, global electricity demand is projected to reach approximately 37,800 TWh by 2035—a 40% increase from today's levels. This surge is being driven by electrification across industries, electric mobility, cooling demand, and the rapid expansion of data centers and artificial intelligence (AI) applications.

Yet, even as clean energy enters the system at an unprecedented rate, the world remains on a troubling trajectory. The IEA's latest analysis projects global warming of 2.5 degrees Celsius by 2100 under stated policies—and nearly 3 degrees under current policies alone. Far from limiting warming to 1.5 degrees or well below 2 degrees as called for in the Paris Agreement, we are heading toward outcomes with severe implications for lives and livelihoods worldwide. Meeting this challenge will require deploying every available clean energy technology at scale while maintaining grid reliability. No single solution can address the complexity of modern power systems. This overview examines how multiple technologies could fit into the evolving global energy mix.

Nuclear: The Foundation of Clean Baseload Power

Nuclear energy is experiencing a global renaissance. According to the *WEO*, momentum for nuclear power is building driven by concerns about rising emissions and energy security. More than 40 countries now include nuclear in their energy strategies and have taken concrete steps to develop new projects. A record high in nuclear power output is expected in 2025.

The construction pipeline is the strongest in decades. More than 70 GW of new nuclear capacity is currently under construction—one of the highest levels in 30 years, according to the IEA. China accounts for close to half of all capacity under construction and is on track to become the world's largest nuclear power operator as soon as 2030. Global nuclear power capacity is projected to increase by at least one-third by 2035 and by three-quarters by 2050 under the IEA's current policies scenario.

Small modular reactors (SMRs) represent a particularly promising development, with technology companies driving new business models. The IEA reports agreements and expressions of interest for 30 GW of SMRs, mainly to power data centers. U.S. technology companies already have plans to finance more than 25 GW of small modular reactors (Figure 1), although most of this capacity is not expected to materialize until after 2035. The International Atomic Energy Agency (IAEA) projects SMRs could account for 24% of new nuclear capacity in its high-case scenario, with about 70 designs proposed worldwide.

The financial landscape is also shifting favorably. In June 2025, the World Bank Group signed a memorandum of understanding with the IAEA to support nuclear energy in developing countries—the World Bank's first concrete step to reengage with nuclear power since financing an Italian reactor in 1959. The agreement focuses on building institutional expertise, extending reactor lifespans, and advancing SMRs, signaling that major development institutions now view nuclear as essential to meeting electricity demand projected to more than double in developing countries by 2035.

1. Amazon invested in X-energy, a leading developer of next-generation small modular reactors and fuel, in October 2024. X-energy's advanced nuclear design will be used in an Energy Northwest project Amazon is supporting in Washington state. Personnel are shown here training in X-energy's simulator. Courtesy: Amazon

Geothermal: Unlocking the Earth's Heat

Geothermal energy offers something few other renewable resources can match: continuous, weather-independent baseload power with capacity factors exceeding 90%. Yet, conventional geothermal resources have remained geographically limited, concentrated in areas where heat, water, and rock permeability naturally converge. Enhanced geothermal systems (EGS) are poised to change that equation. These systems work by creating human-made reservoirs in hot rock formations that lack natural permeability or fluid flow. Major technology companies are taking notice.

The *WEO* highlights geothermal as being backed by prominent hyperscalers seeking dispatchable sources of low-emissions electricity for data centers. The report notes that innovations can spill over from one sector to another, as with shale production techniques now enabling advanced geothermal development.

A report, titled *Pathways to Commercial Liftoff: Next-Generation Geothermal Power*, published by the U.S. Department of Energy (DOE) in March 2024, says next-generation technologies can expand geothermal power by more than a factor of 20, providing 90 GW or more of clean firm power to the U.S. grid by 2050. Furthermore, the report notes there are an estimated 5.5 TW of geothermal energy available for next-generation geothermal development in the U.S. alone, "enough to power the U.S. for thousands of years," it says.

The DOE analysis found that private-sector advances cut estimated EGS capital costs nearly in half from 2021 to 2023, outpacing the trajectory needed to meet the Enhanced Geothermal Shot's 2035 cost targets. Meanwhile, Fervo Energy reported in September 2024 that its Cape Station project (Figure 2) achieved flow rates matching NREL's "Advanced Technology" projections more than a decade ahead of the 2035 target. This coincides with an IEA report released in December 2024, *The Future of Geothermal Energy*, which projects that with continued technology improvements and cost reductions, geothermal could meet up to 15% of global electricity demand growth through 2050—deploying as much as 800 GW of capacity worldwide.

2. Fervo Energy, a next-generation geothermal energy developer, announced in September 2024 that it had achieved record-breaking commercial flow rates at its Cape Station site's first well test. Courtesy: Fervo Energy

Fusion: From Promise to Pilot Plants

Fusion energy has moved from a long-term scientific aspiration to an emerging industrial sector targeting grid-connected pilot plants in the 2030s, but major physics, technology, and fuel-cycle challenges still separate today's demonstrations from commercial deployment.

The DOE's *Fusion Science and Technology Roadmap*, issued in October 2025, is structured around a "Build-Innovate-Grow" strategy aimed at delivering public infrastructure and science needed for private-sector scale-up in the 2030s. The roadmap focuses on closing six core challenge areas—structural materials, plasma-facing components, confinement, fuel cycle and tritium processing, blankets, and plant-level integration—on a 2- to 10-year timeline with quantitative milestones and technical metrics.

The Fusion Industry Association (FIA) says the 53 private fusion companies it surveyed in 2025 had tallied more than $9.7 billion in cumulative investment, with more than $2.6 billion raised in the previous year alone. The U.S. has established itself as the premier national fusion cluster, hosting at least 29 private firms including the three most well-capitalized players—Commonwealth Fusion Systems, TAE Technologies, and Helion Energy—each with funding exceeding $1 billion. Strong regional hubs are also emerging in Asia, Europe, and the UK.

Companies are pursuing a diverse portfolio of concepts, including tokamaks and stellarators, magneto-inertial and inertial fusion, Z-pinch and mirror configurations, and both deuterium-tritium and advanced fuels such as proton-boron (p-B-11). Most firms surveyed by the FIA expect a commercially viable pilot plant with net energy gain between 2030 and 2035, and a majority predict the first grid-connected fusion plant delivering electricity sometime between 2031 and 2040—though industry self-reported timelines have historically proven optimistic.

Top pre-2030 challenges cited by survey respondents include achieving sufficiently high fusion gain, ensuring tritium self-sufficiency, qualifying neutron-resilient materials, and integrating complex systems for continuous operation and maintenance. Public-private partnerships, advanced computing and AI-enabled digital twins, and shared test facilities for blankets, fuel cycles, and materials are seen as critical levers to accelerate progress.

If successful, fusion would provide abundant clean baseload power with a limited waste stream and no meltdown risk—characteristics that distinguish it from fission. While commercial-scale fusion remains a longer-term prospect compared to other technologies in this report, its potential contribution to deep decarbonization beyond 2040 warrants continued investment and attention.

Natural Gas: Bridging and Balancing

Natural gas remains indispensable to power system reliability as variable renewables scale up—and its role has been revised upward in the latest projections. The *WEO* projects 350 billion cubic meters more natural gas consumption by 2035 than its 2024 forecast, driven mainly by higher electricity demand for power generation in the U.S. and slower progress in adding renewables to the generation mix than previously anticipated. In contrast to last year's outlook, gas demand now continues growing into the 2030s.

Natural gas continues to be the single largest source of U.S. electricity generation. The U.S. Energy Information Administration (EIA) forecasts record natural gas consumption of 91.4 billion cubic feet per day in 2025. The IEA notes that a wave of new liquefied natural gas (LNG) exports, led by the U.S., is bringing downward pressure on international prices, which helps explain the revised outlook for gas demand.

The role of gas-fired generation increasingly focuses on providing flexibility and reliability services. The IEA projects that by 2035, natural gas will provide over half of the electricity required by data centers in the U.S., followed by renewables and nuclear at about 20% each. Simple-cycle combustion turbines that can start quickly and ramp rapidly are gaining prominence, providing critical grid stability as intermittent resources proliferate.

Offshore Wind: Harnessing Ocean Resources

Global offshore wind capacity reached approximately 83 GW in 2024, according to the International Renewable Energy Agency (IRENA), continuing a trajectory of strong growth. Meeting climate goals, however, requires dramatic acceleration. IRENA's analysis indicates the world needs roughly 500 GW of offshore wind by 2030, with the Global Offshore Wind Alliance targeting 2,000 GW by 2050.

Cost reductions have been substantial. IRENA data show the global weighted-average levelized cost of electricity (LCOE) for offshore wind fell 62% between 2010 and 2024, from $0.208/kWh to $0.079/kWh. Turbine capacity has grown dramatically as well, with new offshore projects deploying turbines in the 8- to 12-MW range compared to typical onshore turbines of 3 to 4 MW.

The *WEO* expects particularly robust growth in the European Union (EU) offshore wind sector, alongside continued onshore expansion in China. Floating offshore wind technology is particularly promising for accessing deeper waters where stronger and more consistent wind resources exist. IRENA says floating systems could quadruple the ocean surface area available for development compared to fixed-bottom installations.

Challenges remain, including supply chain constraints, permitting delays, and the need for massive transmission investments. The Global Wind Energy Council recently downgraded its 2030 outlook by 25%, and the IEA projects 27% less offshore wind capacity between 2025 and 2030 than forecast in late 2024, reflecting current headwinds particularly in the U.S., where policy changes have resulted in 30% less renewables capacity projected for 2035 than in last year's outlook.

Energy Storage: The Grid's Fast-Growing Flexibility Resource

Battery energy storage has emerged as one of the fastest-growing segments of the power sector. Global battery storage additions reached 77 GW in 2024, according to the *WEO*—a remarkable acceleration driven by strong policy support and declining technology costs. The report projects total installed battery capacity reaching nearly 1,700 GW by 2035 under stated policies.

In the U.S., cumulative utility-scale battery storage capacity reached 27 GW in 2024 after growing more than 68% in a single year, according to EIA data. Capacity was expected to be 45.6 GW by the end of 2025, marking a nearly identical year-over-year growth rate, according to the EIA's December 2025-issued *Short-Term Energy Outlook*. With 18.6 GW of new capacity, battery storage was the second-largest source of capacity additions after solar, which was expected to add 25.1 GW. The EIA projected 20 GW of utility-scale battery storage additions to the U.S. grid in 2026.

The IEA emphasizes that batteries and demand response are set to become major contributors to system reliability,

3. The power sector added workers at twice the pace of the broader energy industry over the past four years, but critical labor shortages threaten to constrain the energy transition. Source: Envato Elements

supplying most of the needed short-term flexibility by 2035. This represents a fundamental shift in how grids maintain stability. While dispatchable sources like hydropower and nuclear remain essential, their role will increasingly shift from bulk generation toward ensuring secure capacity and flexibility.

Costs continue to decline. The National Renewable Energy Laboratory's (NREL's) 2025 update on utility-scale lithium-ion battery storage estimates that capital costs for 4-hour systems could fall by roughly 30% to 56% between 2024 and 2035 in its mid and low cases, while remaining roughly flat in a high-cost case that assumes sustained supply-chain and trade headwinds. The wide spread between scenarios reflects significant uncertainty in future market conditions.

Lithium iron phosphate has become the chemistry of choice for many stationary storage projects, offering improved safety and typically longer cycle life than other lithium-ion chemistries. Looking ahead, sodium-ion batteries and other emerging technologies could further diversify the market, though lithium-based systems are expected to remain dominant through the early 2030s.

Workforce: The Human Foundation

The energy transition's biggest bottleneck may not be technology or capital—it's people. Energy employment worldwide expanded by 2.2% in 2024—1.7 million new jobs—outpacing economy-wide employment growth of 1.3%, according to the IEA. The power sector consolidated its position as the largest provider of employment in the global energy industry with 22.6 million jobs, adding workers at twice the pace of the broader energy sector over the past four years.

Solar photovoltaic (PV, Figure 3) and grids accounted for 40% of all new energy jobs, and low-emissions power generation and grids remain the main employment growth engines looking ahead. Yet, the IEA projected job growth in energy slowed to only 1% in 2025 as policy shifts, tariff uncertainty, and geopolitical risks reshaped market expectations and led firms to take a cautious approach to hiring.

Critical labor shortages threaten to constrain the energy transition. According to the IEA, six of the 10 occupations with the most acute shortages were skilled trades—electricians, grid line workers, solar PV installers, pipefitters, welders, and heating, ventilation, and air conditioning (HVAC) installers. The energy sector relies more heavily on skilled labor than the wider economy. "Technical roles, including skilled trades, technicians, and plant operators, make up over half the energy workforce, more than double their 25% share in the broader economy," the *WEO* says.

Demographic pressures compound the challenge. In advanced economies, retirements are outpacing new entrants. Nearly 30% of union electricians in the U.S. may retire within a decade, according to the *WEO*. The challenge is most acute in nuclear and grids, where for every young person joining there are 1.7 and 1.4 workers nearing retirement, respectively—well above the economy-wide average. Addressing these workforce gaps requires coordinated action to expand vocational education and training systems, strengthen provider-employer partnerships, and broaden access to training programs.

An All-of-the-Above Imperative

The scale of the energy transition demands humility about any single technology's limitations and openness to the full portfolio of solutions. Nuclear provides proven, dispatchable clean baseload power with momentum building after decades of stagnation. Geothermal offers 24/7 renewable generation attracting major technology companies. Fusion holds transformative long-term potential. Natural gas ensures reliability during the transition, with demand revised upward in the latest projections. Offshore wind taps vast ocean resources despite near-term headwinds. Energy storage is becoming the grid's backbone for flexibility. And a skilled workforce makes all of it possible. ■

*—**Aaron Larson** is POWER's executive editor.*

160 Days to Fission: Nuclear Power's Sprint to Execution

For the first time in decades, a wave of nuclear projects across the U.S. is advancing in parallel—from test reactors to early construction. *POWER* examines how first movers are navigating execution risk, supply-chain constraints, and the race to criticality by 2026.

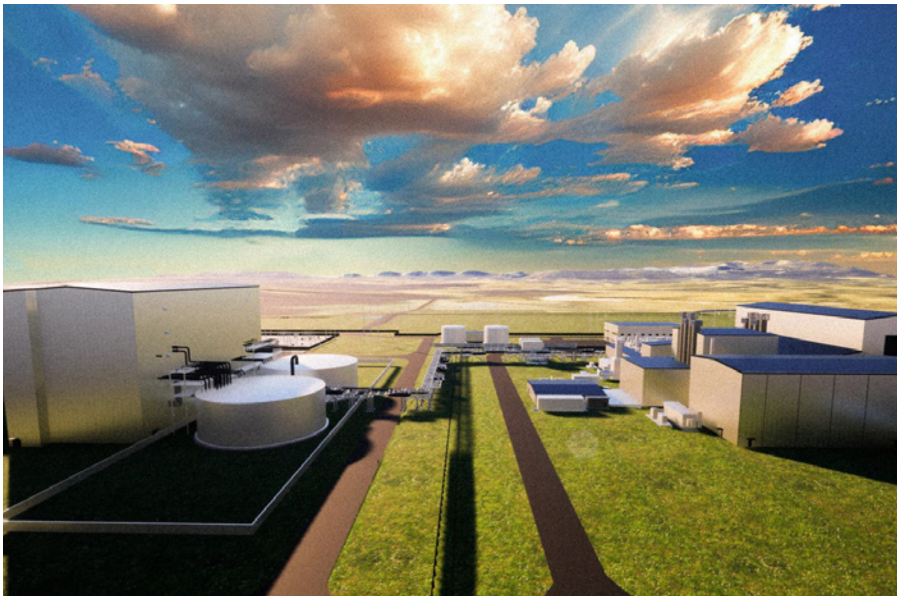
Sonal Patel

For the first time since the 1970s, multiple nuclear projects are under simultaneous construction in the U.S. Between now and July 4, 2026, nearly a dozen companies have set out to achieve criticality at authorized test sites in Idaho, Tennessee, Texas, Wyoming, Kansas, and Utah—a milestone that, in recent history, might have taken a decade to accomplish.

In Tennessee, after a series of regulatory triumphs, Kairo Power has begun pouring nuclear-related concrete and executing site works at Oak Ridge for its Hermes demonstration reactors. A key facet of the company's iterative fluoride salt–cooled design strategy, the engineering will ultimately anchor a commercial partnership with Google that targets up to 500 MW of clean power deployment between 2030 and 2035.

In Texas, X-energy's Xe-100 high-temperature gas-cooled (HTGR) reactors are entering site preparation and early construction phases at Long Mott Energy's pioneering industrial power facility, a project that will scaffold a stunning fleet expansion beyond Dow's four-unit Seadrift Operations, including the Amazon-backed 12-unit Cascade Advanced Energy Facility in Washington, and a 6-GW fleet planned with UK firm Centrica.

And in Wyoming, TerraPower's Kemmerer 1 Natrium project (Figure 1) has moved decisively from planning into early physical construction, with site works underway and long-lead procurement accelerating (see sidebar: "Q&A: Chris Levesque on TerraPower's Path to First-of-a-Kind Execution"). The company has filed its construction permit application and is deploying capital at scale—raising more than $650 million during 2025 alone—to lock in manufacturing slots and secure supply chain commitments. Natrium, distinctive as it is revolutionary, will pair the 345-MWe sodium-cooled fast reactor with molten-salt energy storage, setting the stage for an innovative load-following asset.



1. Rendering of TerraPower's Natrium advanced reactor plant, a sodium-cooled fast reactor paired with molten-salt energy storage to enable flexible power output. Courtesy: TerraPower

While these projects represent the first wave of groundbreakers, they are the first excavations in ground that has not been worked in half a century. For an industry long stalled by cost overruns, licensing drag, and broken construction continuity, they herald a decisive break from the past. But they also reveal a broader national expansion already underway. Alongside advanced reactor demonstrations, feasible prospects through 2030 include microreactors for defense and remote power, the fiercely defended restart of shuttered commercial plants, and fresh optimism, or at least solid renewed consideration, of a new fleet—of up to 10—large, grid-scale reactors.

As Nuclear Energy Institute (NEI) President Maria Korsnick noted during a Congressional hearing in January, for now, industry expects to invest roughly $22 billion to optimize and expand its current fleet. Plant owners are pursuing license renewals at 26 units, power uprates at 29 units, and extended fuel cycles at another 12 reactors facilitated by accident-tolerant fuel programs, she noted. "By making even greater use of existing assets," Korsnick told lawmakers, "the industry will add more than 8 GW of additional nuclear capacity."

However, that work is unfolding with efforts to expand the nation's nuclear capacity. Signaling industry's confidence in new nuclear, NEI member utilities report approximately 23.4 GW of new nuclear capacity under active planning over the next 15 years. "To ensure new deployments are constructed in a timely and cost-effective manner, the industry is applying construction and project-management best practices to improve schedule discipline, enable repeatability, and significantly reduce costs as deployment expands," she said.

Q&A: Chris Levesque on TerraPower's Path to First-of-a-Kind Execution

TerraPower's Natrium reactor represents perhaps the most advanced first-of-a-kind nuclear project under construction in the U.S. With a Nuclear Regulatory Commission (NRC) construction permit expected imminently, fuel loading planned for 2030, and commercial operation targeted for 2032, the company is now gearing up to translate its advanced reactor innovation into disciplined, repeatable execution at scale.

To understand how TerraPower moved from concept to real-world project delivery—and what it reveals about the broader nuclear renaissance—*POWER* spoke with Chris Levesque (Figure 2), the company's president and CEO, in January 2026. The conversation ranged from how the company transformed its culture as it moved from research and development (R&D) into execution, to the fuel supply strategy that emerged after Russia became an untenable source, to the Meta agreement that will test whether Natrium can scale from a single demonstration into a commercial fleet of up to eight units. (This interview has been edited for length and clarity; questions and responses reflect the substance of a longer discussion.)

POWER: TerraPower began with a formidable team of PhDs focused on fundamental physics. How did the company's approach evolve as you moved from design to execution?

Levesque: It was critical that Bill Gates and the founders realized innovation was necessary. In the nuclear industry I grew up in, you were told, "Don't do anything new, just do what was done last time." That raised capacity factors and made the industry very safe, but if you do that for 30 or 40 years, you miss opportunities to employ advanced computing and advanced materials.

In our early years, we designed a reactor that wasn't limited by what's been done before—it was limited by what science allows. You might go into a conference room and see multivariate calculus on the board, because we asked, "What does nature allow?"

But as you move from R&D across the valley of death and engage the supply chain and constructor, you have to convey things in their terms. With Bechtel, there was a realization that our plant consumes far less concrete, steel,

2. Chris Levesque, president and CEO of TerraPower. Courtesy: TerraPower

and labor—leading to lower costs. That's what will let future Natrium plants be built in 36 months, when today's light-water reactors take 10 years or more.

We've moved from talking about Navier-Stokes equations to asking, "How many tons of concrete do we need to pour per day?" Our team went from 40% PhDs to 20%. Some folks left to go back to national labs because they wanted to remain ideas people. But when you get into execution and things don't go right, it's great to reach back to people who know the governing equations—so you can use physics to solve problems, not just ask how someone fixed it last time.

POWER: How did you approach the regulatory process, given both the technical novelty and the evolving regulatory framework?

Levesque: Even before we talk about regulation, it starts with a strong belief that we're building a very safe nuclear reactor. If we're going to have nuclear energy all over the world—in Africa, Indonesia—we really need Generation IV plants that are at the next level of safety. Plants that in a Fukushima scenario will cool themselves naturally with absolutely no human interaction. Today's plants are very safe in the U.S. and Europe, but Gen IV reactors are something like 1,000 times safer probabilistically.

For us, the experience with the regulator began with communication—not just submitting our application and letting them process it, but multiple training sessions with the NRC and Wyoming regulators on the Kemmerer Unit 1 construction permit application. We were the first to employ the Licensing Modernization Project. When we submitted our 14,000-page application in the first quarter of 2025, that was the culmination of years of pre-application engagement.

The process has gone really well as a result. The NRC already issued the safety evaluation, and we expect to receive the construction permit in the coming weeks.

POWER: High-assay low-enriched uranium (HALEU) fuel availability delayed the project by two years. How are you de-risking fuel supply and other critical components for a multi-billion-dollar project?

Levesque: Even before de-risking, we had to create capabilities that didn't exist. There was no HALEU enrichment in the U.S. When the war started four years ago, we made the decision not to utilize Russian fuel—for business reasons and public acceptance reasons.

We recognized that ASP Isotopes in South Africa had this capability, and we're procuring HALEU from them. We made an investment and did serious technical due diligence. They're progressing and will support our schedule.

For metalization, these processes existed around the world, but nothing recently on the commercial side. With just private investor money—no DOE [U.S. Department of Energy] money—we contracted with Framatome to pilot the metalization line in Richland, Washington. We recently publicized production of the first uranium metal pucks. Eventually, those pucks will be extruded into fuel rods.

We do need multiple paths. That's why we're encouraging DOE to award grants under the HALEU Availability Program. DOE has been given over $3 billion by Congress to invest in American LEU and HALEU production. We have a plan we're managing closely for the first core load for Kemmerer in 2030, but we're going to follow the first plant quickly with scale-up. We need lots of capacity and a diverse supply chain. We've invested in one fuel manufacturing facility with Global Nuclear Fuel in North Carolina, but as we deliver additional units, we'll need to expand that industrial capacity.

Bill Gates always asks me two things: how we stay on time for the first unit, and how fast can we scale. Just last week at Davos, he met with HD Hyundai's chairman about scaling up to build multiple Natrium reactors per year at their facility in Korea.

POWER: The Meta agreement announced in January calls for up to eight Natrium units. What's the biggest execution risk in scaling from a single unit to fleet deployment?

Levesque: If you think of typical challenges—regulatory risk is well in hand. We're about to get a construction license early. That's a really new story for nuclear. Long schedule durations? For us, it begins with less steel, less concrete, less labor. That's how you have a faster schedule. We're in the phase with Bechtel where we really understand those quantities and can validate an aggressive schedule.

My biggest concern is labor and supply chain. We haven't been building plants in the U.S., so we don't have enough craft labor. It's important that Natrium consumes less labor—that's part of solving it. But mobilizing many reactors simultaneously requires tens of thousands of workers. We talk with DOE about how to manage this. University presidents come to us wanting to discuss PhD programs. I try to pivot them: "Can we talk about your work with community colleges on apprentice programs for welders and electricians?"

For supply chain, the few reactors built in the free world have been done one at a time, as a project, not a product. We really need to think about continuous flow manufacturing. HD Hyundai makes over 50 ships a year, so they have this operating model down. That's why we're working with them on our reactor enclosure system.

POWER: Natrium pairs a sodium reactor with molten-salt energy storage—a distinctive innovation. How has this shaped your business model as the power industry evolved?

Levesque: About six years ago, we were hearing from multiple utilities that it would be great if we could load-follow. Even though nuclear had been baseload, utilities were saying this because of renewables on the grid. Large gigawatt-scale light-water reactors have limitations in how quickly they can change power.

We had this innovation where we realized we could keep our reactor running at the same power all the time, but use molten salt tanks like a thermal battery to flex our power. The 345-MW plant can vary its output up to 500 MW for five hours.

A big collateral benefit we didn't realize at first: by placing the molten salt tanks between the turbine and the nuclear island, we decoupled the whole secondary plant from the reactor. We made a case to the NRC that our whole energy island—the molten salt tanks and turbine—is non-nuclear. So, when we procure those components and build that part of the plant, it's done with non-nuclear controls.

The paradigm was that the NRC oversees everything onsite. For Natrium, really only about a third of the plant is under NRC cognizance. About two-thirds of Kemmerer is under Wyoming's cognizance. That was a pretty big regulatory breakthrough as well.

POWER: What advice would you give other advanced nuclear developers navigating today's opportunities and uncertainties?

Levesque: At a macro level, we can see the electricity demand. Nuclear has a great story—small land area, small consumption of materials. Multiple technologies make sense. It's really going to be about putting together delivery teams. This is hugely capital intensive, not a business for the faint of heart.

Did we need regulatory changes? Yes, we've been supportive. But you should really prioritize communication with communities and the regulator over a speedy process. That approach has worked for us and will lead to a faster approval in the end. It'll also help with subsequent plants. As we look at the UK and South Korea, we already have significant engagement with regulators. We want to show them the rigor we went through with the NRC. That's super important. If you're focused on safety and rigor, you shouldn't have to worry about expediting the regulator.

Why Innovation Became Inevitable

In some ways, as experts have explained to *POWER*, the breaking of new ground across the global nuclear sector has been a delayed consequence of forces already in motion. In 2020, *POWER* reported on the industry's quest for reinvention, as it grappled with multiple factors, including an aging fleet, market forces, and policy pressures. At the time, the shift felt incremental. But in 2026, it looks inevitable.

"This moment differs from past nuclear 'renaissances' in fundamental ways," Idaho National Laboratory (INL) Director Dr. John Wagner explained to lawmakers in January. "Historic energy demand growth driven by data centers and artificial intelligence (AI) infrastructure, unprecedented private-sector investment flowing into nuclear technologies, the emergence of new innovative reactor developers, and critical national security needs requiring reliable baseload power have converged with bipartisan Congressional support and a federal commitment to removing decades of regulatory barriers," he said."For the first time in decades, market forces, national security imperatives, and federal policy have achieved remarkable alignment. The question is no longer whether America needs nuclear energy, but how much, how quickly, and how to make it happen."

The urgency is underscored by an interesting interplay of geopolitical factors, Wagner noted. China and Russia now dominate global nuclear construction, accounting for roughly 94% of reactors under construction worldwide, while U.S. deployment has remained largely stalled for nearly four decades, aside from the long-delayed completion of Vogtle Units 3 and 4 in Georgia. And while China alone has more than 30 reactors under construction, Russia's state-owned Rosatom is building units across multiple foreign markets, pairing construction with export models designed to lock in long-term influence. "We must reclaim nuclear leadership," Wagner said, warning that nuclear technology has become a strategic asset shaping energy security, industrial competitiveness, and global standards for decades to come.

The Biggest Lever: Policy

In February 2025, adding to a substantial bipartisan buildup (including from previous administrations) championing new nuclear power, the Trump administration outlined an ambitious goal to make nuclear a "pillar of American dominance." Pivotally, it set out an imperative to expand from 100 GW of nuclear capacity to 400 GW by 2050. It followed that policy in quick succession in May 2025 with four sweeping executive orders that addressed several longstanding systemic barriers (see sidebar: "The 2025 Executive Orders That Transformed Nuclear's Trajectory"). These, for example, include regulatory delays that have historically stretched licensing to five years or more, fuel supply vulnerabilities that foster a dependence on foreign enrichment services, and the absence of a coherent federal framework for siting advanced reactors on public lands.

The orders build on progress already established by past Department of Energy (DOE) Office of Nuclear Energy efforts to deploy first-of-a-kind nuclear technologies, including its Advanced Reactor Demonstration Program (ARDP), under which several awardees—notably TerraPower's Natrium and X-energy's Long Mott project—have completed critical design milestones and attracted substantial private investment. In tandem, the DOE has continued to advance Biden-era programs, including the Generation III+ Small Modular Reactor Program, the Demonstration of Operational Microreactor Experiments (DOME), and ongoing efforts to support fuel qualification, materials testing, and spent fuel recycling across the national laboratories.

In December 2025, the department awarded up to $800 million in cost-shared funding under its Generation III+ Small Modular Reactor Program to Tennessee Valley Authority (TVA) and Holtec Government Services, supporting TVA's GE Vernova Hitachi BWRX-300 project

The 2025 Executive Orders That Transformed Nuclear's Trajectory

In May 2025, President Trump signed four executive orders that seek to quadruple U.S. nuclear capacity by 2050—from 100 GW to 400 GW—through fuel security, regulatory reform, accelerated testing, and national security deployments.

EO 14302: Reinvigorating the Nuclear Industrial Base

- Invokes Defense Production Act to mobilize nuclear fuel supply chain commitments.
- Directs Department of Energy (DOE) to expand domestic uranium conversion and enrichment capacity within 120 days.
- Directs DOE to release 20 metric tons of high-assay low-enriched uranium (HALEU) from existing inventories to support demonstrations while expanding domestic fuel fabrication capacity.
- Requires spent fuel management and recycling policy recommendations by January 2026.
- Prioritizes federal loans for reactor restarts, power uprates, and suspended projects.
- Targets 5 GW of uprates at existing reactors and 10 new large reactors under construction by 2030.

EO 14300: Reforming the Nuclear Regulatory Commission (NRC)

- Mandates "wholesale revision" of NRC regulations with final rules within 18 months.
- Establishes fixed licensing deadlines—18 months for new reactor approvals, 12 months for license renewals—with fee caps tied to compliance.
- Directs reconsideration of linear no-threshold radiation model and As Low As Reasonably Achievable (ALARA) standards.
- Narrows Advisory Committee on Reactor Safeguards (ACRS) scope to "truly novel or noteworthy" issues.
- Calls for streamlined National Environmental Policy Act (NEPA) compliance and potential general licenses for standardized microreactors.

EO 14301: Modernizing DOE Reactor Testing

- Establishes Reactor Pilot Program targeting three test reactor criticalities by July 4, 2026.
- Directs "significantly expedited" review processes for qualified test reactors.
- Requires guidance on qualified test reactor criteria within 60 days and regulatory reforms within 90 days.

EO 14299: Deploying Advanced Nuclear for National Security

- Requires an Army-regulated nuclear reactor operational at military base by September 2028.
- Designates artificial intelligence (AI) data centers at DOE facilities as critical defense infrastructure.
- Directs DOE to release 20 metric tons of HALEU from stockpiles for private projects.
- Orders State Department to negotiate 20 new Section 123 agreements for nuclear cooperation by January 2029.
- Expedites Part 810 export authorizations to 30-day reviews.

At the American Nuclear Society's Winter Conference in November 2025, while experts generally acknowledged that the four orders represent an unprecedented alignment of policy, capital, and customer demand, they pointed to several nuanced considerations.

First, panelists stressed that nuclear fuel supply is strategically existential. Because the U.S. now relies on imports for roughly 99% of its enrichment, private fuel-cycle investments—such as new domestic enrichment capacity—must ramp in parallel with reactor deployment, potentially creating a significant coordination challenge between government policy, utilities, and suppliers.

Second, while cultural transformation at the NRC is underway, reforms will only succeed if its unprecedented collaboration with DOE and industry firmly embraces that safety and efficiency can genuinely coexist, so that faster processes are seen as disciplined and risk-informed rather than less rigorous, they said.

Third, panelists warned that execution capacity—not intent—may be the binding constraint. While executive order–driven targets such as first criticality by July 4, 2026, are real, even if highly aggressive, they assume timely fuel delivery, DOE authorizations, NRC alignment, and on-schedule construction from a still-immature supply chain. Success will require DOE, the national labs, and vendors to sustain "concierge-style" project ownership, iterate rapidly on first-of-a-kind builds, and avoid treating the pilot program as a one-off victory rather than the start of a repeatable, scalable deployment model, experts suggested.

And finally, experts generally were optimistic that the Department of War's commitment to programs like Project Janus—the Army's new microreactor program of record, which is built on a NASA-style, milestone-based model with multiple vendors and up to nine initial bases—could break the first-mover problem. By designating an executive agent, funding milestones, and sharing first-reactor risk in partnership with DOE, Idaho National Laboratory, and the Defense Innovation Unit (the Pentagon's rapid-procurement arm for commercial technology), the Pentagon is giving vendors confidence that successful demonstrations will unlock subsequent commercial orders—and that could create a market flywheel that transcends government procurements.

at the Clinch River site in Tennessee and Holtec's planned SMR-300 deployment at the Palisades site in Michigan. Earlier, in July 2025, the DOE made its first conditional selections for testing at the DOME facility at INL, choosing Radiant Nuclear's Kaleidos reactor and Westinghouse's eVinci design for fueled experiments in the repurposed Experimental Breeder Reactor II containment. Testing is slated to begin as early as spring 2026, and additional application rounds are planned annually. The May executive orders, meanwhile, have kick-started new initiatives, most notably the Reactor Pilot Program, the Fuel Line Pilot Program, and the DOE's updated authorization process.

Finally, and as significantly, the DOE's financing office—now called the Office of Energy Dominance Financing (EDF)—has implemented a range of commercialization initiatives. In November, Energy Secretary Chris Wright suggested nuclear would be the primary beneficiary of that authority. "I think the strong pull of AI for more electricity is going to bring billions of dollars of equity capital in from very creditworthy providers. And then that'll be matched three to one, maybe even up to four to one with low-cost debt, dollars from the Loan Programs Office," he said.

Regulatory Momentum and Roadblocks

For now, the DOE's work builds on nearly a decade of bipartisan Congressional groundwork, a foundation that began in 2018 with passage of the Nuclear Energy Innovation and Modernization Act (NEIMA) and the Nuclear Energy Innovation Capabilities Act (NEICA), continued through the Energy Policy Act of 2020's provisions to address fuel availability and commercialization, and culminated in the Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy (ADVANCE) Act of July 2024, which mandates a sweeping modernization of NRC licensing timelines and processes.

In parallel, Congress has appropriated $3.4 billion to strengthen domestic nuclear fuel supply chains through the HALEU (high-assay low-enriched uranium) Availability Program as a response to vulnerabilities laid bare by Russia's 2022 invasion of Ukraine and to the lingering reliance on Russia as the sole commercial supplier of HALEU required by many advanced reactor designs.

The measures have been pivotal for first movers, noted Nuclear Innovation Alliance President Judi Greenwald. Over the past five years, the NRC has made licensing "more risk-informed, performance-based, technology-inclusive, and efficient," progress driven less by abstract rulemaking than by "more than a dozen advanced reactor developers engaging one-on-one with the NRC under existing rules," she said. For example, while Kairos Power's pioneering Hermes 1 construction permit took roughly two years, Hermes 2 was approved in 16 months with 60% fewer NRC resources (Figure 3). TerraPower's Natrium review was completed in 18 months—nine months faster than initially estimated and under budget, and NuScale's US460 design approval came in two months early and 13% below cost. The NRC now estimates construction permit reviews of 18 months for X-energy's Long Mott project in Texas and 17 months for TVA's Clinch River BWRX-300.

3. Kairos Power installs the reactor vessel for its third Engineering Test Unit (ETU 3.0) at the company's Oak Ridge, Tennessee, site in July 2025. The non-nuclear prototype is designed to refine manufacturing and construction methods for the Hermes reactor. Courtesy: Kairos Power

And beyond schedule compression, Greenwald pointed to structural reforms that lower execution risk across the entire pipeline. Under the ADVANCE Act, the NRC finalized licensing fee reform effective October 2025, cutting hourly fees for advanced reactor applicants by more than 50%, extended reactor design certifications from 15 to 40 years to support repeat deployment, and adopted a risk-informed approach to right-sizing emergency planning zones, steps that she said reduce cost, improve predictability, and materially improve fleet viability. At the same time, under NEIMA, the NRC has "nearly completed" the Part 53 rulemaking to establish a "risk-informed, performance-based and technology-inclusive" licensing framework for advanced reactors, potentially moving those gains from case-by-case execution into a durable regulatory backbone.

Still, even with those gains, Greenwald cautioned that execution now hinges on capacity as much as policy. The speed and scope of reform have placed sustained pressure on federal agencies, particularly the NRC and DOE, as they manage staffing constraints, technical expertise, and institutional continuity. Continued progress, she told lawmakers, will require "maintaining staffing levels at various federal agencies," preserving the NRC as "a trusted independent regulator," and ensuring transparency as licensing timelines compress—and that balance will demand steady appropriations, workforce retention, and disciplined coordination across the NRC, DOE, and Department of War. Missed targets, uneven implementation, or erosion of transparency, she said, risk repeating past deployment setbacks that "damaged the industry's credibility for decades."

Ultimately, early movers will carry a substantial burden of proof, she suggested. "In recent years, industry, advocates, policymakers, and stakeholders have worked hard to rebuild that credibility through technology and commercial

The July 4 Reactor Pilot Gambit

In June 2025, the U.S. Department of Energy (DOE) unveiled an audacious challenge rooted in four Trump administration executive orders signed in May 2025: to demonstrate three reactors achieving criticality by July 4, 2026, the U.S.'s 250th anniversary. Under the DOE Reactor Pilot Program, which operates outside traditional Nuclear Regulatory Commission (NRC) licensing pathways, participating reactors are subject to DOE safety review and NRC technical coordination, but do not require an NRC operational license for demonstration purposes. While sometimes miscast as a regulatory "shortcut," the DOE's long-standing authority is limited to federally owned research, test, and fuel-cycle facilities, and does not bypass the NRC's role over the commercial fleet.

So far, as of January 2026, the 11 projects from 10 companies picked under the DOE's Reactor Pilot Program have announced notable progress toward criticality. As Idaho National Laboratory (INL) Director John Wagner explained in January Congressional testimony, "When enough fissile material is assembled in the right configuration, it achieves criticality, which is a sustained fission chain reaction"—a foundational physics milestone every reactor must reach to validate its design, safety case, and readiness. "So, it's a normal progression of the technology testing and demonstration that occurs. It's sort of an early step in that process."

Energy Secretary Chris Wright tempered expectations in November 2025, saying, "We will have at least one, maybe two, by [the] July 4 date, and others next year, and several others in the following year." In January, Wagner offered his perspective. "I doubt they will all make it," he said, referring to the 11 reactors pursuing DOE authorization. "But the thing that's really exciting is that I do think three can make it and the others will follow quickly thereafter. So, while July 4 is a major milestone, there's an August and a September and October that will follow, and I think we will see quite a number of these reactors again as their initial demonstration in 2026 that will lead to commercial deployment," Wagner predicted optimistically.

For now, *POWER's* analysis shows that at least seven projects have signed Other Transaction Authority (OTA) agreements with the DOE, while four have broken ground, and three have reached major design milestones within the past 60 days.

Antares Nuclear—MARK-0 500-kWth Sodium Heat-Pipe Microreactor | INL. Antares Nuclear cleared a decisive regulatory barrier on Jan. 25, 2026, when the DOE approved its Preliminary Documented Safety Analysis (PDSA), making it the first reactor to receive that approval under the DOE Reactor Pilot Program. Mark-0, which relies on passive sodium heat-pipe thermosyphon circulation, is slated to go live "before July 4," and will "validate fueling operations, reactor controls, and core physics," the company said. "This demonstration is a critical step toward generating electricity from advanced microreactors. Mark-0 uses a full-scale core and the same facility and fuel that will support our next reactor test in 2027," it said.

Antares began machining the graphite core on January 12 at its Antares Prime facility, locking in one of the project's most schedule-sensitive components. The company's fabrication of high-assay, low-enriched uranium (HALEU) tri-structural isotropic (TRISO) fuel began in October, following a DOE allocation in August. While the company closed a $96 million Series B round in December—bringing total capital raised to $130 million—its active contracts with the Department of War and NASA tally to more than $13 million. Final DOE operational authorization is expected within roughly 90 days. If that timeline holds, Antares positions itself as one of the clearest candidates to achieve demonstration-level criticality in 2026, with power ascension testing planned for later this summer or fall.

Oklo—Aurora-INL 75-MWe Liquid-Metal Fast Reactor | INL. Oklo broke ground on Sept. 22, 2025, at INL, marking the first private-sector fast-reactor construction at a U.S. national laboratory. Kiewit Nuclear Solutions is serving as the engineering, procurement, and construction (EPC) contractor under a master services agreement signed in July 2025. Oklo has secured five metric tons of HALEU fuel down-blended from the Experimental Breeder Reactor-II (EBR-II), the same facility on which Aurora's design is based. Fuel fabrication will occur at Oklo's Aurora Fuel Fabrication Facility at INL, which the DOE approved for its Nuclear Safety Design Agreement in November 2025.

Oklo began major procurements in 2025, including in-vessel and ex-vessel handling machines, primary and intermediate sodium pumps, and reactor trip systems. The company has mobilized heavy equipment for site earthwork and scheduled controlled blasting and excavation to begin in late 2025 and early 2026. Aurora scales proven sodium-cooled fast-reactor technology demonstrated at EBR-II between 1964 and 1969 to 75 MWe. Oklo is pursuing DOE authorization to accelerate the timeline to initial operations at Aurora INL and will transition to NRC licensing for full commercial deployment. Power ascension is projected in the fourth quarter of 2026.

Valar Atomics—Project NOVA/ Ward-250 100-kWth High-Temperature Gas-Cooled Reactor | Utah San Rafael Energy Lab. Valar Atomics achieved zero-power criticality on Nov. 17, 2025, at Los Alamos National Laboratory's National Criticality Experiments Research Center at the Nevada National Security Site. Project Nova is a critical assembly—a zero-power physics experiment, not a power-producing reactor—that used the same graphite, TRISO fuel elements, fuel-to-moderator ratio, B4C control rods, and cladding specifications planned for Ward-250, Valar's DOE Reactor Pilot Program project, which targets power criticality by July 4, 2026, at Utah's San Rafael Energy Lab.

Over a week-long campaign in November at Project Nova, the company conducted 10 critical configurations and 26 subcritical tests, generating 100 GB of experimental data, including foil activation measurements and external helium-3 detector readings to validate neutronics codes and control rod worth calculations. CEO Isaiah Taylor emphasized that Valar is the first startup to design and build a reactor core from scratch and achieve criticality—distinct from companies that place fuel in existing reactors for irradiation. Project Nova validated Valar's neutronics predictions before Ward-250 construction. The power plant will follow the same commissioning sequence: cold zero-power critical, hot zero-power critical, then power ascension. Series A funding of $130 million closed in November 2025. Construction broke ground in September 2025, with Kiewit Nuclear Solutions as the EPC contractor.

4. Aalo Atomics CEO Matt Loszak leads a team site visit to the company's reactor construction facility at Idaho National Laboratory (INL). The photo captures the scale of Aalo-X, a 10-MWe sodium-cooled microreactor selected for the Department of Energy Reactor Pilot Program targeting July 4, 2026 criticality. Courtesy: Matt Loszak / Aalo Atomics

Aalo Atomics—Aalo-X 10-MWe Sodium-Cooled Microreactor | INL. While Aalo completed a major design review on Jan. 22, 2026, that involved DOE and NRC participation, its 40,000-square-foot Austin manufacturing facility is already fabricating reactor modules for on-site assembly at INL, demonstrating factory-built deployment readiness. Construction kicked off at the previously disturbed INL parcel already approved for the canceled Versatile Test Reactor program, accelerating siting approvals (Figure 4).

In 2025, Aalo scaled its team five times, launched a pilot manufacturing factory in Austin, Texas, and completed major DOE milestones including design reviews and the Critical Assembly Facility at INL. "They said you can't even build a tool shed at the desert site [in] under 2 years," noted Chief Technology Officer Yasir Arafat. "Well, at Aalo Atomics, we just built the building for our first reactor in 36 days."

HALEU fuel will be supplied through Oklo's Aurora Fuel Fabrication Facility once authorization is completed by May 2026. Aalo's vertical basalt-drilling approach and standardized module design seek to reduce construction cost and schedule versus conventional builds. Series B funding ($100 million) provides runway through criticality. CEO Matt Loszak has committed to "founding to fission in less than three years," with July 4 a stated target.

Natura Resources—MSR-1 1-MWth Molten Salt Reactor | Abilene Christian University (ACU), Texas. Natura Resources' MSR-1 project at ACU has fully installed its reactor vessel and is awaiting fuel insertion. On Jan. 4, 2026, the DOE allocated FLiBE coolant salt—a lithium fluoride–beryllium fluoride mixture containing 99.99% enriched lithium-7 sourced from Oak Ridge's historic Molten Salt Reactor Experiment. The DOE separately committed HALEU fuel for the reactor. Detailed engineering is complete and procurement is underway at ACU's Science and Engineering Research Center.

The university holds the NRC research reactor construction permit issued in September 2024, and MSR-1 operates under DOE Authorization for Experiment. Natura's design builds on proven molten-salt technology from the 1965–1969 Oak Ridge operations with modern safety enhancements. CEO Doug Robison said the salt allocation "ensures we can remain on track to deploy our MSR-1 in 2026." Power ascension is targeted for the third quarter 2026. The company has secured $120 million in private funding and a $120 million state commitment from Texas.

Last Energy—PWR-5 5-MWe Pressurized Water Microreactor | Texas A&M-RELLIS. Last Energy closed Series C funding of more than $100 million in December 2025, allocating about $35 million to complete the PWR-5 pilot at Texas A&M-RELLIS campus. The company procured a full-core load of LEU fuel in December 2025 and secured a land lease at RELLIS. The PWR-5 and commercial PWR-20 share identical physical designs, so pilot testing will directly advance commercialization pathways. Texas A&M and Last Energy signed a collaboration agreement in October 2025. Testing is slated to begin in summer 2026, targeting safe low-power criticality. Separately, Last Energy is advancing a 30-unit data center project in Haskell County, Texas.

Radiant Industries—Kaleidos 1-MWe Helium-Cooled Microreactor | INL Demonstration of Microreactor Experiments (DOME) Facility. Radiant is targeting a spring 2026 installation and 60-day operation at INL's DOME facility. The company secured the first Western commercial HALEU contract with Urenco in September 2025, de-risking fuel supply for commercial production. Series D funding of more than $300 million in December 2025 will bring its total capital above $500 million and accelerate the groundbreaking of the R-50 factory in Oak Ridge, Tennessee, targeting 50 reactors annually by 2030.

Heat rejection systems are being tested in California ahead of installation. Founded by former SpaceX engineers, Radiant has demonstrated execution velocity across procurement, regulatory approval, and manufacturing scale-up. It suggests a July 4 criticality is an explicit company target.

Terrestrial Energy—Project TETRA/Project TEFLA Integral Molten Salt Reactor (IMSR) Pilot and Fuel Facility | Texas and UK. Terrestrial Energy signed an OTA with the DOE on Jan. 6, 2026, for Project TETRA, a molten salt reactor pilot that runs on standard-assay LEU (<5% U-235), sidestepping the HALEU bottleneck entirely. A parallel OTA for Project TEFLA, signed Jan. 22, covers a fuel fabrication pilot. The commercial IMSR design produces 822 MWth (390 MWe). CEO Simon Irish said the agreement "allows the company to expedite key elements of its program to prepare licensing applications for commercial plant operation." The siting and construction timelines remain unannounced.

Deep Fission—Gravity Reactor 15-MWe Pressurized-Water Reactor, Underground Borehole | Parsons, Kansas. Deep Fission held a groundbreaking on Dec. 9, 2025, at the Great Plains Industrial Park in Parsons, Kansas, a 14,000-acre site formerly used for munitions production. The Gravity reactor sits one mile underground in a 30-inch borehole, where bedrock provides passive shielding and natural containment. The approach eliminates costly above-ground structures, the company says. Deep Fission estimates a 70% to 80% cost reduction compared to conventional plants and a six month timeline from groundbreaking to operation.

The design combines established nuclear, oil-and-gas drilling, and geothermal technologies, using standard LEU fuel. Deep Fission targets July 4, 2026, criticality pending DOE authorization. The company, founded in 2023 by father-daughter team Richard and Elizabeth Muller, reported 12.5 GW in letters of intent from potential customers in Kansas, Texas, and Utah. A letter of intent with the Great Plains Development Authority supports future commercial expansion at the same site.

Atomic Alchemy—VIPR 15-MWth Light-Water Reactor for Radioisotope Production | Texas. Atomic Alchemy, an Oklo subsidiary, signed an OTA with the DOE on Jan. 7, 2026, for the Versatile Isotope Production Reactor (VIPR), a 15-MWth light-water reactor designed to produce medical and industrial radioisotopes including molybdenum-99 and actinium-225. The facility will irradiate targets for diagnostics, disease treatment, medical research, and national security applications. CEO Jacob DeWitte said the OTA "establishes a framework for execution and risk reduction. By building and operating a pilot reactor, we generate the data and experience to streamline future commercial deployments."

VIPR uses established light-water technology optimized for neutron flux rather than power generation. Atomic Alchemy withdrew its previous NRC construction permit application for the Meitner-1 commercial facility at INL to focus on the pilot. The facility location has not been announced. Atomic Alchemy projects first isotope revenues following pilot operations, positioning VIPR as one of the few DOE pilot projects with near-term commercial revenue potential outside electricity generation.

innovation, setting more realistic expectations, implementing federal programs and regulatory reforms, and demonstrating steady progress," she noted. "Public support for nuclear energy is growing again, but successful early mover projects and maintaining public trust are essential to sustain that momentum."

A Multi-Pronged Execution Landscape

Perhaps the most elaborate, distinctive factor driving the current momentum for nuclear is the scope of its architecture. Federal policy seems to have essentially opened four lanes at once, each advancing under distinct authorities, financing models, and timelines.

One lane runs through DOE-authorized demonstrations, and it includes programs such as the Reactor Pilot and the ARDP, honing in on first-of-a-kind performance, fuel qualification, and construction sequencing. These projects, however, are being propelled by a compressed schedule (see sidebar: "The July 4 Reactor Pilot Gambit").

The second lane centers on commercial deployment backed by long-term offtake. Utilities and industrial customers are pairing new reactors with committed demand from hyperscalers, manufacturers, and grid operators, and it includes a series of lucrative deals and power purchase agreements (PPAs) that *POWER* has reported on in detail from companies such as Amazon, Meta, Google, Microsoft, and Dow. These projects serve to anchor financing decisions and pull projects forward from demonstration into scale.

A third lane involves government-led projects, which Wagner described as mission-oriented deployments advancing on a separate track from commercial power—citing the Department of War's Project Pele (Figure 5) developed by BWX Technologies, DOE-led test reactors such as MARVEL at INL, and the Army's Project Janus program, which seeks to deploy microreactors at multiple military installations by 2027–2028.

The fourth lane, which involves a resurgence for large reactors, appears to be now coming to the fore. Executive Order 14300 requires at least 10 new large reactors under construction by 2030, and as Wagner noted, "An August 2024 INL analysis identified 65 potential sites across the U.S., finding that 18 sites are particularly promising for near-term AP1000 deployment, with an additional 29 sites having strong potential." While no projects have broken ground,

5. Project Pele, developed under the Department of War's Strategic Capabilities Office, is a mobile microreactor designed to deliver 1 MW to 5 MW of power for military and critical infrastructure applications. INL staff prepare to receive tri-structural isotropic (TRISO) particle fuel manufactured by BWX Technologies Inc. for the reactor's planned testing in December 2025. Source: INL

in October 2025, Westinghouse owners Brookfield and Cameco announced an $80 billion agreement with the U.S. government centered on large reactor deployment, though no details have yet been disclosed.

Westinghouse has suggested it is fielding a substantial pipeline, including efforts to restart construction at the V.C. Summer site in South Carolina (where Brookfield has partnered with Santee Cooper), as well as proposals by Fermi America to build four AP1000 units in Texas. Other potential projects include sites that already hold NRC early site permits, including Clinton in Illinois, Grand Gulf in Mississippi, North Anna in Virginia, Vogtle in Georgia, PSEG's Salem-Hope Creek site in New Jersey, TVA's Clinch River site in Tennessee, and Turkey Point Units 6 and 7 in Florida, where the NRC has authorized construction but no work has begun.

"We are past what we call the first-of-a-kind stage," said James Wyble III, Westinghouse's vice president of AP1000 project development, who emphasized that the AP1000's design is complete, supply bottlenecks are mapped, and the company now views the challenge as moving rapidly into "next-of-a-kind and Nth-of-a-kind" construction by reinvigorating domestic manufacturing, labor, and long-lead procurement.

Still, John Williams of Southern Nuclear Operating Company, drawing directly on Southern's experience completing Vogtle Units 3 and 4, cautioned that despite AP1000 design maturity, new large reactors remain constrained by high upfront capital costs, exposure to construction "tail risk," balance-sheet and credit pressures on sponsors, and an underdeveloped domestic supply chain. "The construction of Vogtle Units 3 and 4 is a textbook example of how these kinds of events, over which the developer has no control, can cause disruption, impede progress, and raise costs," Williams recently told lawmakers, arguing that targeted federal risk mitigation is necessary to bridge the gap from early projects to true "Nth-of-a-kind" deployment. Some specific policy mechanisms that could serve as evidence-based solutions include enhanced investment tax credits for early projects, federal cost-sharing to address construction tail risk, and reforms to tax-credit transferability to improve cash flow during construction, he suggested.

The Supply Chain Bottleneck: Five Constraints on First Movers

As several first movers told *POWER*, however, the biggest challenge that lays ahead is rooted less in policy ambition and more in the physical realities of fuel supply, manufacturing capacity, and labor availability. Gaps, they suggested, persist across multiple, interdependent layers.

HALEU Enrichment Remains an Immediate Choke Point. Many advanced reactor designs require HALEU, fuel material enriched up to 19.75% U-235, compared with roughly 5% for today's operating fleet. But, "Currently, no commercial-scale HALEU production exists in the U.S.," Wagner noted. While Centrus Energy's Ohio demonstration facility began limited HALEU production in October 2023—producing roughly 900 kilograms by mid-2025—and INL can supply small quantities from existing inventories for fuel qualification and testing, neither pathway supports sustained commercial deployment. So far, the DOE's January 2026 award of $2.7 billion to enrichment projects under the HALEU Availability Program marked progress, but deconversion capacity—a step required to turn enriched uranium into reactor-ready fuel—has yet to be awarded.

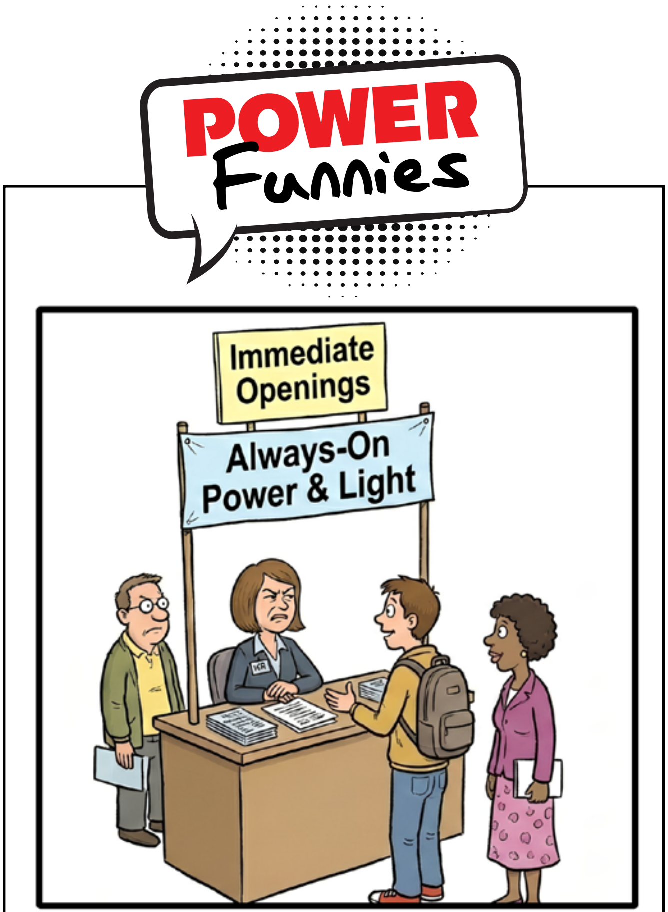
Advanced Fuel Fabrication Is an Emerging Constraint. Beyond enrichment, several advanced reactor designs depend on specialty fuels that are significantly more complex to manufacture than conventional fuel assemblies. High-temperature gas-cooled reactors and some microreactors require TRISO fuel—uranium kernels encased in multiple ceramic and carbon layers designed to retain fission products under extreme conditions. While DOE-supported production has allowed limited quantities for defense and demonstration projects, including early fuel for Department of War programs, experts note that current fabrication capacity is insufficient to support scaled commercial deployment. Even where enrichment pathways exist, fuel qualification, throughput, and quality assurance remain gating steps that must expand in parallel with reactor construction schedules.

Large-Component Manufacturing Presents a Parallel Constraint. Another key consideration is that reactor pressure vessels, steam generators, and other nuclear-grade forgings require specialized capabilities that the U.S. largely lost during decades of inactivity. Wagner warned that domestic production of long-lead components "remains insufficient to meet expected demand," forcing developers to rely on overseas suppliers. Southern Nuclear's Williams noted that although Vogtle Units 3 and 4 retired major technology and licensing risks, the lag in follow-on projects has already led to some atrophy in the workforce and supply chain advances achieved during construction. Today, notably, nuclear-grade forgings are sourced primarily from Japan, South Korea, and France, and industry estimates suggest rebuilding certified domestic capacity could require five to seven years—and a sustained multi-unit order book—to justify the capital investment.

Workforce Availability Compounds Both Challenges. Finally, several experts have pointed out to *POWER* that deploying new nuclear capacity at the scale envisioned will require tens of thousands of additional engineers, licensed operators, technicians, and craft workers. The bottleneck appears most acute in nuclear-qualified trades. While Vogtle alone employed roughly 9,000 craft workers at peak construction, the simultaneous builds of multiple large reactors would require multiples of that workforce. Without a visible, continuous pipeline of projects, experts caution that training capacity, credentialing, and labor retention remain fragile.

"Rebuilding and scaling these supply chains takes time and sustained investment," noted Korsnick. "Clear demand signals, execution certainty, and federal support can help manufacturers make the investments needed to deliver components reliably and at scale." For now, continued coordination among Congress, the Trump administration, states, educational institutions, labor, and industry could help the U.S. ensure it has the people, capabilities, and industrial capacity needed to deliver nuclear energy over the long term. ■

*—**Sonal Patel** is a POWER senior editor.*



"MY QUALIFICATIONS? .. I KNOW HOW TO POWER UP A VIDEO GAME CONSOLE!"

Closed-Loop Geothermal Systems Require Precision Drilling and Ranging

Geothermal energy now stands out as a reliable, low-carbon solution in the transition to a balanced energy mix. While conventional geothermal systems rely on specific geological conditions, such as hot rock, abundant water, and permeability, these conditions only exist in specific regions. As a result, traditional geothermal development faces geographic limits and high capital costs.

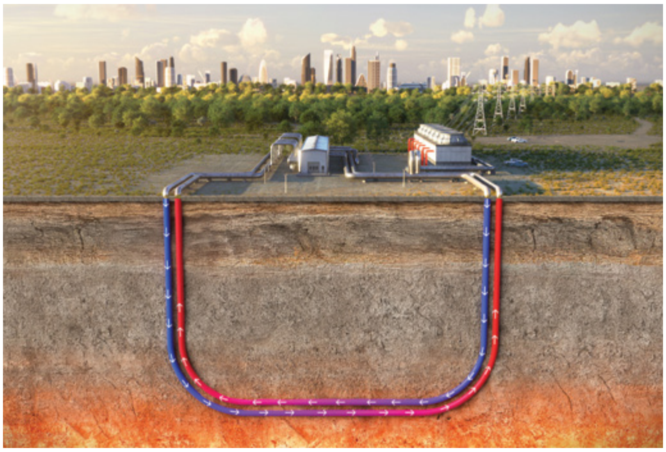
Closed-loop geothermal systems extract heat conductively, through the casing, removing the complexity/challenges of fluid exchange with the reservoir, and offer another method of harvesting geothermal energy. They operate in sealed subsurface loops, which allows operators to deploy them in regions that lack traditional hydrothermal reservoirs. With its expertise in drilling and completions, along with advanced drilling and ranging technologies, the oil and gas industry is uniquely positioned to build closed-loop geothermal systems.

How closed-loop systems expand geothermal viability

Closed-loop systems circulate fluid through a sealed network of subsurface pipes. The fluid absorbs heat from the rock and carries it to the surface, where it powers turbines or provides direct heating. This approach eliminates the requirement for natural hydrothermal reservoirs and helps operators avoid environmental risks associated with fluid reinjection.

This design simplifies permitting and expands geographic flexibility. Operators can construct systems in sedimentary basins, depleted oil fields, and other locations once considered unsuitable for geothermal development. This flexibility opens new markets and reduces reliance on rare geological conditions.

Several startups have begun the commercialization of closed-loop systems. One example includes a startup that deploys a novel configuration that uses directional drilling and subsurface magnetic ranging to create efficient heat exchange pathways. Another startup has developed a proprietary thermally conductive cement that improves thermal transfer and bolsters system durability. These innovations will help revolutionize closed-loop geothermal production.



Precision drilling makes closed-loop geothermal possible

Closed-loop systems require precise well placement regardless of the configuration. Operators must drill accurate well paths with minimal deviation to land in the target window and/or thread the needle to intersect wellbores. Both configurations demand advanced directional drilling technologies.

High-temperature rotary steerable systems and positive displacement motors support this precision. These tools operate at temperatures up to 392°F (200°C) and use metal-to-metal power sections that resist degradation. Real-time inclination and azimuth data, combined with azimuthal gamma ray sensors, facilitate accurate geosteering and borehole quality control. Halliburton has drilled thousands of parallel wellbores for applications such as steam-assisted gravity drainage relief wells and complex plug-and-abandonment operations that require magnetic ranging technology. These projects demonstrate the ability to maintain trajectory control and spacing accuracy in complex subsurface environments.

*—**Tim Stephens,** global geothermal account manager, Halliburton*

Continue the article on POWER Magazine's website

Geothermal Groundbreakers: The Projects Redefining Firm Clean Power

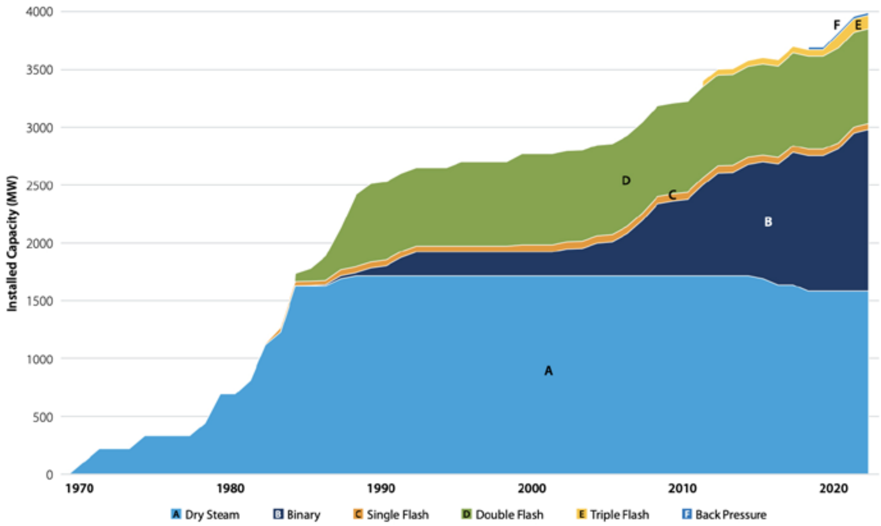
A handful of geothermal projects are crossing from experimentation into execution, testing whether drilling gains, reservoir control, and new market demand can turn subsurface risk into firm, contractable power.

Sonal Patel

Since 2021, geothermal power's proposition has been quietly shifting, driven primarily by encouraging policy, but also a new class of decisive buyers. In response to reliability concerns and rising demand for firm power, utilities, corporations, and data center operators have signed dozens of new power agreements. But, as the *2025 U.S. Geothermal Market Report*, released in January 2026 by the National Laboratory of the Rockies (NLR, formerly the National Renewable Energy Laboratory) and Geothermal Rising, shows, the commercial activity, long centered on conventional geothermal (Figure 1), has morphed into fresh support for emerging geothermal technologies, including enhanced geothermal systems (EGS) and advanced (closed-loop) geothermal (CLG).

According to the report, a collaborative effort that updates a landmark 2021 U.S. industry-federal assessment, next-generation geothermal systems now account for 60% of all geothermal power purchase agreements (PPAs) signed between 2021 and mid-2025—a remarkable pivot for a technology that secured its first commercial PPA only in 2022. Utilities have procured or agreed to procure 984 MW of next-generation capacity across California, Nevada, New Mexico, Texas, and locations east of the Rocky Mountains through 11 PPAs. The report also notes that while companies at the forefront of developing and commercializing these technologies have raised more than $1.5 billion in private capital since 2021, enhanced geothermal and closed-loop technology companies brought in $990 million and $604 million, respectively, between 2021 and mid-2025.

That momentum, meanwhile, also has international traction. In a January update, the International Energy Agency (IEA) revealed that financing for next-generation geothermal reached nearly $2.2 billion in 2025—an 80% year-over-year increase from just $22 million in 2018. Conventional geothermal attracted nearly $5 billion in funding in 2025, a fourfold increase from 2018, while geothermal heating projects secured more than $11.5 billion in 2025 alone. In another key finding, the IEA analysis suggests that investor confidence is maturing, noting that the global share of equity financing declined from 70% between 2018 and 2020 to just over half between 2023 and 2025, as companies increasingly secured debt alongside data center power and critical mineral supply agreements.



1. Dry steam and flash technologies have historically underpinned U.S. geothermal generation, but capacity additions since 2020 have shifted decisively toward binary plants. From 2020 to 2024, binary systems accounted for 53 of 61 new geothermal plants, reflecting their flexibility in utilizing lower-temperature resources and reduced operational complexity compared with flash technologies. Source: National Laboratory of the Rockies and Geothermal Rising, 2025 U.S. Geothermal Market Report (January 2026)

Three Forces Converging on Next-Generation Geothermal

For now, the reports point to three overlapping forces that appear to be accelerating a transition to next-generation geothermal (Figure 2), propelling them from pilot-stage experimentation toward commercial relevance. These include rapid technology gains, a market shift that places new value on firm power, and policy frameworks designed to absorb early risk.

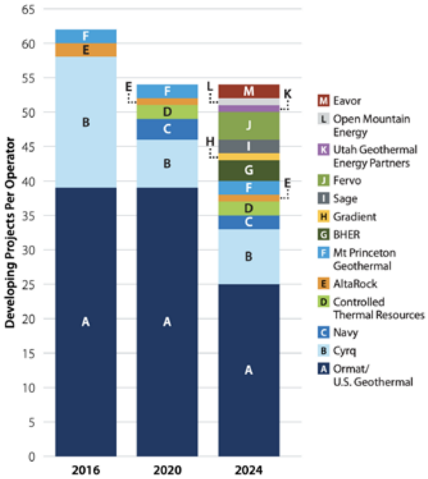
First, drilling and subsurface engineering advances are materially changing project economics. The *2025 U.S. Geothermal Market Report* documents measurable performance improvements at both government-backed testbeds and private-sector developments. At the U.S. Department of Energy's (DOE's) Utah Frontier Observatory for Research in Geothermal Energy (FORGE), drilling performance has improved substantially over a short period. The report notes that "reduction in on-bottom drilling hours" has been a defining outcome of recent campaigns, with drilling rates improving from roughly 8 meters per hour (m/hr) in early campaigns to nearly 15 m/hr by 2024, and peak rates reaching 26 m/hr during select intervals.

The gains are being replicated at Fervo Energy's Cape Station in Utah, where the EGS firm reported drilling rates of 30 m/hr and a reduction in drilling costs to roughly $350 per foot. Many improvements, which include "advances in polycrystalline diamond compact bit design and use of physics-based techniques to optimize mechanical specific energy and maximize sustained rate of penetration," derive directly from shale oil and gas practices. Innovations have helped cut well costs by up to 30% while meeting expectations that asset lifetimes can extend beyond 25 years, the report suggests.

Meanwhile, electricity markets are beginning to pay explicitly for firm, always-available power. The report also suggests that next-generation geothermal projects are no longer competing solely on energy price against variable renewables. Until 2023, most developers "could only secure electricity price guarantees equivalent to solar and wind projects," typically in the range of $30/MWh to $60/MWh, it notes, but that pricing dynamic has changed as load growth accelerates and reliability constraints sharpen, particularly in data-center-heavy regions.

According to the IEA, geothermal's appeal lies in its ability to provide "an around-the-clock, low-emissions source of power," particularly as "power systems place a growing premium on firm supply." The IEA notes that developers are now securing higher-value contracts, including with big tech players, noting that some agreements are reaching about $130/MWh. Google's 115-MW agreement with Fervo Energy and Meta's commitments to source 150 MW from Sage Geosystems and additional capacity from XGS Energy illustrate that this premium pricing extends even to first-of-a-kind projects.

Third, policy interventions are deliberately targeting early-stage risk. Both U.S. and international analyses emphasize that next-generation geothermal remains highly capital-intensive and exposed to significant upfront uncertainty. Geothermal projects "remain among the most capital-intensive in the energy sector, with drilling and well costs often representing up to 80% of total costs,"



2. U.S. geothermal project activity by operator (2016–2024). Ormat remains the most active geothermal developer in the U.S., accounting for 26 of the 54 commercial projects currently reported as under development. While several previously active companies have exited the market since 2016, newer entrants—most notably next-generation developers—have expanded the project pipeline. Fervo Energy now has four enhanced geothermal system (EGS) projects in development, including a Nevada project supplying electricity to Google data centers. Source: National Laboratory of the Rockies and Geothermal Rising, 2025 U.S. Geothermal Market Report (January 2026)

placing many developments in what it calls the "technology valley of death," where projects are "too big for venture capitalists alone and too risky for established corporate energy players," the IEA notes. Bridging that gap, however, are targeted policy tools—including the DOE's geothermal research and development funding, Germany's accelerated permitting paired with drilling risk insurance, and risk-mitigation facilities in the Philippines, Germany, and East Africa.

Groundbreakers: Projects Redefining What Geothermal Can Do

So far, a small but growing set of geothermal projects are moving beyond theory and pilot-scale promise to test what next generation technologies can deliver under commercial conditions.

Fervo Cape Station Phase 1: Proving EGS Economics at Commercial Scale. Fervo Energy's Cape Station in Beaver County, Utah (Figure 3), represents the Houston-based company's effort to scale EGS from pilot scale to utility-grade capacity, with a planned 500-MW buildout—100 MW in Phase 1 targeted for 2026 and 400 MW in Phase 2 by 2028. The project draws directly

3. Fervo Energy's Cape Station site in Beaver County, Utah, where construction of Phase I wells and power plant infrastructure is advancing toward a targeted 100-MW in-service date by the end of 2026. Courtesy: Fervo Energy

from Project Red in Nevada, which in 2023 became the first commercially viable EGS by demonstrating that an enhanced geothermal resource could be drilled, stimulated, tested, and integrated into an existing utility-scale power plant without new grid infrastructure. Project Red delivered 3.5 MW, sustained peak production of 63 kilograms per second (kg/s) at 191C for 37 consecutive days, and began supplying power to NV Energy's Blue Mountain facility in November 2023 under a standard PPA.

Cape Station's significance lies in demonstrating that EGS economics can work at a commercial scale. As of September 2024, 15 wells had been drilled at the site, with 29 planned for Phase 1. Drilling costs have fallen from roughly $1,050 per foot at Project Red to an average of $450 to $550 per foot at Cape Station, with the best wells approaching $350 per foot; recent appraisal wells were drilled in just 16 days. According to the company, 30-day testing has achieved flow rates of up to 107 kg/s—enabling more than 10 MW per production well, roughly triple Project Red's per-well output. Through 2024, the project secured $973 million in financing ($642 million equity and $331 million debt), marking the first large-scale institutional lending for EGS, and all 500 MW of capacity is fully contracted, led by Southern California Edison, Shell Energy, and California community choice aggregators.

Operational momentum has continued into 2025. Fervo reports that nearly all Phase 1 wells have now been drilled, including 12 completed between April and October 2025, one of the most active drilling periods to date. Wells feature laterals averaging about 5,000 feet, supported by dense subsurface monitoring using fiber-optic cables, borehole seismometers, and surface nodal arrays. In testimony before the House Natural Resources Subcommittee in December

2025, CEO Tim Latimer emphasized the pace of improvement, stating, "We've already shown a 75% reduction in drilling time and a 70% cost per foot reduction since 2022." He also highlighted a mid-2025 milestone in which Fervo drilled a 16,000-foot well in 16 days at bottomhole temperatures approaching 520F—a 79% reduction relative to DOE baselines—strengthening the case for EGS deployment well beyond traditional geothermal regions.

Utah FORGE: De-Risking EGS Reservoir Connectivity and Seismicity. The DOE's Utah FORGE site, which sits adjacent to Fervo Energy's Cape Station in Beaver County, Utah, completed a 28-day continuous circulation test between August and early September 2024 that directly addressed two longstanding barriers to EGS commercialization: reservoir sustainability and induced seismicity control. Since 2017, seven wells have been drilled at the site, including paired deviated injection and production wells—16A(78)-32 and 16B(78)-32—linked by a multistage hydraulically stimulated fracture network completed in March 2024.

During the circulation trial, cold water injected into the reservoir was produced at stable temperatures of approximately 185C to 196C. "In early September 2024, a 28-day circulation test was completed at Utah FORGE, during which 15 MW of thermal power was continuously produced, fulfilling a major milestone," said Stuart Simmons, a geoscientist on the Utah FORGE team. Tracer testing and downhole diagnostics confirmed that flow remained confined to the engineered fracture network rather than dispersing into uncontrolled pathways, validating reservoir connectivity without excessive fluid loss.

Induced seismicity was monitored using a dense surface and subsurface seismic network and actively managed through a traffic-light protocol. Simmons emphasized that the site's low-to-moderate natural seismicity, combined with real-time monitoring, enabled effective risk control during stimulation and circulation. While FORGE does not generate commercial electricity, the test produced critical performance data that underpinned DOE's February 2024 awards for EGS pilot demonstrations and helped de-risk private financing for projects such as Fervo's Cape Station.

Sage Geosystems–Ormat Partnership: Pressure Geothermal Brownfield Deployment. In January 2026, Houston-based Sage Geosystems joined forces with Ormat Technologies to deploy the world's first commercial Pressure Geothermal power generation facility at an existing geothermal plant in Nevada. The project, which will leverage brownfield infrastructure to de-risk execution and accelerate timelines, will drill deeper beneath an Ormat conventional geothermal site to access hot dry rock, deploying Sage's proprietary Geopressured Geothermal System (GGS)—a single-well EGS variant using controlled pressurization to create vertical fractures in low-permeability formations without requiring paired injection-production well doublets. By utilizing Ormat's existing turbines, grid connections, and offtake agreements, the partnership eliminates permitting, interconnection, and surface plant construction delays, reducing development timelines by 1.5–2 years compared to greenfield projects. The facility will produce 4–6 MWe and targets online status in 2027.

The technology's commercial viability was validated through Sage's San Miguel Electric Cooperative Inc. (SMECI) Well #1 in Christine, Texas, which achieved 70–75% roundtrip efficiency, 17-hour discharge capability, and <2% water loss while operating as the world's first commercial-scale pressure geothermal energy storage facility. Commissioned August 2025 and grid-interconnected December 2025, the project was a *POWER* Top Plant last year.

The Ormat partnership signals Tier-1 industry validation. In January 2026, Ormat co-led Sage's $97 million Series B funding alongside Carbon Direct Capital, bringing total equity raised to $114 million. While Ormat CEO Doron Blachar emphasized that the collaboration aims to "significantly reduce the time and costs needed to bring EGS to market," Sage CEO Cindy Taff has described the Nevada facility as validating "the technology and allows us to scale it quicker" ahead of the company's 150-MWe PPA with Meta Platforms, signed in August 2024 (with a 2027 commissioning target), to supply data center baseload power. Additional government validation includes a $1.9 million U.S. Air Force grant awarded in September 2024 and Department of War contracts for Naval Air Station Corpus Christi and Marine Corps Air-Ground Combat Center Twenty-Nine Palms, both awarded in August 2025. If the Ormat deployment meets targets in 2026–2027 and the Meta project achieves its 2027 commissioning milestone, Sage's single-well pressure geothermal architecture could become a preferred EGS design for sedimentary basins and brownfield expansions.

Eavor Geretsried Commercial Deployment: First Closed-Loop Grid Delivery. Eavor Technologies' Geretsried project in Bavaria, Germany, achieved a technical milestone in December 2025 by delivering its first electricity to the commercial grid from a CLG system. The project validates that sealed-wellbore multilateral drilling at 4.5-kilometer (km) depth can produce power without requiring natural reservoir permeability or subsurface water interaction. Construction began in October 2022, and drilling commenced in July 2023 to build four planned Eavor-Loop installations, targeting an aggregate electric output of 8.2 MWe (or 64 MWth in district heating mode).

As of January 2026, one loop has been commissioned and is delivering power to the German grid. Each loop comprises two vertical wells with six horizontal laterals sidetracked from each (12 total per loop), connected underground via magnetic ranging to form a 16-km continuous wellbore radiator. The work builds on previous projects, including the first two-leg multilateral deep geothermal well in the U.S. in New Mexico. "In that project, Eavor drilled a single vertical well with a sidetrack to a true vertical depth of 18,000 ft and rock temperature of 250C, a first in the U.S. geothermal industry," the NLR report notes.

While Geretsried represents a first-of-a-kind demonstration project, it is heavily supported by public financing (€136.6 million in grants and subsidized debt) and Germany's €250/MWh feed-in tariff. The project secured €350 million in total investment, including €91.6 million European Union Innovation Fund grant and €45 million European Investment Bank debt. Eavor documented a 50% reduction in drilling time and an improvement in bit performance across successive laterals, demonstrating CLG learning potential. Still, commercial viability will depend on performance from remaining loops through 2026–2027 and whether costs can approach market competitiveness in future deployments. Eavor, notably, signed a 20-MWe PPA with NV Energy in 2022 for potential U.S. expansion.

On The Horizon

While near-term growth in geothermal power is being driven by EGS and closed-loop deployments, a wider set of emerging technologies and applications are also poised to reshape geothermal's long-term role.

One notable frontier is superhot geothermal, which targets fluids above the critical point of water (374C, 221 bar). At these temperatures, individual wells could deliver five to 10 times the energy output of conventional geothermal systems, and modeling suggests they could achieve levelized costs up to 50% lower than today's systems. Mazama Energy, for example, is drilling toward superhot conditions at Newberry Volcano in Oregon (see sidebar: "Mazama Energy's Push Toward Superhot EGS"). Meanwhile, the Advanced Research Projects Agency-Energy's (ARPA-E's) $30 million Stimulate Utilization of Plentiful Energy in Rocks Through High-Temperature Original Technologies (SUPERHOT) program, launched in 2025, seeks to address materials durability, drilling survivability, and reservoir control. Multiple assessments by the Clean Air Task Force conclude that the physics are sound, though the think tank notes commercial deployment will hinge on testing equipment under sustained superhot conditions.

Hybridization—pairing geothermal with solar thermal, photovoltaic (PV) generation, or storage—represents perhaps a more near-term opportunity. NLR modeling suggests that geothermal–solar thermal hybrids could reduce system levelized cost of energy (LCOE) by up to 50% relative to PV plus batteries, while improving overall conversion efficiency by roughly 20% versus standalone geothermal plants. Several hybrid configurations are already operating at projects in Nevada led by Ormat Technologies and Cyrq Energy.

Underground thermal energy storage, which reframes geothermal as a storage medium rather than a purely extractive resource, is another emerging theme. Technologies such as aquifer thermal energy storage, geological thermal energy storage, and borehole thermal energy storage are already widely deployed in Europe for heating and cooling. In the U.S., pilot projects in California and Texas are exploring megawatt-scale power applications, including Carnot battery concepts that store surplus electricity as subsurface heat.

Closely related is the shift toward flexible and dispatchable geothermal operations. Historically operated as baseload plants, geothermal facilities are increasingly capable of load-following, ramping, and ancillary services such as frequency regulation and spinning reserve. Empirical analysis shows that flexible geothermal dispatch could increase plant value by up to $4/MWh in markets such as California by curtailing output during low-price periods and increasing generation during high-price intervals, the NLR report notes. It also notes that more recent modeling suggests that coupling EGS with in-reservoir pressure or thermal storage could increase project energy value by 30% to 60% compared with strictly baseload operation.

Critical mineral extraction, particularly lithium from geothermal brines, has also emerged as one of the most commercially advanced non-power applications. U.S. Geological Survey assessments indicate that brines in Arkansas's Smackover Formation and California's Salton Sea could supply a substantial share of domestic lithium demand. At the Salton Sea, companies including Controlled Thermal Resources are already integrating geothermal generation with lithium production, seeking to turn drilling-intensive projects into diversified industrial assets. While high upfront capital costs remain a barrier, operating costs appear competitive with hard-rock mining. ■

—***Sonal Patel*** *is a POWER senior editor.*

Mazama Energy's Push Toward Superhot EGS

In October 2025, Dallas, Texas–based Mazama Energy disclosed that it had reached a 331C (629F) bottomhole temperature at its enhanced geothermal system (EGS) pilot site at Newberry Volcano, Oregon (Figure 4)—marking the hottest reported operating temperature achieved in an EGS reservoir to date. While still below the superhot geothermal threshold—defined by conditions exceeding the critical point of water at 374C and 221 bar—the result is a "breakthrough" that "sets a new global benchmark for geothermal technology and marks a critical step towards delivering low-cost, carbon-free baseload power at terawatt-scale, targeting less than 5 cents/kWh," the company said.

4. Mazama Energy's Newberry geothermal pilot in Oregon reached a reported bottomhole temperature of 331C (629F) in October 2025, marking the hottest operating EGS disclosed to date. Courtesy: Mazama Energy

The pilot at Newbury, one of the largest geothermal reservoirs in the U.S., builds on decades of federally supported EGS research—beginning with Los Alamos National Laboratory's Fenton Hill experiments and extending through Utah FORGE—but it advances into substantially hotter and more heterogeneous volcanic rock. At Newberry, Mazama interconnected a legacy injector well with a newly drilled 10,200-ft deviated production well, confirming circulation and reservoir connectivity at temperatures beyond those previously validated in U.S. EGS demonstrations.

Mazama reports that drilling and completion activities maintained well integrity under ultra-high-temperature conditions, enabled by proprietary technologies combined under its MUSE (Modular Unconventional Superhot Energy) platform. These include high-temperature directional drilling, the Thermal Lattice stimulation process designed to enhance fracture connectivity, and Heat Harvester modeling tools intended to forecast long-term thermal output and well integrity.

Mazama now plans to advance to a 15-MW pilot beginning in 2026, followed by a proposed 200-MW development at Newberry. Longer-term ambitions include drilling into superhot rock regimes exceeding 400C, which the company argues could deliver materially higher power density per well, reduce total well counts, and lower water use relative to conventional EGS designs. That trajectory positions Mazama as one of the most technically consequential tests underway of whether superhot EGS can transition from experimental validation to a scalable, always-available power source—particularly for industrial and data center loads seeking firm, carbon-free energy.

Help Wanted: Staffing Strategies for the Power Industry

With retirements outpacing new entrants and data centers driving unprecedented demand for electricity, the power generation sector faces a critical inflection point in workforce development.

Aaron Larson

The U.S. power industry is confronting a workforce challenge unlike any it has faced in decades. An aging workforce is accelerating toward retirement, taking with it irreplaceable institutional knowledge and specialized skills. At the same time, surging electricity demand—driven by data centers, manufacturing reshoring, and grid modernization—is creating unprecedented need for skilled workers. The question facing the industry is no longer whether a labor shortage exists, but how severe it will become and what can be done to address it.

According to the U.S. Department of Energy's 2025 *U.S. Energy and Employment Report (USEER)*, the energy sector employed 8.5 million workers in 2024, accounting for 5.4% of all U.S. jobs. Electric power generation alone employed nearly 933,800 workers with a median wage of $65,430. Yet, these numbers mask a troubling reality: the industry is struggling to find workers with the specialized skills needed to keep the lights on.

The International Energy Agency's (IEA's) *World Energy Outlook 2025 (WEO)* puts this challenge in global perspective. Energy employment worldwide expanded by 2.2%—1.7 million jobs—in 2024, outpacing the economy-wide employment growth rate of 1.3%. The power sector consolidated its position as the largest employer in the global energy industry with 22.6 million jobs. The IEA noted, however, that skilled labor shortages "are already constraining energy operations," with half of the more than 600 companies surveyed reporting "critical hiring bottlenecks" that result in "project delays, longer lead times, and cost overruns."

To better understand how these macro trends are playing out on the ground, *POWER* spoke with executives at American Professional Staffing Solutions (APS Solutions), a Sedalia, Missouri–based staffing firm that specializes in placing workers at power generation facilities across the country. Their insights reveal an industry at a crossroads—one where traditional fossil generation is experiencing renewed demand even as the skilled workforce capable of operating these plants continues to shrink.

1. *Specialized welding skills, such as those needed for boiler work and high-pressure piping, are among the hardest to find. Source: Envato*

The Talent Shortage Is Real

Al Simon, President and CEO of APS Solutions, offered a blunt assessment. "Today's labor pool is challenging," he said, noting that the issue extends beyond technical qualifications to include lack of awareness and knowledge with some younger workers. On the skills side, Simon emphasized that while there may be "plenty of video game developers and people who know how to code," the same cannot be said for highly specialized trades (Figure 1). "There are very few people left who know how to 'buddy' weld or mirror weld, get skinny to fit in tight places while a back draft is killing your arc. There, a huge skill shortage exists. Angle welding, pipefitting, heavy-lift pickers—those skills are becoming harder to replace."

"The talent shortage has become an increasing issue over time as folks reach retirement and leave the industry without nearly as many entering the industry as there used to be," said Bob Coggin, Staffing Manager at APS Solutions. "This has led to an unfortunate experience gap as well that creates challenges in the transference of tacit knowledge and industry wisdom to younger generations."

The Bureau of Labor Statistics (BLS) data supports these observations. While overall employment of power plant operators, distributors, and dispatchers is projected to decline 10% from 2024 to 2034 due to technological advances and greater efficiency, the agency still projects about 3,800 openings annually—all expected to result from workers transferring to other occupations or exiting the labor force to retire. The median annual wage for these positions was $103,600 in May 2024, reflecting the premium employers must pay for experienced talent.

Where the Gaps Are Most Acute

Not all skill categories are equally affected. According to APS Solutions executives, certain disciplines have suffered greater shortages than others. "Electrical commissioning personnel, for example, have become increasingly harder to find," Coggin noted. "Specialty skill sets such as technical advisors, protective relay technicians, and even power plant experienced civil/structural folks are becoming more of a rarity."

Chris Cooley, Chief Operations Officer at APS Solutions, expanded on this theme: "The most common skill gaps we see are in experienced craft trades and technically trained field roles, particularly among professionals with advanced safety certifications, specialized equipment experience, and strong industrial maintenance backgrounds. Lead field positions such as foremen, supervisors, and project coordinators who blend technical expertise with leadership are also in high demand."

Simon specifically highlighted operations and maintenance workers for older technology, especially vintage coal plants, as a critical gap. "Skilled crafts—tube welders, boiler makers—under certain administrations there was a focus on shutting down these types of plants, so naturally younger talent is shying away from this type of work," he explained. "The question now is, are these plants and older technology going away any time soon?"

The IEA's analysis reinforces these concerns at a global level. The agency found that six out of 10 occupations in the energy sector where shortages are most acute are in skilled trades—including electricians, grid line workers, solar photovoltaic (PV) installers, pipefitters, welders, and heating, ventilation, and air conditioning (HVAC) installers. Notably, the latest liquefied natural gas (LNG) investment cycle has been particularly marked by shortages of welders, pipefitters, and electricians, driving up costs industry-wide, the agency said.

The Aging Workforce Challenge

The aging workforce problem is perhaps the most frequently cited concern in the industry, and for good reason. Britt Smith, Sales Manager at APS Solutions, described the situation starkly: "The aging workforce in power generation is creating a critical gap between retirements and operational expertise, forcing customers and utilities—especially those operating legacy and coal assets—to rely on APS Solutions to develop a flexible, experienced contract staffing plan to maintain reliability and compliance."

2. Experienced workers pass along decades of institutional knowledge to the next generation—a transfer that becomes harder as retirements outpace new entrants. Courtesy: APS Solutions

Coggin called it "a very acute and very real challenge," noting that "many industry veterans are at, or have already reached, retirement age and thus are taking many years of collective wisdom, insight, and industry knowledge with them when they leave."

The data is sobering. According to IEA analysis, in advanced economies, retirements are outpacing new entrants across the energy sector (Figure 2). Nearly 30% of union electricians in the U.S. may retire within a decade, the *WEO* says. Notably, for every young person joining the grid sector, there are 1.4 workers nearing retirement—well above the economy-wide average. Meanwhile, Canada expects retirements of 700,000 trade workers by 2028, the report notes.

A September 2025–issued report from the Center for Strategic and International Studies (CSIS) examining the labor demands of artificial intelligence (AI) infrastructure development notes that nearly one-fifth of construction workers are 55 or older, with a median age of 42. Many retire in their late 50s due to the physical demands of their work—meaning the retirement wave will hit just as AI infrastructure projects peak.

However, there is a silver lining. "Many contractors in the industry choose to continue working well past retirement age, and that is helping bridge this gap somewhat as long as there are sufficient mentorship initiatives in place," Coggin observed. Simon echoed this point, noting that APS Solutions has built relationships with utility workers nearing retirement. "When they retire, they come and join our team at APS Solutions as a W-2 contract employee. It is really a great opportunity for them, and a win-win-win for them, us, and our end customers, who get the talent they need."

A Shifting Energy Landscape

The mix of staffing needs has shifted notably in recent years, reflecting broader changes in the energy landscape. While renewable energy jobs have seen significant growth, APS Solutions executives report that their clients are experiencing a resurgence in demand for traditional generation expertise.

"In recent years, energy staffing leaned heavily on renewable energy roles like solar, wind, and storage," Cooley explained. "Today, while renewables remain necessary, their intermittent nature—combined with the rapid growth of data centers and the resulting need for consistent, reliable power—is driving a

3. Specialized technical roles are expanding rapidly, yet the industry remains in direct competition with traditional sectors for essential skilled labor. Courtesy: APS Solutions renewed increase in demand for traditional energy sectors such as natural gas, nuclear, and other fossil fuel operations."

Gabe Norman, Director of Staffing and Recruiting at APS Solutions, was more direct: "We are seeing the demand for renewable energy expertise diminish and the demand grow for traditional fossil fuel, and specifically temporary power operations. The temporary power market is in huge demand right now due to fracking and data center growth."

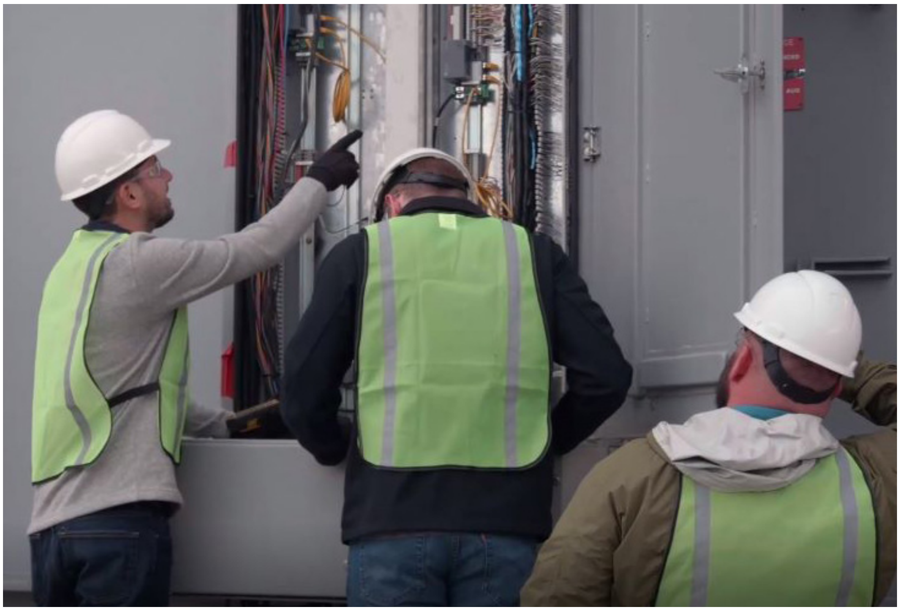
The DOE's employment data as reported in recent *USEERs* paints a more nuanced picture, however. While natural gas power generation employment did grow a robust 3.8% in 2024—the largest percentage gain among electric power generation subsectors—clean energy technologies still accounted for roughly four out of five net new energy jobs overall, with solar adding more than 6,000 positions. The apparent contradiction may reflect the difference between aggregate hiring trends and specific skill demands: construction roles drove 86% of net new energy employment in 2024 (Figure 3), potentially masking tighter labor markets for operations and maintenance personnel in traditional generation. Both realities can coexist—and likely will, as utilities and independent power producers work to balance grid reliability with long-term capacity expansion.

Data Centers: A New Driver of Demand

The explosive growth of data centers—driven largely by AI applications—is emerging as one of the most significant factors in energy workforce planning. While the core skill requirements haven't changed dramatically, the scale and pace of construction are creating new challenges.

"Owners, contractors, and operators all agree that they will need a certain portion of their workforce to be skilled contractors," Simon explained. "Most of these plants are not built near where the technical and skilled talent lives. New construction of a simple cycle baseload LM6000 facility takes about 120 to 150 days. You will need a construction/commissioning manager, mechanical, electrical, I&C. Our customers have some of this talent in house, but finding the rest local will be a challenge."

The CSIS report projects between 63,000 and 140,000 additional skilled workers will be needed beyond baseline growth to meet demand. That includes electricians, HVAC pipefitters, heavy-equipment operators, construction laborers (Figure 4), and welders. "These figures matter because skilled trades are not easily fungible," the report says. "Electricians cannot be trained overnight, HVAC technicians cannot be repurposed from other sectors, and welders or equipment operators require years of preparation. Labor needs of this magnitude cannot be met by reallocating the existing workforce; they require an expansion of the pipeline itself."



4. Skilled construction workers remain in high demand as power generators expand capacity to meet growing electricity needs from data centers and industrial reshoring. Courtesy: APS Solutions

Norman noted that the varied generation mix at data center facilities creates its own staffing challenges. "Understanding that due to unit availability these facilities are oftentimes using a mix of different methods of generation, being able to leverage contract employees that have varied experience is key. They may be operating frame units, trailer-mounted temporary power, etc. Sometimes these are locally controlled vs. a standardized control room, and having seasoned operators that can support these projects is key," he said.

Nuclear's Workforce Implications

The growing interest in nuclear power—both for existing fleet support and new builds, particularly small modular reactors (SMRs)—represents another dimension of the workforce challenge. However, most APS Solutions executives say the immediate impact on hiring remains limited.

"This remains to be seen," Coggin said. "SMR technology will likely take the lead on new nuclear construction and operation as utilities tend to shy away from the cost and public scrutiny of building new baseload capacity nuclear power plants. However, even SMR reactors have yet to be implemented into the industry on a wide enough scale to significantly impact staffing needs. I expect that will change in the very near future."

Cooley offered a similar assessment. "At this time, we're not seeing a major impact on the construction and commissioning workforce demand from nuclear, largely because nuclear projects have long development cycles before approvals and construction begin," he reported. "That said, we are seeing more independent power producers, utilities, and developers planning nuclear additions, particularly around SMRs. So, while the immediate effect is limited, the talent demand is coming, and it will be important for the industry to prepare for it in the near future."

The nuclear sector faces particularly acute demographic challenges. The IEA found that nuclear has one of the most severe ratios of retiring workers to new entrants, with 1.7 workers nearing retirement for every young person joining the sector.

Compensation Trends

How are wage expectations and compensation packages evolving in response to these pressures? There's clearly money flowing into certain skill categories and positions, but it's not always the more educated workers who are cashing in.

"Wages and benefits are evolving to where they should be," Simon said. "Very talented carbon steel or dissimilar-metal welders are making more money than degreed engineers these days." He noted power producers are having to pay more to attract talented skilled craftsmen and high-level project managers, while compensation for plant engineers has stayed relatively flat.

Coggin mentioned that from the traveling contractor's perspective, expectations have remained relatively stable. "Traveling contractors have always expected to 'live on the road' and are mostly willing to work anywhere as long as the pay and package is right," he said. Notably, however, he has observed that clients are beginning to evaluate overall costs differently, with some seeking talent from local markets to reduce living and travel expense reimbursement.

Cooley emphasized the strategic advantage of geographic flexibility: "The wider the geographic area a company is willing to draw talent from, the greater the pool of skilled, qualified candidates available—and that's a major advantage in today's competitive labor market."

Cross-functional skills command a premium. "As the talent pool tightens, cross-functional workers are becoming increasingly valuable and in demand," Cooley noted. "However, that versatility comes at a premium, and employers need to be willing to pay more for professionals who can wear multiple hats and add value across functions."

Contract Staffing: From Stopgap to Strategy

Perhaps one of the most significant shifts in the industry is the evolving role of contract and temporary staffing. Once viewed primarily as a stopgap measure, supplemental staffing is increasingly becoming a permanent structural feature of workforce planning.

"In the heavy industrial markets we serve—power, energy, process, oil and gas, and renewables—workforce needs are inherently project-based and cyclical," Cooley explained. "What's changing is that more companies are recognizing they don't have the internal infrastructure to effectively manage contract labor at scale, even if they believe they do. As a result, partnering with supplemental staffing firms, such as APS Solutions, is becoming a permanent structural solution."

Simon characterized APS Solutions' role as helping customers "hyperscale," which he called "incredibly important in the fast-paced projects to support infrastructure for artificial intelligence campuses." He noted that while APS Solutions employees remain APS Solutions employees and the company is not a temp-to-hire organization, they have several customers that rely on APS Solutions to handle all field hiring. "They decided they didn't want to carry that overhead, risk, and workload," he said.

Norman pointed to the practical advantages for clients. "With the fluctuating labor demands for existing plants or new construction projects, I feel that supplemental staffing is becoming a more feasible option for clients to build into their long-term plans," he said. "It is much easier to lean on a company like APS Solutions that can provide temporary short-term or long-term solutions with qualified individuals, rather than putting the burden on a company's internal HR [human resources department] and hiring teams."

5. Vocational programs help develop the next generation of skilled trades workers—a pipeline the industry is working to diversify. Courtesy: APS Solutions

Retention and Development Strategies

Amid the challenges, some strategies are proving effective for workforce development and retention. "The most effective strategies we're seeing focus on retention through stability, engagement, and clear career paths," Cooley observed. "Clients who invest in consistent work schedules, competitive compensation, and strong safety cultures tend to keep talent longer. We're also seeing success where companies partner closely with staffing providers to create longer-term, project-based assignments rather than short-term fills, which gives workers more certainty and loyalty."

The IEA emphasizes the critical role of vocational education and training (VET) systems in meeting future energy workforce needs (Figure 5). The agency calls for coordinated policies to expand and modernize VET systems, with priorities including expanding certification capacity, modernizing training to match emerging technologies, strengthening provider-employer partnerships, improving the perception of vocational degrees, and broadening access to VET programs.

Cooley highlighted active engagement with educational institutions. "One of the root causes [of the talent shortage] is a long-term shift in education away from promoting the skilled trades in favor of technical and white-collar paths, which are important but shouldn't come at the expense of the trades," he said. "That's why APS Solutions actively works with local high schools, technical schools, and colleges to raise awareness and help rebuild the pipeline of qualified craft and technical professionals our industry depends on."

Major technology companies are also stepping up. One example is Google's support for an effort to train 100,000 electrical workers and 30,000 new apprentices in the U.S. With funding from Google.org to the electrical training ALLIANCE (etA), an organization created by the International Brotherhood of Electrical Workers (IBEW) and the National Electrical Contractors Association (NECA), etA will integrate AI tools into its curriculum and boost the number of apprentices nationally.

In a Reuters article published in April 2025, Kenneth Cooper, president of the IBEW, said, "This initiative with Google and our partners at NECA and the electrical training ALLIANCE will bring more than 100,000 sorely needed electricians into the trade to meet the demands of an AI-driven surge in data centers and power generation."

On the Ground: Real-World Solutions

The APS Solutions executives shared several examples of how their staffing solutions have addressed real workforce challenges at power facilities.

Smith described a scenario involving a large utility that had announced the planned shutdown of several baseload plants: "Once the closures were made public, a significant portion of the full-time workforce left to secure long-term employment elsewhere, even though the utility was still required to operate the plants through their official closure dates. APS Solutions worked closely with the client to develop a project-based staffing plan, supplying experienced contract professionals ranging from plant management to maintenance craft roles. This approach allowed the utility to maintain safe, reliable operations with minimal disruption until each facility reached its scheduled shutdown."

Simon described a similar situation where employees at a utility in the southern U.S. were "put between a rock and hard place" as they faced a choice between staying at plants scheduled for closure or accepting longer-term positions elsewhere. "Everyone would do what is best for their families. There is no blame," he said. "APS Solutions provided temporary operations support to backfill these key positions. Our employees are still out there today—everyone is happy!"

Crisis situations are common. Smith recalled a scenario involving a coal facility. "A customer operating a highly critical coal facility experienced a sudden departure of several key team members including CROs [control room operators], AOs [auxiliary operators], and maintenance personnel who left for opportunities at a nearby data center," Smith explained. "APS Solutions immediately developed and executed a staffing plan, rapidly mobilizing experienced personnel to fill the critical roles and stabilize operations."

Simon described another rapid-response situation. "A customer was in a jam. Independent power producer—peaking combined cycle facility and had to ramp up to baseload for eight months," he described. "We mobilized an operations strike team to embed with their current staff and management to round out 24/7 operations support. Customer met their eight-month schedule—and we redeployed our employees to other projects."

6. APS Solutions retains high performers by transitioning them between projects, cutting recruitment costs and focusing on strategic redeployment. Courtesy: APS Solutions

The Path Forward

The power industry's workforce challenges are not going away anytime soon. The IEA projects that energy-related employment will expand in the medium and long term across all scenarios, but it says the pace of growth depends on the availability of specialized workers (Figure 6). Weldingworkforcedata.com, a website endorsed by the American Welding Society (AWS), estiimates that 320,500 new welding professionals will be needed in the U.S. by 2029. That's significant, considering there are reported to be about 771,000 welding professionals working in the U.S. today with more than 157,000 approaching retirement.

Norman offered a note of optimism about the younger generation. "In recent years, there has been a shift in the younger generations pursuing trade schools and/or apprenticeships," he said. "That will still lead to an overall skills gap in the industry that will take some time to cover, but there will be an incoming generation that will be eager to take advantage of that and rise to the occasion. The opportunities in front of them will be great!"

For plant managers struggling to maintain adequate staffing levels, Simon's advice was straightforward. "Find a great staffing partner and build a great relationship with them. They can really help support you and take some of the staffing worry off your plates," he said.

Cooley elaborated, "First, take a hard look at your compensation strategy and be willing to adjust where needed. For urgent gaps, consider partnering with a firm like APS Solutions to supplement staffing through contract/temporary labor while you work through longer-term hiring. Using experienced contract talent allows plants to maintain performance and avoid penalties while taking the time to hire and properly onboard the right full-time employee—often with that contract professional helping train their replacement once hired."

When asked what differentiates successful client relationships, Simon pointed to APS Solutions' fundamental philosophy. "We believe in three strong pillars at APS Solutions: Employee Care, Employee Redeployment, and Customer Service. We believe if you take care of the first two—the last one takes care of itself," he said.

The power industry has weathered numerous challenges over the decades—fuel crises, regulatory upheavals, and technological disruptions. The current workforce crisis may prove to be among the most consequential. How the industry responds—through training partnerships, competitive compensation, flexible staffing models, and renewed investment in vocational education—will determine not just its ability to keep the lights on, but its capacity to meet the electrification demands of an increasingly digital economy. ■

*—**Aaron Larson** is POWER's executive editor.*

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Research Brings Results in Search for 'Holy Grail' of Clean Energy

Scientists around the world are making progress as they try different techniques to bring commercial fusion energy to fruition.

Darrell Proctor

Much of the discussion about nuclear fusion has long revolved around its promise, which is the potential to create limitless amounts of energy. The reality for this so-called "holy grail" of clean energy, though, has been that it's always out of reach, with scientists long unable to achieve a substantial "net energy gain" from a fusion reaction—one where the energy output significantly outweighs the energy needed to create that reaction.

That's changing. Progress is being made, thanks to projects such as the multinational ITER (International Thermonuclear Experimental Reactor) in France, and research at U.S. labs including the National Ignition Facility (NIF) in California, which in 2022 became the first site to achieve ignition. That's the point where a nuclear fusion reaction becomes self-sustaining, producing more energy than is needed to start and maintain it, creating a net gain of energy—in other words, producing more energy from the fusion reaction than was needed to spark it.

Several companies are involved in research and development projects related to fusion; for many, the goal is to build a commercial-scale fusion power plant. Several of these groups have provided information to *POWER* about their progress in the fusion space, detailing their projects that would bring a major transformation to the power generation sector.

1. Commonwealth Fusion Systems is building its SPARC fusion machine at the company's campus in Devens, Massachusetts. Courtesy: Commonwealth Fusion Systems

Commonwealth Fusion Systems

Massachusetts-headquartered Commonwealth Fusion Systems (CFS) has created much of the buzz around commercial fusion energy. Industry experts have said that years of worldwide research have established the tokamak-based configuration as the highest-performing approach to fusion. Many tokamaks built to date have been large in size; CFS is taking a different approach, "using revolutionary high-temperature superconducting [HTS] magnets developed in collaboration with MIT [Massachusetts Institute of Technology] to build smaller and lower-cost tokamak fusion systems," according to the company.

CFS is manufacturing these magnets, and is building what it calls "the world's first commercially relevant net energy fusion machine, called SPARC." The company has said SPARC (Figure 1) will pave the way for the world's first fusion power plant, called ARC, which is envisioned as a grid-scale fusion power plant in Virginia, with support from Dominion Energy Virginia. CFS said it is working "to design, build, and scale fusion power plants that will deliver cost competitive, clean fusion energy to combat climate change."

CFS was part of the CES event in January in Las Vegas, Nevada. CES—long known as the Consumer Electronics Show, and one of the world's largest technology events—has in recent years included a growing energy technology component. Bob Mumgaard, co-founder and CEO of Commonwealth Fusion Systems, spoke at the conference as part of an opening keynote in a fireside chat with Siemens AG CEO Roland Busch.

Mumgaard in Las Vegas announced that CFS would collaborate with chipmaker NVIDIA and Siemens to develop a digital twin of its SPARC fusion machine. The companies said their work will apply artificial intelligence (AI), and data and project management tools, to accelerate commercial fusion. NVIDIA CEO Jensen Huang during his keynote reiterated that his company wants to be immersed in so-called "AI factories," providing all manner of technology—blueprints, hardware, operating systems—to keep AI's future on track. That would include supporting the energy needed to power AI.

"CFS will be able to compress years of manual experimentation into weeks of virtual optimization using the digital infrastructure developed by NVIDIA and Siemens," said Mumgaard. "Through this collaboration, we're demonstrating how AI and integrated digital engineering can accelerate progress from design to grid power. This will allow us to transform how we build and operate fusion machines in the race to commercial fusion."

Mumgaard prior to the event said, "CES is where the future shows up first. Being here signals that fusion is entering the mainstream of technology. Fusion is about hope—building a future that promises energy abundance and that will one day power all of the innovations that CES showcases."

Joe Paluska, the company's chief marketing officer, said the company's showcasing of its SPARC technology at CES marks a milestone. "We want everyone, not just physicists, to feel invited into the story of commercial fusion energy. That's why we're excited to have fusion where people who are thinking about the next big thing are," said Paluska.

CFS already uses Siemens' digital tools to improve the efficiency of its manufacturing processes and operations at the company's magnet factory in Devens, Massachusetts. CFS in December 2025 completed and delivered its first super-strong magnet, which it said is the "culmination of years of work to develop and manufacture the foundational technology to bring fusion energy to the grid."

The 24-ton steel-clad magnet was moved across the CFS campus in Devens to the SPARC facility. It's one of 18 D-shaped toroidal field (TF) magnets (Figure 2) needed for SPARC. Brandon Sorbom, the company's chief science officer and co-founder, commented on the importance of the milestone in a company blog post, noting the progression from ideas to prototypes, and from initial manufacturing to full production.

"We didn't just make a single magnet. We made a whole manufacturing facility that can make many, many magnets," said Sorbom. "We learned how to set up a factory and run it at speed. Full steam ahead!"

SPARC and ARC feature three types of HTS magnets: toroidal field (TF), poloidal field (PF), and central solenoid (CS). The company builds its TF magnets with NINT technology (non-insulated, non-twisted construction) that houses many layers of HTS tape within a spiral groove in a flat steel plate. The company calls the plates pancakes, and a stack of 16 pancakes forms a single TF magnet. "Basically, NINT allows us to build stronger, smaller magnets faster," Sorbom said, noting the NINT pathway is available because SPARC's TF magnets run with a steady electrical current.

CFS wrote that "with steady current, we don't need electrical insulation between the turns of a magnet. When the magnet is cooled down and then charged up, the electricity naturally flows along the superconducting pathway and ignores the surrounding metal with its relatively high resistance. It's like the difference between skiing on fast snow instead of concrete.

2. *A worker assembles one of the magnets used by Commonwealth Fusion Systems in its SPARC fusion machine. Courtesy: Commonwealth Fusion Systems*

"The 'NT' part of NINT refers to the superconducting tape being non-twisted. Again, the steady current makes this simpler approach possible: the TF magnets don't require the helical twist that's electromagnetically helpful for the superconducting cables in pulsed magnets."

Mumgaard, in a video update on the project in early January, said, "The activity in Devens at the SPARC facility continues to be at an all-time high." He continued, "This is the six months where the plant turns into an operation and the tokamak turns into what looks like a tokamak."

Type One Energy and Tennessee Valley Authority

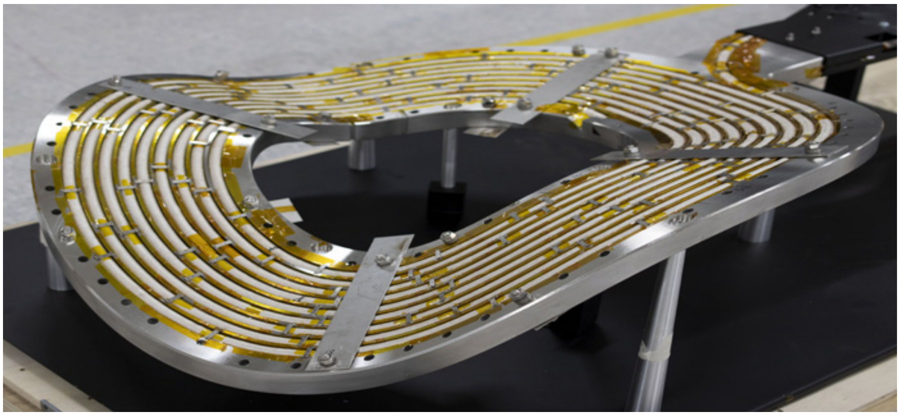
A retired coal-fired power plant site in Tennessee is now home to a collaborative effort to build a fusion power plant. Type One Energy, which began as a spinoff at the University of Wisconsin and is now headquartered in Knoxville, Tennessee, has partnered with major Southeast U.S. utility Tennessee Valley Authority (TVA) to build a prototype stellarator at TVA's retired Bull Run fossil plant in Clinton, Tennessee.

Type One Energy last year announced completion of the first formal design review of Infinity Two, a 350-MW stellarator fusion pilot power plant. In addition to TVA, Oak Ridge National Laboratory also is involved in the project. Type One has said the stellarator "is the only fusion technology to have demonstrated stable, steady-state operation with high efficiency, characteristics which are important for TVA and others in the industry who need to reliably generate on-demand power at competitive prices."

"TVA is a leader in pursuing advanced nuclear technologies we need to power America's economic prosperity and fuel artificial intelligence, quantum computing, and advanced manufacturing," said Don Moul, TVA president and CEO, last summer. "We are strategically partnering with innovative companies like Type One Energy to advance the development of nuclear technologies, and I am excited about the possibility of the first U.S. commercial stellarator fusion power plant being built in the Tennessee Valley."

Type One's team told *POWER* that as an original equipment manufacturer (OEM) and fusion technology provider to electric suppliers and utilities, the company can repurpose the infrastructure and the workforces at retired and aging fossil fuel power plants.

"We're currently working with TVA to repurpose the infrastructure at their retired Bull Rull coal-fired power plant in the United States," said Type One Energy CEO Chris Mowry. "It is a ready-made platform for hosting the future of energy: fusion. This repurposing of existing infrastructure is a strategy that fits well with the challenges and opportunities facing other energy markets around the world. According to the U.S. Energy Information Administration, the United States is home to 339 retired fossil power plants with 157 of them identified by the U.S. Department of Energy as candidates for repurposing. Each of these plants have significant infrastructure that can be repurposed to build safe, af-



3. *Magnet Zero is the first non-planar, high-field, high-temperature superconducting stellarator magnet. The technology is part of the Type One Energy fusion project in Tennessee. Courtesy: Type One Energy*

4. *This photo shows a planar magnet array used by Thea Energy in its fusion project. Courtesy: Thea Energy*

fordable fusion energy plants."

The company said repurposing old fossil-fueled power plants could include not only their workers but also infrastructure such as land, water access, power grid access, and switching facilities.

"The very first employee that we hired at Bull Run was the plant manager of the old coal power plant that—when it was commissioned in the 1960s—was the largest, most efficient power generation device on earth," said Mowry. "This is not just about a new technology, which is really important, but it's also about the opportunity to repurpose talent and the workforces that already exist in communities. We always talk about repurposing infrastructure, but we can also repurpose talent. That's a real value proposition to local communities."

Type One Energy has said the Infinity Two architecture is grounded in stellarator fusion technology (Figure 3). The company said the "technology has, uniquely within the fusion industry, demonstrated stable, continuous steady-state operation at large scale by the W7-X machine. By properly architecting Infinity Two, Type One Energy is creating a proprietary fusion power plant design that supports a compelling two-year power plant operating cycle separated by 30-day planned maintenance outages using today's existing materials and enabling technologies. The company also made use of its partner-rich commercialization program to access the power generation industry's deep expertise in power plant engineering design. Among other firms, AtkinsRealis assisted in developing the design of those Infinity Two systems and structures not part of Type One Energy's core focus on the stellarator fusion technology."

The W7-X machine refers to Wendelstein 7-X, which is the world's largest stellarator fusion device, located in Germany. Researchers have said the W7-X is designed to prove the feasibility of continuous operation for future fusion power plants, unlike pulsed reactors. The technology, according to developers with the Max Planck Institute for Plasma Physics in Germany, uses complex magnetic fields to confine superheated plasma. Testing of the device has shown promise toward the stellarator's potential for steady-state energy generation.

Thea Energy

A Kearny, New Jersey–based company is building what it calls "a more economical and scalable version of a stellarator system architecture." Thea Energy officials told *POWER* it has applied a phased array control system to fusion, which allows for simpler and less-expensive hardware, "and the ability to dynamically tune system performance in the software stack over an asset's lifetime."

Thea Energy was spun out of the Princeton Plasma Physics Laboratory (PPPL) and Princeton University; the Ivy League school is where the stellarator was originally invented. The company completed a $20 million Series A funding round in 2024, and was selected as one of eight inaugural awardees of the U.S. Department of Energy's Milestone-Based Fusion Development Program. Thea Energy co-founder and CTO David Gates developed stellarator magnet array technology at PPPL as part of the ARPA-E BETHE (Advanced Research Projects Agency-Energy Breakthroughs Enabling THermonuclear-fusion Energy) program.

The company has said its "proprietary stellarator technology utilizes arrays of planar magnets (Figure 4), eliminating the prohibitively complex and expensive 3D magnetic field coils required in all other proposed stellarator architectures. Combined with the advent of modern high-temperature superconductors, our stellarator breakthroughs have changed the trajectory of fusion energy."

Brian Berzin, co-founder and CEO of Thea Energy, told *POWER*: "Commercial fusion power will bend the trajectory of humanity sharply upward. Thea Energy is building a more practical, scalable, and economical fusion system based on the stellarator, one of the most scientifically mature fusion architectures. We have done this by leveraging a software-controlled array of simpler, mass-manufacturable superconducting magnets to replace the historically limiting 3-dimensional coils that were required by prior generations of stellarators."

Berzin, who said Thea Energy has a team of more than 80 engineers, physicists, and commercialization experts based in Kearny, added his group is "really excited about our ability to commercialize a practical, cost-competitive fusion power plant—our architecture utilizes an array of about 300 wound magnets to eliminate the prior, major limitation of the stellarator: the 3-dimensional magnets that were wildly difficult and expensive to manufacture due to their complexity and precision requirements. Our proprietary architecture can individually control each planar magnet in the array using a software stack, while also tuning out manufacturing and assembly errors as well as system wear and tear over its operational lifetime. You can think of it as calibrating and playing a video on your computer screen.

"Our planar coil stellarator architecture can also uniquely leverage AI to increase real-time system performance and allow for long-term software level system updates, meaning for the first time, fusion systems are no longer limited by fixed hardware," said Berzin. "We recently announced our Helios stellarator power plant architecture. The initial paper provides a comprehensive view of a fusion power plant that does not require any miracles to commercialize. Our Helios power plant (Figure 5) will unlock the deployment at scale of fusion energy, enabled by more traditional system manufacturing and construction, efficient maintenance, a high capacity factor, and competitive economics.

"Helios achieves several world firsts for fusion, including magnets adaptable to real-world conditions, an 'X-point divertor' capable of commercial operations [such as the exhaust system for a fusion power plant], and a sector-based maintenance scheme enabling high power plant uptime," said Berzin. "Our breakthrough Helios design is now accelerating the formation of commercial partnerships and the first customers for Thea Energy fusion power plants."

The company told *POWER* it is currently designing and considering siting locations for its first integrated fusion system, Eos, that will produce fusion neutrons at scale and in steady state. Site selection is scheduled for this year. The group said operation of Eos, planned by 2030, "will catalyze the subsequent deployment of fusion energy on the grid via the company's Helios power plant."

TAE Technologies

California-based TAE Technologies made a splash with its recent $6 billion merger with Trump Media & Technology Group (TMTG). The deal creates one of the first publicly traded fusion energy companies.

TAE said it wants to site and start construction of a 50-MW utility-scale fusion power plant this year, and also wants to build more stations in the 350- to 500-MW range. Officials have said the company has engaged in more than a quarter century of research and development to "significantly reduced fusion reactor size, cost and complexity." It said it "has built and safely operated five fusion reactors."

5. This is a rendering of Thea Energy's Helios power plant. The pilot plant preconceptual design has been certified by the U.S. Department of Energy as part of the Milestone-Based Fusion Development Program. Courtesy: Thea Energy

The new company's CEO—former California congressman Devin Nunes—in early January said the group is accepting applications from state and local governments interested in being home to fusion reactors. Requirements to apply include a minimum of 20 acres to site multiple fusion reactors, along with access to a grid interconnection, and the ability to provide security. Nunes said a decision is expected within weeks, noting the company would like to begin construction this year.

Nunes, who has worked closely with President Donald Trump, also said to no surprise, "We're only going to be building this in a red state," which means left-leaning states including his own California need not apply. Nunes in a statement wrote, "The TMTG team is actively holding discussions with multiple states and entities about potential sites as we look forward to completing this merger. These are the initial steps to spark a renaissance in American energy to secure safe, clean, abundant, and affordable fusion power that will lower Americans' energy bills and guarantee Americas predominant position in the AI revolution."

TAE has said its "fusion machine design is compact and linear so a commercial fusion power plant would be readily scalable for mass manufacturing." The company said it "is pursuing fusion with hydrogen-boron [also known as p-B11 or p11B] because it is abundant and non-radioactive, making it the most sustainable option for operating and maintaining commercial fusion power plants." The company also said its technique to produce fusion power is called "advanced beam-driven Field-Reversed Configuration (FRC)," which it said "solves challenges to delivering scalable, sustainable commercial fusion power."

Helion Energy

A group headquartered in Everett, Washington, is working toward a commercial fusion power plant in that state. Helion Energy is building its seventh-generation fusion prototype, with a goal of proving its technology can provide grid-scale power.

Construction of the company's Orion fusion power plant in Malaga, Washington, began in July of last year. Tech giant Microsoft has signed on to start receiving power from the Orion facility as soon as 2028. *POWER* in 2023 covered Helion's agreement with Nucor, the largest steel producer and recycler in North America, to develop a 500-MW fusion power plant at a Nucor steel manufacturing facility in the U.S.

Helion's approach is to directly convert fusion energy into electricity, using deuterium-helium-3 (D-He3) fuel and a field-reversed configuration system for what it calls "potentially cheaper, smaller-scale fusion power."

David Kirtley, the company's co-founder and CEO, has said the group's goal is more than just proving fusion energy is possible. Kirtley on the company's website wrote: "We use a unique fusion fuel: deuterium-helium-3 (D-He-3). This sets us apart from most fusion approaches because it requires higher temperatures than more traditional fuels while relying on a fuel source that isn't naturally abundant on Earth.

"Why did we choose this approach? Among other benefits, D-He-3 maximizes our ability to directly capture electricity, a large advantage when building a fusion system for commercial deployment," wrote Kirtley, who added: "By focusing on D-He-3 fusion, we believe we are on a more efficient and cost-effective path to commercial fusion power. Our first-principles approach, assessing each fuel's potential for commercialization, consistently pointed to D-He-3 as the fastest route to market-ready fusion energy. While there are intermediary challenges, overcoming them promises the most robust and economically viable solution for fusion power."

The company last fall leased space near its Everett headquarters that will house an assembly line to build the capacitors needed to deliver power to its fusion generator, and then capture the energy produced. Melanie Nakagawa, Microsoft's chief sustainability officer, at last July's groundbreaking for Orion said, "While the path to commercial fusion is still unfolding, we're proud to support Helion's pioneering work here in Washington state as part of our broader commitment to investing in sustainable energy."

Tokamak Energy

Tokamak Energy, headquartered in the UK, in December of last year said it set three performance records ahead of a major upgrade to its ST40 fusion energy machine. The company said it ended the year by achieving its highest plasma current, highest stored energy, and highest fusion triple product, which it said are "all key measures on the path to delivering clean, limitless fusion energy."

The December announcement came on the heels of a November 2025 report that the group had recorded "These superb results are a great way to finish the year and demonstrate how the ST40 team continues to push the limits, improving the already impressive performance of our compact high-field device," said Otto Asunta, the company's experiments chief for ST40, in a news release. "Breaking into the mega-amp range with our plasma current is a major milestone as we continue to build our knowledge of what will be needed for delivering fusion energy to future grids. We now look forward to working with the U.S. and UK governments on a new wave of experiments to deliver more cutting-edge science with our industry-leading device that has always punched above its weight."

The company said the ST40 set a record by reaching 1 MA (1,000,000 amperes) of plasma current, surpassing its previous best of 0.85 MA, while stored energy was nearly doubled compared to previous campaigns. The group said, "This demonstrates that a plasma volume of just one cubic meter can hold immense power—an important insight on the path to energy-producing devices."

Tokamak Energy noted, "Plasma current—the electric current flowing through the plasma inside a tokamak—is crucial for confinement. It generates a poloidal magnetic field that, together with the magnetic fields from coils, keeps the plasma confined and away from material surfaces inside a tokamak. In future devices, a high plasma current is required to also trap the fusion-born alpha particles. The fusion triple product, a measure combining plasma temperature, density, and energy confinement, is a key indicator of plasma performance."

The company also said that its "latest campaign also saw the implementation of a new software called RT-GSFit that can reconstruct the plasma shape during a pulse at a millisecond time resolution (a thousand times per second). Integrating RT-GSFit into the ST40 Plasma Control System allowed the team to control plasma shape in real-time."

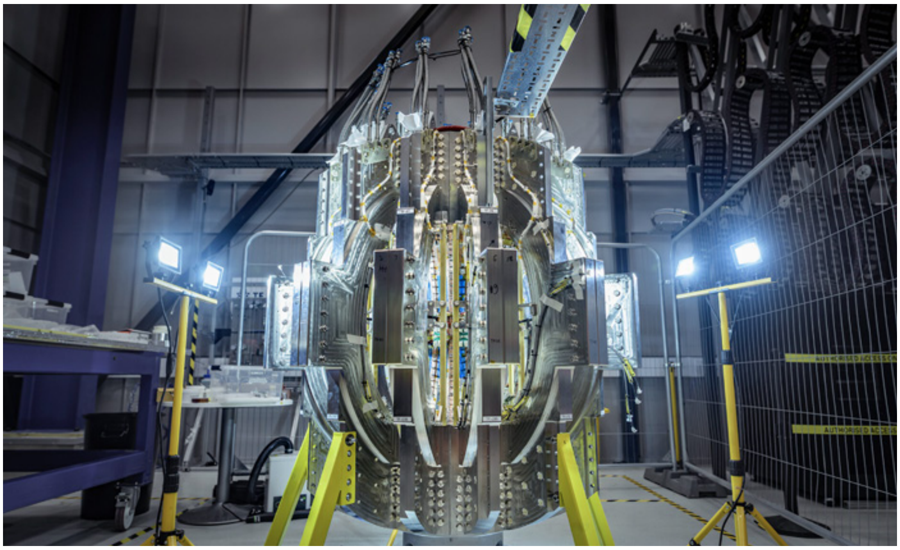
The company said the ST40 "has now paused operations for the $52-million upgrade program, known as LEAPS (Lithium Evaporations to Advance PFCs in ST40), in partnership with DOE and DESNZ. The program will apply lithium coatings to all plasma-facing components (PFCs) using a lithium evaporation technique, building on pioneering work by Princeton Plasma Physics Laboratory and others that has shown lithium PFCs can significantly improve plasma performance." The ultimate goal is to enable fusion conditions with good confinement that is compatible with sustainment for long durations in a future fusion pilot plant.

The company also provided an update on its Demo4, a complete set of HTS magnets built in a tokamak configuration, noting it has produced "milestone results at the company's headquarters outside Oxford, achieving field strengths of 11.8 Tesla at –243C in recent tests. The world-first system had an incredible seven million ampere turns of electrical current running through its centre column, demonstrating huge potential for power distribution as HTS can deliver around 200 times the current density of copper."

Warrick Matthews, Tokamak Energy CEO, said: "These results are a major victory for the race to deliver fusion and HTS

breakthrough results for its strategy to replicate fusion power plant fields for the first time with its magnet system. The company said its Demo4 (Figure 6) "also demonstrates the transformative potential of high-temperature superconducting (HTS) technology across a range of spin-out applications, from power distribution for data centers, electric motors for zero emission flight, and fast, efficient magnetic levitation transport systems."

Tokamak Energy said the compact spherical tokamak at the company's Oxfordshire headquarters is now preparing for a major upgrade for a new campaign of what it called "groundbreaking experiments in partnership with the U.S. Department of Energy (DOE) and the UK Department for Energy Security and Net Zero (DESNZ)."



6. Tokomak Energy's Demo4, built at the company's headquarters in the UK, is designed to demonstrate the potential of high-temperature superconducting technology for fusion. Courtesy: Tokomak Energy as a disruptive new commercial technology. Demo4 represents over a decade of HTS innovation at Tokamak Energy. Born from our fusion mission, it validates one of the technical solutions for getting clean, limitless, safe, and secure fusion energy on the grid.

"Demo4 is also best in class at showcasing and demonstrating the transformative potential for superconductors, including power distribution for high-demand environments like data centers and applications across science, power systems, propulsion, and beyond," said Matthews.

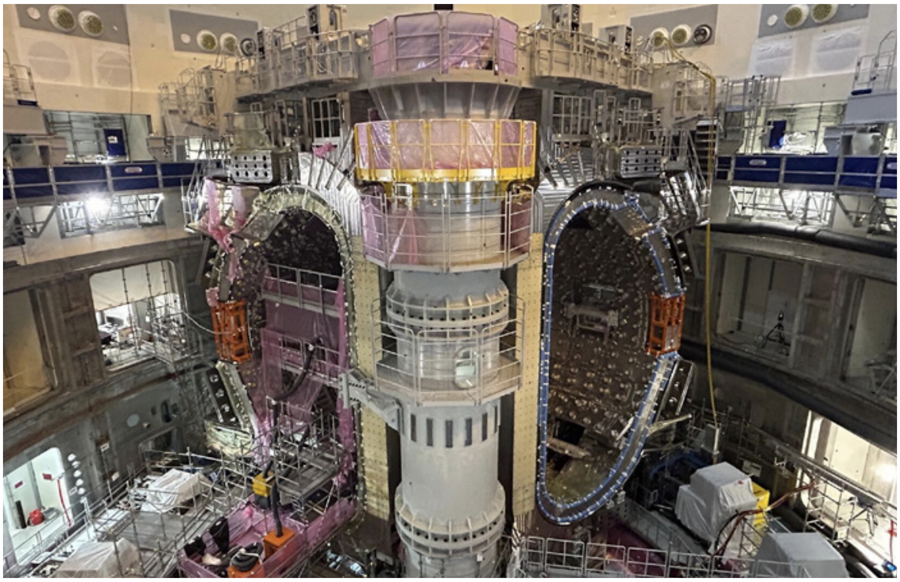
The ITER Project

Construction continues on the ITER (International Thermonuclear Experimental Reactor) project in Saint-Paul-lez-Durance, in the south of France, an experiment in fusion that was launched in 1985. The ITER facility is designed to demonstrate the scientific and technological feasibility of fusion power, and would be the world's largest experimental fusion facility. ITER is a global collaboration of nearly three dozen nations, that as of January includes the 27 member countries of the European Union, in addition to China, India, Japan, South Korea, the Russian Federation, and the U.S.

Switzerland is also a participant after renewing its association on January 1 of this year. The UK, following Brexit and its subsequent withdrawal from Euratom, is no longer participating, though ITER for now is honoring existing contracts with UK companies and research institutes that have been involved with the project.

Officials with the ITER project (Figure 7) have said its primary objective is the investigation and demonstration of burning plasmas. Those are plasmas "in which the energy of the helium nuclei produced by the fusion reactions is enough to maintain the temperature of the plasma, thereby reducing or eliminating the need for external heating. ITER will also test the availability and integration of technologies essential for a fusion reactor [such as superconducting magnets, remote maintenance, and systems to exhaust power from the plasma] and the validity of tritium breeding module concepts that would lead in a future reactor to tritium self-sufficiency."

Greg Demchak, vice president, Emerging Technologies with Pennsylvania-based Bentley Systems, told *POWER*, "Bentley Systems role in the ITER project is to provide advanced 4D visualization tools with comprehensive tracking and planning capabilities along with digital twin technology. The Bentley SYNCHRO software is essential for planning and executing the complex construction and assembly process of the fusion reactor. This technology allows engineers to create a 'living, breathing replica of the physical project' that is updated in real-time, which, when combined with 4D planning, enables them to visualize the construction process step-by-step."



7. The ITER project in France, launched in 1985, continues to move forward as a key element of global research into fusion energy. Courtesy: ITER

Demchak added, "To support projects like ITER and others requiring advanced visualization, Bentley has continued to enhance its 4D visualization capabilities. These improvements include leveraging technology from Cesium, a leading 3D geospatial company acquired by Bentley, to deliver more interactive and navigable virtual models. This enables teams to identify potential issues, refine installation sequences, and maintain alignment across all teams and stakeholders."

The ITER team in a recent update said another penetration benchmark was reached in December with the infilling of 15 busbar openings on the L3 and L4 levels of the Tokamak Building. According to an ITER news release, "The infilling team spent months qualifying a bright blue elastomer produced by the Norwegian company Elkem to ensure it met the required fire segregation, radiation shielding, leak-tightness confinement function, and other standards. Among other assessments, the fire qualification tests included heating the elastomer to 1,100C in a specialized furnace and ensuring it did not permit a heat transfer in excess of 120C on the other side of the opening. By undertaking this qualification process, which was done in partnership with the Efectis laboratory in France, the teams ensured that future fusion construction projects can use this elastomer product from day one if they have matching safety requirements. The elastomer is readied by mixing two different liquids and then pressurizing it to remove the gas bubbles."

"This was the first time this type of infilling had been done at ITER, so we had a very complex problem and, together, we found a simple solution," said Jose Manuel Sanchez Cuevas, the mechanical and piping supervisor. Cuevas was the contract responsible officer for the busbar infillings. Officials said there are thousands of small penetrations, or openings, in the Tokamak Complex to allow pipes, cables, and components to pass through walls and slabs. Those spots "need to be infilled using different solutions that meet the same safety and nuclear safety standards as the surrounding wall material."

The ITER Council at its 37th meeting, held in November 2025, said the project is ahead of schedule, and in a report wrote that it "welcomed the steady progress on assembly and installation of the sector modules." The Council also noted "progress on assembly of the central solenoid, start of production of all divertor components, installation of the first gyrotron for electron cyclotron heating, completion of the bioshield penetrations in the Tokamak Building, and sustained positive interaction with the French nuclear safety regulator." ■

*—**Darrell Proctor** is a senior editor for POWER.*

New Gas-Fired Plants Bring Needed Generation, Flexibility to the Power Sector

Several natural gas–fueled units are being developed as a way to support the industrial sector, including data centers, and to help integrate more renewable energy to the grid.

Darrell Proctor

The need for more baseload power generation to maintain grid reliability has power producers looking at many options. Modern natural gas-fired power plants, with a combination of operational flexibility and lower emissions thanks to advanced technologies, have emerged as a dependable firm power source.

Utilities are building new gas-fired power generation capacity not only as a baseload resource, but also as a way to support more integration of renewable energy resources. Gas-fired power stations can ramp up quickly at times of higher demand for power, with energy analysts again touting gas-fueled units as the bridge from retiring coal-fired power to cleaner forms of energy.

The U.S. is seeing significant development of new natural gas–fired power plants, in part to satisfy power demand from artificial intelligence (AI) and data centers. More than 100 GW of new generation capacity has been publicly announced, though the buildout has been slowed by supply chain issues including a backlog of turbine orders. Siemens Energy, among the major turbine manufacturers, recently said it is offering upgrades to existing units in order to unlock more capacity and improve operational efficiency.

"Natural gas–fired plants are doing the hard work of reliability in a grid that's adding load from AI/data centers and integrating more intermittent resources. In the near term, new gas capacity is the only scalable way to add firm megawatts while markets continue to explore medium- to long-term solutions like nuclear, geothermal, and long-duration storage," Carson Kearl, an analyst with Enverus Intelligence Research, told *POWER*.

Experts in the power generation space agree that the near-term outlook for natural gas is strong, in large part due to the need for more baseload power, the availability of gas, and shorter timelines to build gas-fueled units compared to other baseload options.

"Natural gas–fired power plants remain popular because they're flexible, relatively clean [compared to coal], and quick to ramp up or down," said David Sheldrake, Global Senior Vice President of Sales360 at POWWR.

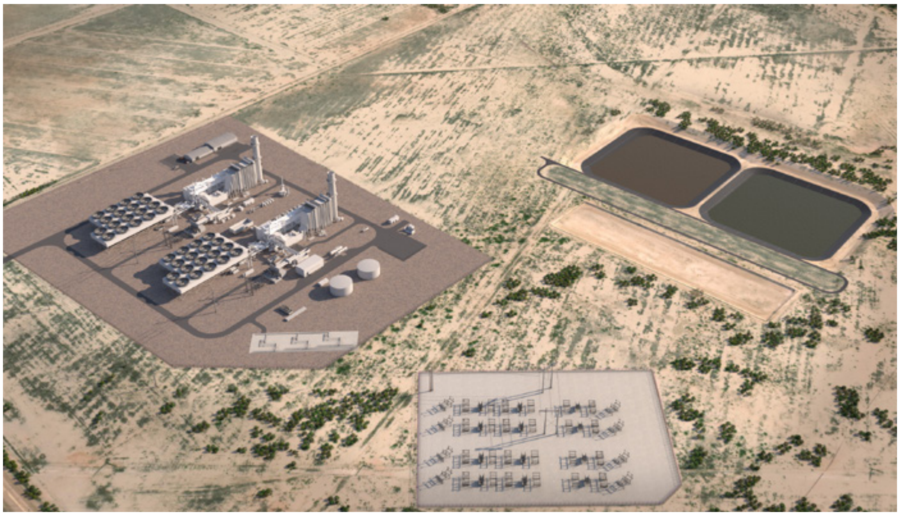
Though gas prices can be volatile, and vary by region, U.S. wholesale prices had dropped significantly from early December 2025 through mid-January 2026. The U.S. Energy Information Administration in its latest forecast said U.S. prices would fall about 2% this year compared to 2025 levels. Sheldrake told *POWER*, "This drop in costs will provide a greater benefit to gas-fired power plants moving forward, by way of the investment they make to generate a better electricity economical future."

Scott Gromer, CEO of Colorado-based Mesa Power Solutions, told *POWER*: "All the indications we see in the market and from our customers confirms the strength in the growing adoption of natural gas generation for utility systems. In addition to generation distributed along distribution circuits, utilities are also finding use cases for generators in substations for a variety of roles ranging from system capacity to resiliency for distribution circuits in the event of transmission system outages."

Gromer continued, "It's no surprise to anyone that the supply chain for generation equipment is inelastic at this point." Many industry analysts have noted that a buildout of gas-fired facilities has been impacted by supply chain issues. "Mesa has been fortunate to have more control over availability due to the fact that we assemble our own equipment for sales, lease, and maintenance opportunities," said Gromer.

CPV Basin Ranch

Texas, a deregulated power market that continues to build more generation in-



1. The CPV Basin Ranch natural gas–fired power plant, shown in this rendering, will have 1,350 MW of generation capacity. The facility, sited in Ward County, Texas, is targeted for commercial operation in 2029. Courtesy: Competitive Power Ventures frastructure, established a program designed to provide funding for new baseload energy projects. The 1,350-MW CPV Basin Ranch Energy Center (Figure 1) is a major natural gas–fired power station benefiting from the strategy. Competitive Power Ventures (CPV) and the Public Utility Commission of Texas executed a $1.1 billion Texas Energy Fund (TxEF) loan for the facility, which is being built in Ward County, in the Permian Basin area in the western part of the state. The Permian Basin is the largest oil-producing region in the U.S., and second only to the Appalachia region in the Northeast in the nation's production of natural gas.

Officials have said they expect CPV Basin Ranch to enter commercial operation in 2029. A report from the Washington, D.C.–based Environmental Integrity Project, which also has an office in Austin, Texas, published last summer said more than 100 new gas-fired power plants were being considered in Texas.

The Texas Energy Fund was created in the wake of the February 2021 Uri winter storm, when an estimated 10 million Texans lost power, prompting officials to look at how to avoid future blackouts caused by extreme weather or other events.

Texas Gov. Greg Abbott last fall said, "Texas is powering the future of reliable, affordable energy across the nation and around the world. Through the Texas Energy Fund, CPV Basin Ranch will bring hundreds of megawatts of new, reliable power online and help keep prices affordable. This 1,350-megawatt investment will further grow our power supply and ensure continued reliability for homes and businesses in Texas as we add more power and fortify the state grid."

"CPV is committed to responding to Texas's rapidly growing demand for new, dispatchable power generation," said Sherman Knight, CEO of CPV. "Texas offers the opportunities and incentives to drive future development, our team at CPV looks forward to doing our part to make this a reality."

Gemma Power Systems is leading efforts for CPV Basin Ranch, a combined cycle facility that will feature GE Vernova H-Class 7HA.03 turbines with a carbon capture option, along with other GE Vernova technology. Peter Podurgiel, CPV's president of Low Carbon Generation, in late October 2025 said, "Over the last four years, we've worked diligently to advance this project and are grateful for the supportive framework provided by the TxEF program. I have no doubt CPV Basin Ranch will be an invaluable asset to the community and the state for decades to come. Once complete, CPV Basin Ranch will rank among the most efficient and modern plants in Texas. In addition to utilizing the latest advances in combined cycle power generation, our team is always looking to what is next including the option to deploy carbon capture technology in the future."

CPV Basin Ranch is part of the company's current development pipeline of more than 10 GW of dispatchable and renewable power generation.

2. Thurrock Power is a 450-MW flexible generation station in southeast England. It features Jenbacher engines with rapid start-up capability. The power plant is adjacent to the Thurrock Storage battery energy storage facility. Courtesy: Rehlko / Clarke Energy

Desert Sun Power Plant

Arizona Public Service (APS) last fall said it would develop the 2,000-MW natural gas–fired Desert Sun Power Plant as part of the utility's plan to add more flexible power generation in that state. The company said the two-phase project, located west of Gila Bend, Arizona, would support current customer growth through a competitive procurement process in Phase 1, and enable new extra-large customer investments—such as data centers—via a subscription model in Phase 2.

"The Desert Sun Power Plant will help maintain safe, reliable energy for APS customers as our state grows," said Jacob Tetlow, APS executive vice president and chief operating officer. Tetlow told *POWER*, "Our focus is on protecting residential and small business customers from cost shifts through our 'growth pays for growth' model, which is designed to ensure fairness and responsibly meet the needs of data centers while keeping service affordable for Arizonans."

Tetlow earlier had outlined how Phase 2 of the project, with its proposed subscription model, would ensure that the new generation would be paid for by the "extra-large" customers who would use it, and not by the utility's existing residential or business customers. Those users needing large loads of electricity would be subject to long-term contracts covering the capital costs of the project, along with assuming development risks. Tetlow said that model "protects customers while supporting data centers needed for the U.S. to compete globally."

APS has said it wants a balanced energy portfolio to ensure reliability and affordability for customers. The utility has said it plans to add some 7,300 MW of new generation resources to its fleet by 2028. Tetlow said, "Natural gas is an important partner to the large quantity of renewable resources we're adding to our portfolio and provides flexible, on-demand energy to ensure reliability for customers, especially on our hottest summer days."

APS has said the Desert Sun plant will have advanced emissions controls. Phase 1 of the power plant is scheduled to begin serving customers by late 2030; Phase 2's operation date will be determined through a collaborative process with participating extra-large customers.

Thurrock Power

Clarke Energy and INNIO are collaborating on a landmark project with UK-based Statera Energy to support grid reliability in the UK. The companies recently said they have completed delivery of a full fleet of "Ready for H2" Jenbacher J624 engines at Statera Energy's project in Thurrock in southeast England.

Thurrock Power will be a 450-MW flexible generation station (Figure 2), and will sit alongside Thurrock Storage, a 300-MW co-located battery energy storage system that is designed to integrate with intermittent renewable energy. Officials told *POWER* the project is targeting late 2026 for full operation.

The companies noted that the Jenbacher engines feature high electrical efficiency, and a rapid start-up capability (less than five minutes). Scalable deployment allows for high efficiency at partial loads, with power generation ramping from as low as 2.25 MW to the full 450-MW capacity, enabling flexibility to swiftly respond to fluctuations in electricity supply and demand.

Alex Marshall, group director of Clarke Energy, told *POWER*: "This project represents a critical milestone in the UK's energy transition. As the country rapidly expands its renewable generation, the ability to deliver 450 MW of flexible, fast-start power to support up to 1 million UK homes ensures that intermittent renewables can be integrated reliably—without sacrificing system resiliency and security of supply."

The companies told *POWER* the Thurrock Flexible Generation Project will provide "strategic support" for the UK's energy transition, helping move the area near London toward a secure, low-carbon power mix. The project marks the second major collaboration among Statera Energy, Clarke Energy, and INNIO Group, after deployment of the Creyke Beck Power flexible generation project in Cottingham, Humberside, in northeastern England.

Matt Arnold, director of BESS and Flex-Gen at Statera Energy, in a statement said: "Thurrock Power represents a significant milestone for Statera. Once operational, it will be the UK's largest flexible generation project, providing critical capacity to balance the grid and enable the transition to a renewables-led energy system. Together with Thurrock Storage, our sites support grid resilience and energy security. We selected Clarke Energy and INNIO Group's Jenbacher technology for their rapid deployment capabilities, fuel flexibility, and exceptional start-up performance—essential features for meeting the UK's evolving energy demands."

Xcel Energy

Xcel Energy recently said it purchased 10 gas-fired turbines from Siemens Energy to support construction of two power plants. Xcel said it is retiring the coal-fired generation and installing five Siemens Energy SGT6-5000F gas turbines, and five SGen6-1000A generators, at the 928-MW Tolk Station in Muleshoe, Texas. The company is supplying five more F-class turbines, and five generators, to support construction of a 1,160-MW gas-fired plant in Gaines County, New Mexico.

"As demand for reliable energy grows, dispatchable power is no longer optional," said Luke Baker, head of Gas Services Sales, North America, at Siemens Energy. "Our turbine technology ensures availability and flexibility in a region critical to America's energy future."

"These power plant projects are part of a broader portfolio that includes 17 new power initiatives and more than 5,000 megawatts of added capacity by 2030," said Adrian J. Rodriguez, president, Xcel Energy—Texas, New Mexico. "We are committed to thoughtfully investing in a balanced mix of energy resources that deliver reliable service to our customers and support long-term economic growth across the region. This approach ensures we can meet today's energy needs with confidence and deliver lasting value, while preparing for the evolving expectations of tomorrow's customers and communities."

Anticipated commercial operation dates for the projects are aligned to meet Southwest Power Pool's increased regional planning reserve margin requirements.

Siemens Energy

Siemens Energy also is supporting construction of the Taiba 2 and Qassim 2 combined cycle power plants in Saudi Arabia, each with generation capacity of about 2 GW. The company is also supplying turbines for the Beiji Gas Power Plant 2 in Iraq, and for a hydrogen-ready gas-steam plant in Grudziadz, Poland. Many of these new projects are hydrogen-ready, with some designed to run on a blend of hydrogen and natural gas, or eventually on 100% hydrogen.

Siemens also is supplying equipment for a new plant in Frankfurt, Germany, that will feature an SGT5-9000HL gas turbine capable of running on up to 30% hydrogen. A new plant in Italy will be the first in that country to feature an SGT5-9000HL turbine, again with a 30% hydrogen capability.

Babcock & Wilcox in mid-January said it selected Siemens Energy to supply turbines for a 1.2-GW project that would power data center operations for Applied Digital. The project, which would include four 300-MW gas-fired units, is expected to be completed by year-end 2028.

Kenneth Young, chairman and CEO of Babcock & Wilcox, in a statement said, "This arrangement brings together two companies with long histories of innovation and leadership in the power generation industry. Leveraging Siemens Energy's advanced turbine technology alongside B&W's proven boiler systems positions us to meet critical schedule milestones and deliver reliable power by the end of 2028."

Tobias Panse, senior vice president of Steam Turbine and Generators at Siemens Energy, said, "By pairing our steam turbine systems with B&W's established boiler technology, we can deliver a straightforward, cohesive setup for large-scale power."

Siemens Energy last year announced a partnership with energy technology group Eaton to develop an on-site modular gas-powered solution for the data center sector. Siemens Energy said it would provide data center customers with a "modular and scalable power plant," with a standard configuration of 500 MW of capacity. Generation equipment would include multiple SGT-800 gas turbines from Siemens, each with a capacity of between 45 MW and 62 MW, allowing for flexibility of scale for each specific customer, according to the companies.

Net Power and Project Permian

Net Power in November of last year said it is proceeding with its Project Permian clean firm power hub in West Texas (Figure 3). The company earlier had announced it was delaying the project after encountering unexpected higher costs. Net Power said it has signed a letter of intent with Entropy, a carbon capture technology group, to deploy Entropy's post-combustion capture (PCC) technology for power generation in the U.S. Net Power, known for its project using carbon dioxide to produce low-emission gas-fired power at a demonstration plant in La Porte, Texas, also said it would jointly develop projects with Entropy.

Net Power in a recent project update said it has secured 60 MW of gas turbines to be delivered in 2028, and said documents are being finalized for oil and gas group Occidental to purchase 30 MW of the power and 100% of the captured carbon dioxide. A final investment decision for this first phase is expected in the first half of 2026, with targeted commercial operations in 2028. Danny Rice, Net Power's CEO, said the project would have a Phase II and could potentially add a Phase III. The company said a final investment decision should come soon.

3. This is a rendering of a Net Power site, where the company will use Entropy's post-combustion capture technology for power generation. Courtesy: Net Power

4. The coal-fired Coleto Creek Power Plant in Texas, set for retirement in 2027, will be converted to burn natural gas as part of Vistra's plan to add gas-fired generation capacity to its fleet. Courtesy: Luminant

Net Power in its update also discussed a clean firm power hub that would serve the northern Midcontinent Independent System Operator (MISO) territory. The company has a 300-MW interconnect request for MISO. The company said it is designing Phase I of the project to utilize gas turbines paired with Entropy PCC, with a final investment decision expected in 2027, and commercial operations beginning in 2029.

Rice in the update said, "Over the last several years, we've assembled a world-class power team and established attractive sites for clean firm power hubs, and our new partnership with Entropy enables us to accelerate development of these sites—as well as potentially originate new ones—to meet the market's demand for clean firm power now."

Vistra Corp.

Vistra Corp. last fall announced a plan to build more than $1 billion worth of new natural gas–fired generation capacity in the Permian Basin in Texas, in part to supply power for the state's oil and gas industry. The company said it would build two gas-fired units, with total generation capacity of 860 MW, at its existing 325-MW Permian Basin Power Plant.

"As the leading competitive generator in Texas, customers from residential to commercial and industrial are turning to Vistra to help them meet their energy needs," said Jim Burke, president and CEO of Vistra, in a news release. "We recognize that energy is critical to powering this economic opportunity, and we expect Texas will play an outsized role. Based on our ongoing conversations with customers, we are affirming our multi-year plan to add more than 2,000 MW of new capacity in ERCOT [Electric Reliability Council of Texas] between 2024 and 2028. Given Vistra's fleet, interconnections, and experience in improving, redeveloping, and building power plants, we are uniquely positioned to deliver solutions that provide reliable, affordable power to our residential customers as well as industries across Texas and the United States to ensure our economic competitiveness and national security."

Vistra from 2020 to 2023 added about 1 GW of new generation capacity in Texas by increasing the power output of its gas-fired fleet, and bringing new projects online. The company also plans to repower the coal-fired Coleto Creek Power Plant (Figure 4), which was set for retirement in 2027, with natural gas. The company said it would invest in upgrades at the site, including a pipeline expansion, and would repurpose much of the existing infrastructure. The company said the plan "will restore approximately 630 MW of generation to the grid."

Duke Energy

Duke Energy, one of the largest U.S. electric utilities, recently announced plans for a new $3.2 billion natural gas–fired plant in South Carolina. The company hopes to receive regulatory approval in the near future. Officials have said they expect a final decision by the end of April.

Heather Shirley Smith, in a permit application to state regulators, wrote: "We're at a critical juncture in preparing for South Carolina's reliable energy future. Swiftly expanding our generation capacity is essential to keep pace with the state's booming development and economic success." The 1,400-MW plant is sited near Anderson. If approved, Duke Energy said it could begin construction in 2027, and bring the plant online in early 2031. Duke Energy already has a contract to buy 11 turbines from GE Vernova, in addition to eight turbines the company said it has on hand.

The new plant could connect to the existing Transcontinental Gas Pipeline, which runs through the area and is less than a mile from the power plant site. Duke Energy said it would be the main owner of the plant, but at least five electric cooperatives plan to take an ownership stake and buy some of the facility's output. Five co-ops in North Carolina are expected to do the same.

Duke Energy last fall announced a plan that calls for adding about 9.7 GW of natural gas–fired generation capacity by 2033 in both North and South Carolina. ■

*—**Darrell Proctor** is a senior editor for POWER.*

Offshore Wind Industry Posts Record Growth Amid U.S. Policy Setbacks

Record capacity, record auctions, and record-breaking turbines mark a maturing industry, but U.S. policy reversals and macroeconomic headwinds threaten to slow momentum.

Aaron Larson

The global offshore wind industry achieved significant milestones in 2024 and early 2025, with installed capacity surpassing 83 GW and a record-breaking 56 GW awarded in competitive auctions worldwide. Yet, this momentum faces significant headwinds, particularly in the U.S., where the Trump administration's executive actions have halted construction on five major projects representing nearly 5.8 GW of capacity. As turbine technology continues its rapid evolution—with units now reaching 26 MW—and floating wind advances toward commercial scale, the industry finds itself at a critical juncture that will shape its trajectory for years to come.

1. The Coastal Virginia Offshore Wind (CVOW) project faces challenges due to President Trump's executive actions. Still, the global offshore wind industry is expected to grow significantly over the next decade. Courtesy: Dominion Energy

Asia-Pacific Leads as Europe Rebuilds Momentum

Global offshore wind capacity reached 83 GW by the end of 2024, according to the Global Wind Energy Council's (GWEC's) *Global Offshore Wind Report 2025*. New numbers won't be released by the GWEC until April, but all signs point to another banner year for the industry in 2025. An additional 48 GW was under construction as of May 2025, positioning the sector for accelerated growth through the decade.

The Asia-Pacific region has emerged as the industry's center of gravity. China alone accounts for 41.8 GW of installed capacity—roughly half the global total—having added 4 GW in 2024. The Chinese market's dominance extends beyond deployment. The country's manufacturers now produce the world's largest turbines, and its shipyards are building installation vessels for operators worldwide.

Europe, with 36 GW installed, representing 44% of global capacity, added 2.7 GW in 2024. The continent's mature markets are working to regain momentum following auction failures in 2022–2023 that exposed vulnerabilities in contract structures during a period of high inflation and elevated interest rates. Reforms to contract-for-difference (CfD) mechanisms and improved risk allocation are beginning to restore investor confidence.

The market outlook remains robust despite near-term challenges. Industry forecasts project more than 350 GW of new capacity additions between 2025 and 2034 (Figure 1), bringing total global installations to approximately 441 GW. Annual deployment is expected to exceed 30 GW by 2030 and reach 50 GW by 2033.

Auction activity in 2024 reached unprecedented levels. The 56 GW awarded globally represented a record year, with significant allocations across Europe, Asia-Pacific, and emerging markets. This contracted pipeline provides visibility for the supply chain, though grid connections, permitting delays, and financing challenges in some markets could affect realization timelines.

Policy Reversals Halt Progress in U.S.

The U.S. offshore wind industry faces an existential challenge following a series of executive actions by the Trump administration that have effectively frozen the sector's development.

On Jan. 20, 2025—his first day back in office—President Trump signed an executive order withdrawing all outer continental shelf areas from new offshore wind leasing, ordering a review of existing leases, and halting new or renewed approvals for wind projects. The order marked a dramatic reversal of the Biden administration's goal of deploying 30 GW of offshore wind capacity by 2030.

The more consequential blow came on Dec. 22, 2025, when the U.S. Department of the Interior (DOI) announced it was pausing leases for the five large-scale offshore wind projects currently under construction along the East Coast. The affected projects—Vineyard Wind 1, Revolution Wind, Coastal Virginia Offshore Wind Commercial, Sunrise Wind, and Empire Wind 1—have a combined capacity of approximately 5.8 GW and represent billions of dollars in investment.

The DOI cited "national security risks" identified in classified Pentagon reports as justification for the pause. Specifically, the agency pointed to radar interference concerns, noting that the movement of turbine blades combined with reflective towers creates "clutter" that can obscure legitimate moving targets and generate false readings. The DOI stated the pause would allow agencies to assess potential mitigation measures.

Critics, including national security experts, have challenged the rationale. Kirk Lippold, former commander of the USS Cole, told NPR that the projects had undergone years of review by state and federal agencies, including the Coast Guard, Naval Undersea Warfare Center, and Air Force.

"The record of decisions all show that the Department of Defense was consulted at every stage of the permitting process," Lippold said, arguing that diversifying the country's energy supply through offshore wind would actually benefit national security.

The December pause came just two weeks after a federal court dealt the administration a legal setback. On Dec. 8, Judge Patti Saris of the U.S. District Court for the District of Massachusetts vacated Trump's Jan. 20, 2025, executive order, ruling that the blanket halt on wind energy approvals was "arbitrary and capricious" and violated the Administrative Procedure Act. The ruling came in response to a lawsuit filed by a coalition of 17 state attorneys general and Washington, D.C., led by New York Attorney General Letitia James.

Legal challenges to the December lease pause mounted quickly. On Dec. 23, Dominion Energy filed suit in the U.S. District Court for the Eastern District of Virginia, arguing that the U.S. Bureau of Ocean Energy Management's (BOEM's) stop-work order for its 2.6 GW Coastal Virginia Offshore Wind (CVOW, Figure 2) project "sets forth no rational basis, cannot be reconciled with BOEM's own regulations and prior issued lease terms and approvals, is arbitrary and capricious, is procedurally deficient, violates the Outer Continental Shelf Lands Act, and infringes upon constitutional principles that limit actions by the Executive Branch."

In a statement, Dominion warned: "Stopping CVOW for any length of time will threaten grid reliability for some of the nation's most important war fighting, AI [artificial intelligence], and civilian assets. It will also lead to energy inflation and threaten thousands of jobs."

The market impact has been severe. The International Energy Agency (IEA) revised its U.S. renewable capacity forecast down approximately 50% for the 2025–2030 period following the administration's actions. Wind energy, specifically, saw a 60% downward revision, representing 57 GW of capacity—both onshore and offshore—that is now unlikely to be built during the forecast period. Ørsted, the Danish developer with significant U.S. exposure including the Revolution Wind project, saw its share price drop 12% on Dec. 22, the day of the pause announcement, although the price returned to its previous level within two weeks.

The Conservation Law Foundation, a Boston, Massachusetts–based group, characterized the administration's approach as a "desperate rerun" of failed attempts to kill offshore wind. Other environmental groups also objected. "For nearly a year, the Trump administration has recklessly obstructed the build-out of clean, affordable power for millions of Americans, just as the country's need for electricity is surging," said Ted Kelly, director and lead counsel, U.S. Clean Energy, with the Environmental Defense Fund. "Wind—when allowed to move forward—offers some of the most affordable, reliable power," he claimed.

2. Dominion Energy's CVOW project has been in the works for more than 10 years. The first monopile foundations for the project arrived in Portsmouth, Virginia, in October 2023. Courtesy: Dominion Energy

The Race to Scale Continues

Offshore wind technology continues its relentless march toward larger, more powerful machines. The average capacity of turbines installed offshore in 2024 reached 10 MW, according to GWEC, a figure that would have seemed implausible a decade ago. Yet, the frontier has already moved well beyond that threshold.

Chinese manufacturer Dongfang Electric Corp. commissioned the world's largest operational wind turbine in late 2025: a 26-MW behemoth (Figure 3) featuring 150-meter (m, 492-ft) blades and a rotor diameter of 310 m (1,017 ft). Goldwind launched its 22-MW platform in December 2024, while most other major Chinese original equipment manufacturers now offer turbines rated at 16 MW or greater, GWEC reported.

This rapid scaling reflects intense competition among Chinese manufacturers, supported by massive domestic testing infrastructure. GWEC said new facilities include offshore test sites in Guangdong and Fujian provinces, a 40-MW test bench operated by Shanghai Electric Wind Power Group in Yancheng, and a 35-MW six-degrees-of-freedom drivetrain test bench from SANY in Beijing. Blade testing capabilities have expanded with new sites in Jiangsu province's Dafeng district and Lianyungang.

3. The 26-MW offshore wind turbine developed by Dongfang Electric Corp. is currently the world's largest unit. The first grid connection of this design was successfully completed on Oct. 29, 2025. Source: State-owned Assets Supervision and Administration Commission of the State Council

Western manufacturers are responding. Siemens Gamesa's 14-MW platform is being deployed across major European and Asian projects, while Vestas and other suppliers advance their own large-turbine programs. However, the scale of Chinese investment in manufacturing capacity and testing infrastructure has opened a significant lead in turbine ratings.

Meanwhile, GE Vernova is supplying wind turbines for what developers claim "will become the world's largest offshore wind farm when fully operational." The project, Dogger Bank, is a joint venture partnership between SSE Renewables (40%), Equinor (40%), and Vårgrønn (20%). SSE Renewables is leading on the development and construction of the wind farm, while Equinor will operate it over its expected 35-year lifespan.

The project is located in the Dogger Bank Offshore Development Zone, which is between 125 kilometers (km, 78 miles) and 290 km (180 miles) off the east coast of Yorkshire, England, and extends over approximately 8,660 km^2 (2,140,000 acres) with water depths ranging from 18 m to 63 m (59 ft to 207 ft). The current project (Figure 4) is being constructed in three phases—A, B, and C—and will consume only a portion of the development zone (less than 20%). When fully completed, Phases A and B will each have 95 GE Vernova Haliade-X wind turbines rated at 13 MW each, and Phase C will have 87 Haliade-X turbines with an upgraded 14-MW rating.

Floating Wind Approaches Commercial Scale

Floating offshore wind technology—which enables deployment in deeper waters unsuitable for fixed foundations—is transitioning from demonstration projects toward commercial scale. GWEC reported global installed floating capacity reached 278 MW by the end of 2024, distributed across Norway (101 MW), the UK (78 MW), China (40 MW), France (27 MW), Portugal (25 MW), and others.

More significantly, 2.4 GW of floating wind capacity has now secured routes to market through competitive auctions or contracts. GWEC said France awarded 750 MW across its AO5 and AO6 tenders at strike prices of €85.5/MWh to €92.7/MWh ($98.40/MWh to $106.6/MWh). South Korea awarded the 750-MW Bandibuli floating project, while the UK's CfD Allocation Round 6 included the 400-MW Green Volt floating project.

China is pursuing floating wind at scale with its 1-GW Wanning project in Hainan province. A 100-MW prototype phase, featuring turbines of 16 MW to 18 MW from Shanghai Electric, Dongfang, CRRC, and Windey, was scheduled to complete by the end of 2025, the GWEC report says.

Japan's offshore wind ambitions received a significant boost in June 2025 when the Diet (the country's bicameral national legislature) passed the Exclusive Economic Zone Bill, enabling floating wind development in waters beyond Japan's territorial sea. This legislation opens vast new areas for potential development in a nation with limited shallow-water continental shelf.

Despite this progress, floating wind faces significant headwinds. The technology remains more expensive than fixed-bottom installations, and the specialized vessels, mooring systems, and dynamic cables required add complexity to project execution. More broadly, the IEA revised its global offshore wind forecast downward in its most recent forecast by 27% from the previous year, citing U.S. policy changes, macroeconomic pressures, and supply chain challenges that have undermined project bankability in several markets.

Foundation and Installation Innovations

As turbines grow larger, so too must the foundations that support them—and the equipment that handles these massive components. Monopile foundations, the industry's workhorse for bottom-fixed installations, now regularly exceed 2,000 tonnes and 80 m (262 ft) in length.

4. *Heerema's Sleipnir vessel installs an Aibel-manufactured high-voltage direct-current (HVDC) platform at Dogger Bank C, marking the completion of offshore substation installation at the world's largest offshore wind farm. The pioneering design reduces topside weight by as much as 70%. Courtesy: Dogger Bank Wind Farm*

A notable innovation in monopile logistics debuted at the Windanker project in Germany during 2024–2025. Dutch heavy-lift specialist Mammoet deployed its XXL monopile transport system at the port of Rønne in Denmark to marshal foundations for the 315 MW project. The system employs MTC1600 terminal cranes (Figure 5) with a combined lifting capacity of 3,200 tonnes, capable of handling monopiles up to 2,150 tonnes and 87 meters in length.

The significance lies in operational efficiency. Conventional monopile handling requires extensive port reinforcement, Ro-Ro (roll-on/roll-off) operations, and sequential vessel loading. Mammoet's approach eliminates ground reinforcement requirements and enables continuous feeding of installation vessels—a critical capability as project scales increase and weather windows constrain offshore operations.

Manufacturing processes are also evolving. Lincoln Electric reported its Long Stick-Out (LSO) welding technology has been deployed worldwide for fixed foundation fabrication, achieving deposition rates of more than 37 kilograms/hour (kg/hr) with tandem configurations and more than 40 kg/hr with triple-arc setups. These rates represent 30% to 100% improvements over conventional submerged arc welding, which typically achieves less than 27 kg/hr. Faster welding translates directly to higher factory throughput and shorter lead times for foundation delivery.

The installation vessel fleet is expanding to address a longstanding bottleneck. China now operates 65 jack-up vessels and barges plus 47 heavy-lift vessels dedicated to offshore wind construction, according to GWEC. Chinese shipyards have become suppliers to European installation contractors, building wind turbine installation vessels to specifications capable of handling the latest turbine generations. Orders placed in 2021–2022 are now delivering, gradually easing vessel availability constraints.

5. *With the ballast weight of the MTC crane positioned much further away from the pivot point of the boom, in comparison to a large crawler crane, the load-bearing pressure was far less. This helped to spread the load over a greater distance, avoiding the need for specialist foundations or temporary civil work. Courtesy: Mammoet*

Projects in Progress: A Global Portfolio

Offshore wind construction activity spans at least four continents, with major projects advancing across varying stages of development and completion. The following are a sampling of notable projects well-underway or recently finished.

Europe. Construction continues on the previously mentioned Dogger Bank offshore wind farm in the North Sea. Phases A, B, and C are all underway, with Phase A in commissioning and generating first power. Developer SSE and partner Equinor have finalized the lease for Phase D (1.5 GW), with terms agreed in August 2025. The full project is expected to contribute £6.1 billion ($8.3 billion) to UK gross domestic product (GDP) and support 3,600 full-time equivalent jobs during its peak construction year.

Van Oord's Svanen heavy-lift vessel has installed 21 monopiles for the 315-MW German Windanker project in the Baltic Sea. As mentioned previously, the foundations were marshalled through Rønne port in Denmark, using Mammoet's specialized handling equipment.

In Poland, Baltica 2, a 1.5-GW PGE and Ørsted joint venture, achieved a significant milestone in December 2025 with the delivery of four 450-MVA transformers to the onshore substation at Osieki Lęborskie. The facility will convert power from 275 kV to 400 kV for transmission to the national grid. Commercial operation is targeted for 2027, when the project will supply renewable electricity to approximately 2.5 million Polish households.

Dieppe-Le Tréport in France is a 496-MW project (Figure 6). Ocean Winds' consortium installed the project's first jacket foundation in September 2025. The 62-turbine array, located 17 km offshore, secured €2.4 billion ($2.8 billion) in financing in April 2023, with Sumitomo Mitsui taking a 29.5% stake. Commercial operation is expected in 2026.

Yeu-Noirmoutier, also in France, is a 500-MW wind farm. Construction began in April 2023 for this Ocean Winds consortium project. The first Siemens Gamesa–supplied 8.2-MW turbines began generating power in June 2025. The project is reportedly on track to reach full operational capacity during the first quarter (Q1) of 2026.

Asia-Pacific. Hai Long (Taiwan, 1,044 MW) is a three-phase project being developed by Northland Power and Yushan Energy. It reached a major milestone in December 2025 when all 21 turbines at the Hai Long 2A phase achieved mechanical completion. Commissioning is underway for the Siemens Gamesa SG 14-222 DD turbines, with the full 73-turbine array progressing toward commercial operation.

In Japan, the 112-MW Ishikari Bay project achieved commercial operation in early 2024, adding to Japan's nascent but growing offshore wind portfolio. Meanwhile, the Jeju Hallim project was the largest commercial offshore wind farm in South Korea, featuring 18 Doosan 5.56-MW turbines. It also achieved full commissioning in 2024, as did the nearby Jeonnam 1 project (96 MW), GWEC reported.

Still, China is currently leading the way in offshore wind worldwide. Among its projects is Fujian Zhangpu Liu'ao Phase II. This project achieved full grid connection in July 2024, and was notable for deploying the first commercial 16-MW turbines. The array comprises 7 Goldwind GWH252-16MW units alongside 13 GWH252-14.3MW machines. Yangjiang Qingzhou Phase VI is another Chinese project featuring Goldwind turbines. It has 74 GWH252-13.6MW units. This substantial project is expected to reach full commercial operation this year.

Wanning Floating Offshore Wind is perhaps the most notable project in Hainan province. It's being watched by the international energy community for two main reasons: scale and typhoon resistance. Wanning is 10 times larger than most previous floating offshore wind projects, aiming to solve the cost-per-kilowatt problem through sheer volume. Additionally, the Wanning area is prone to intense tropical cyclones. The project serves as a live test for active ballast systems and mooring technology designed to keep 17-MW turbines stable during intense storms.

6. The successful installation of the first foundation at the Dieppe-Le Tréport offshore wind farm was announced on Sept. 10, 2025. For such operations, specialized vessels raise themselves above the waterline on extendable legs, creating a stable platform for precision heavy-lift operations in open seas—a capability essential to the global expansion of offshore wind. Courtesy: Ocean Winds

Market Challenges and Industry Response

The offshore wind sector faces a complex set of challenges that vary significantly by region but share common themes.

Macroeconomic headwinds—including inflation, increased capital costs, and supply chain constraints—have squeezed project economics across markets, according to GWEC. Supply chain bottlenecks persist for critical components such as transformers, submarine cables, offshore substations, and installation vessels. Grid connection delays have emerged as a binding constraint in several European markets, with Germany, Belgium, and the Netherlands experiencing transmission infrastructure backlogs, GWEC said.

Permitting remains a persistent friction point. Many markets contend with slow approval processes, fragmented regulatory systems, and under-resourced permitting agencies. Auction design has proven problematic in some jurisdictions. For example, tenders in the UK and Denmark failed to attract bids due to what GWEC described as "poor commercial viability" and strike prices that failed to reflect rising costs from inflation and higher interest rates.

Policy instability represents perhaps the most significant risk, as events in the U.S. demonstrate. The IEA noted that "regulatory and political risks remain high" globally, with the sharp downward revision in U.S. forecasts reflecting not technical limitations but policy choices.

Industry associations and market participants have advocated for reforms including two-sided CfDs that provide floor prices alongside caps, better risk allocation between developers and offtakers, predictable project pipelines, and indexed power purchase agreements that adjust for inflation. Permitting recommendations focus on centralized review processes, designating renewable energy development as an "overriding public interest" for environmental assessments, and deploying digital tools to accelerate reviews.

Grid planning has emerged as a critical area for coordination. Industry groups are calling for anticipatory transmission investment—building infrastructure ahead of confirmed generation capacity—and clearer delineation of responsibilities for offshore and onshore connection works.

Despite these headwinds, the global pipeline remains substantial. With 48 GW under construction, 56 GW awarded in recent auctions, and multiple gigawatt-scale projects progressing through development, offshore wind appears positioned to deliver continued growth—though the pace and geographic distribution of that growth will depend heavily on how policymakers in key markets address the structural challenges confronting the sector. ■

*—**Aaron Larson** is POWER's executive editor.*

Battery Storage Comes of Age: From Grid Accessory to Essential Infrastructure

From plunging costs to policy upheaval, the global battery storage sector is transforming grid design—and facing unprecedented challenges.

Aaron Larson

The energy storage industry stands at a pivotal crossroads. On one side, costs are plummeting so dramatically that utility-scale batteries can now deliver solar power around the clock at competitive prices. On the other, regulatory upheaval—particularly in the U.S.—threatens to disrupt supply chains and slow deployment at the very moment storage is most needed. This complex landscape presents both unprecedented opportunities and significant challenges for utilities, developers, and grid operators worldwide.

As data centers proliferate, electrification accelerates, and aging thermal plants retire, the need for flexible, reliable power has never been greater. Energy storage is increasingly viewed not merely as a complement to renewable generation, but as the backbone of future grid design (Figure 1). This comprehensive analysis examines the forces reshaping the industry across multiple continents and explores what the coming years may hold.

The Cost Revolution: Batteries Achieve Economic Breakthrough

The economics of battery storage have transformed so rapidly that industry veterans struggle to keep pace with the new reality. According to research released in December 2025 by energy think tank Ember, the cost of storing electricity with utility-scale batteries has fallen to just $65/MWh—a figure that fundamentally changes how solar power can be deployed.

"After a 40% fall in 2024 in battery equipment costs, it's clear we're on track for another major fall in 2025," said Kostantsa Rangelova, global electricity analyst at Ember. "The economics for batteries are unrecognisable, and the industry is only just getting to grips with this new paradigm."

1. SSE's 50-MW/100-MWh battery energy storage system (BESS) at Salisbury in Wiltshire, England entered commercial operation in April 2024. The company has said battery storage "will play an increasingly important role in our energy mix." Courtesy: SSE Renewables

Ember's analysis assessed the cost of a complete battery storage system connected to the grid at only $125/kWh as of October 2025 for long-duration (four hours or more) utility-scale projects in global markets outside China and the U.S. Core battery equipment delivered from China now costs about $75/kWh, while installation and grid connection typically add approximately $50/kWh.

The implications are profound. Ember's researchers said if half of daytime solar generation is shifted to evening hours through storage, the $65/MWh storage cost adds roughly $33/MWh to solar's total cost. Combined with the global average solar price of $43/MWh in 2024, this yields dispatchable clean electricity at approximately $76/MWh—competitive with many conventional generation sources.

"Solar is no longer just cheap daytime electricity, now it's anytime dispatchable electricity. This is a game-changer for countries with fast-growing demand and strong solar resources," Rangelova said.

Europe Charts a Course for Strategic Storage Deployment

The European Network of Transmission System Operators for Electricity (ENTSO-E) released a comprehensive policy paper in December 2025 outlining market design principles for utility-scale storage deployment. The paper notes that while Europe currently has approximately 73 GW of energy storage capacity installed—predominantly pumped hydro—the continent will require roughly 200 GW by 2030 and at least 600 GW by 2050 to meet its flexibility needs.

The ENTSO-E framework identifies three primary policy pathways for enabling storage investment: improving conditions for merchant investments, adapting capacity mechanisms to increase storage participation, and designing effective non-fossil flexibility support schemes.

"Storage systems not only reduce curtailment by shifting renewable generation from periods of excess supply to periods of higher demand but also deliver fast-responding balancing energy and high-value ancillary services," the ENTSO-E paper states. The organization emphasizes that storage can provide black-start capability and, depending on technology, mechanical or synthetic inertia—services increasingly valuable as synchronous thermal generation retires.

The European policy landscape presents both opportunities and complexities. Grid connection requests for battery storage have surged dramatically, with German TSOs collectively reporting about 230 GW of battery energy storage system (BESS) connection applications, while Italy's Terna reports approximately 300 GW of storage connection requests. However, ENTSO-E notes that many of these requests remain speculative, submitted before firm investment decisions are made.

Italy has emerged as a frontrunner,

2. President Trump signed the One Big Beautiful Bill Act into law on July 4, 2025. Energy storage retained its primary tax incentives, though the sector now faces stricter foreign-sourcing and domestic-content requirements. Source: The White House

establishing a dedicated competitive mechanism called MACSE (Mercato per l'Approvvigionamento di Capacità di Stoccaggio Elettrico) for procuring new utility-scale storage capacity. In September 2025, approximately 10 GWh of new BESS was procured at an average price below €13,000/MWh-year, with delivery starting in 2028 for a 15-year period.

Germany's innovative "Grid Booster" projects represent another approach, using large-scale batteries as "virtual transmission lines." In one example, TenneT's system deploys two 100-MW/100-MWh battery installations supplied by Fluence at geographically distinct substations in Schleswig-Holstein and Bavaria. When transmission line outages occur, the northern unit absorbs excess power while the southern unit injects energy, providing automated redispatch that maintains system stability without operator intervention.

U.S. Storage Sector Navigates Regulatory Upheaval

The American energy storage market has weathered considerable turbulence in 2025, with fluctuating tariffs and the passage of the One Big Beautiful Bill Act (OBBBA, Figure 2) creating both uncertainty and, ultimately, relative clarity for the sector. While wind and solar projects face accelerated phase-outs of tax credits under the new legislation, energy storage emerged comparatively unscathed—its credits not phased out until after 2033.

"Those who are driving renewable build out, including all of the AI [artificial intelligence] data center growth, have come to appreciate the role of baseload power and firm supply," explained a vice president at one of the world's leading investment banks in an analysis by law

Key Storage Technologies Compared

Lithium Iron Phosphate (LFP). The most widely deployed lithium-ion chemistry for utility-scale and behind-the-meter battery energy storage, with typical system round-trip efficiency in the 85% to 90% range depending on design and operating conditions. Typical discharge duration for current grid-scale projects is 2–4 hours, though systems are increasingly configured for 1–6+ hours based on application needs. Supply chains for key materials and cell manufacturing remain significantly concentrated in China, even as regional diversification efforts and policies targeting tariff and Foreign Entity of Concern (FEOC) exposure gain momentum.

Sodium-Ion. An emerging battery technology that uses more abundant materials, positioning it as a potential lower-cost alternative to lithium-based chemistries over the long term. Sodium-ion generally exhibits lower gravimetric and volumetric energy density than LFP, which can translate into larger system footprints and, at present, higher installed costs per kWh for many grid applications. Challenges related to voltage profile, calendar life, and temperature sensitivity require tailored battery management and power electronics strategies, and early commercial development and manufacturing activity is currently led by Chinese suppliers, with growing interest in other regions.

Iron-Sodium (Sodium Metal Chloride). A long-duration storage approach that uses iron and salt-based electrochemistry (often described as sodium metal chloride or iron–sodium) and has reported round-trip efficiencies in the 80%-plus range in recent third-party tests. Developers indicate that adding storage duration—from 4 to 24 hours—primarily involves scaling relatively low-cost active materials and balance-of-plant, which can limit incremental cost increases to well below the multiples typically seen when extending lithium-ion systems to very long durations, although independent cost data remain limited. The chemistry's operating mechanism and temperature regime significantly reduce the risk of classic lithium-ion thermal runaway, and at least one manufacturer has announced plans to start U.S. production lines with commercial ramp-up targeted by 2026.

Flow Batteries. Electrochemical storage systems such as vanadium, zinc-bromine, and iron-chromium flow batteries store energy in liquid electrolytes, allowing energy capacity to scale largely with tank volume while power scales with stack size. Typical round-trip efficiencies for commercial systems fall in the roughly 65%–80% range, trading some efficiency relative to lithium-ion for long cycle life, deep depth-of-discharge capability, and inherent safety advantages due to separation of energy storage media and power conversion components. These systems are primarily targeting 4- to 12-hour applications today, with the option to extend duration further by increasing electrolyte volumes where space and cost allow.

Pumped Hydro Storage. A mature mechanical storage technology that shifts water between lower and upper reservoirs, and remains the dominant source of installed grid-scale storage capacity in many regions. In Europe, pumped hydro accounts for the bulk of installed storage capacity—on the order of tens of gigawatts out of total storage capacity in the same range—illustrating its central role in current long-duration storage portfolios. While it can provide multi-hour to multi-day duration, deployment is constrained by geography, environmental impacts, and long permitting and construction timelines that commonly span 6–10 years or more for new projects.

Iron-Air and Hydrogen. Iron-air batteries and hydrogen-based storage (including electrolysis, storage, and reconversion via fuel cells or turbines) are being developed to deliver very long durations, often targeting 100-plus-hour applications, multi-day backup, and seasonal shifting of renewable energy. Both approaches typically exhibit lower round-trip efficiency than lithium-ion or LFP—particularly for hydrogen systems that involve multiple conversion steps—but could offer very low levelized cost per kWh for infrequent, high-value discharge events if capital and fuel costs can be reduced at scale. Commercial deployment remains limited to pilot and early commercial projects, with significant research, demonstration, and policy support still needed to validate cost, durability, and system integration performance at scale.

firm Troutman Pepper Locke. "This was a factor in OBBBA in that, while you saw a phase out for wind and solar tax credits, that is not the case for baseload power, including geothermal, nuclear, and battery storage."

However, the OBBBA's Foreign Entity of Concern (FEOC) rules pose significant challenges for an industry heavily dependent on Chinese supply chains. These restrictions prevent entities linked to adversarial nations, particularly China, from accessing U.S. energy tax incentives—either directly or indirectly.

The FEOC rules are "really handicapping the industry pretty significantly," Tom Cornell, CEO of battery storage system supplier Prevalon, a Mitsubishi Power Americas and EES joint venture, said in the Troutman Pepper Locke report. "There's just not enough time to move the supply chain that quickly, especially around the battery cells, so that's really our big concern," he said.

Andrew Waranch, CEO of Spearmint Energy, took a more optimistic view in the report, noting that forward-thinking companies began preparing months before the regulations took effect. "Our team took aggressive action in May 2024, six months before the election," he said. "We started evaluating suppliers all over the world." Waranch traveled extensively to Europe, Japan, and Korea seeking alternative suppliers, and many manufacturers made similar contingency plans after witnessing tariffs' impact on the solar industry.

Beyond Lithium-Ion: The Search for Alternatives

Supply chain pressures and the need for longer-duration storage are accelerating interest in technologies beyond conventional lithium-ion batteries (see sidebar). Antonio Baclig, CEO of Inlyte Energy, sees the current moment as an inflection point.

"The driver for storage has fundamentally changed in the past year," Baclig explained in an exclusive interview with *POWER*. "Rapid load growth is straining the existing grid and energy storage provides the flexibility to modify power flows and flatten load variation, allowing us to get more out of the grid we have. New energy—solar—is part of that, but firm capacity and flexibility are the strengths of storage."

Inlyte Energy recently completed a factory acceptance test of its first full-scale iron-sodium battery storage system, witnessed by representatives from Southern Company at Inlyte's UK facility. The system achieved 83% round-trip efficiency including auxiliaries—competitive with high-performance lithium-ion and substantially above the 40% to 70% range typical for other long-duration energy storage technologies. Installation at Southern Company's energy storage test site in Wilsonville, Alabama, is planned for early 2026.

"To win the future, we need abundant and secure supplies of energy in the U.S., and at the same time we need to make costs go down, not up," Baclig said in a statement to the press. "We can't do that by building the same thing as China. We need to make better technologies, with batteries that are fundamentally lower cost, safer, and longer lasting."

Baclig expressed skepticism about sodium-ion (Na-ion) technology as an alternative to lithium iron phosphate (LFP) batteries. "Na-ion has a relative disadvantage compared to LFP due to lower energy density," he told *POWER*. "This means that the overall system will cost more per kWh. It also has a very wide voltage profile that does not integrate as well with the common power electronics used for lithium ion." He noted that China already dominates the Na-ion supply chain, meaning even greater protectionist policies would be needed to build domestic U.S. capacity.

The economics of extending duration represent a key advantage for some alternative chemistries. According to Baclig, "The cost to make a 24-hour iron-sodium system is only slightly higher (<25%) than a 4-hour system, because the battery allows us to add more iron and salt active material into the existing vessel to achieve the higher energy." In contrast, achieving 24-hour duration with lithium-ion technology would cost nearly six times as much as a 4-hour system.

The Winter Peaking Challenge Emerges

A fundamental shift in grid planning is underway as utilities grapple with winter peaking challenges that differ substantially from traditional summer demand patterns. Baclig highlighted this emerging concern: "The main difference between summer and winter peaking is the lack of significant, reliable daily solar energy that separates one day from the next to allow for storage recharge. Wind is relatively difficult to predict and rely on for daily energy. Major cold snaps tend to persist for multiple days at a time."

The February 2021 Winter Storm Uri, which devastated the Texas grid, demonstrated the stakes involved. As climate volatility increases and heating electrification accelerates, the need for storage capable of multi-day discharge is becoming increasingly apparent in utility planning studies.

"Long-term studies for 2030 and beyond point to the growing importance of 10- to100-hour solutions to address resource adequacy, driven by winter peaking needs," Baclig said. "Gigawatts of 24-plus-hour storage will be contracted by 2030 in the U.S.," he predicted.

"Energy storage is essential for creating a reliable and flexible energy grid," Steve Baxley, Southern Company's energy storage and use research and development manager, said in Inlyte's news release. "As the grid evolves toward longer-duration storage, developing solutions that are both low-cost and safe is critical to ensuring affordable, dependable service for customers."

Global Project Pipeline Accelerates

Despite policy uncertainties, the global storage project pipeline continues to expand rapidly. Major announcements in December illustrate the breadth of deployment activity:

Arizona. Copenhagen Infrastructure Partners (CIP) acquired the 250-MW/1-GWh Beehive Battery Energy Storage System from EDF Power Solutions. Located in Peoria, Arizona, the project has a 20-year tolling agreement with Arizona Public Service Co. (APS) and is expected to reach commercial operation in the first half of 2026. "With electricity demand rapidly increasing in the Southwest, we anticipate battery storage will play a critical role in powering innovation and economic growth," Tim Evans, partner and head of North America at CIP, said in a statement.

Australia. e-STORAGE, part of Canadian Solar, will deliver a 204-MW/408-MWh alternating-current (AC) battery system for Vena Energy's Tailem Bend 3 project in South Australia, targeted for operation in 2027. Separately, Wärtsilä announced its tenth Australian BESS project—a 100-MW/223-MWh system for renewable energy retailer Flow Power. The project, known as Bennetts Creek BESS, is located adjacent to the Morwell Terminal Station in Victoria, and will also provide frequency regulation services when operational in 2028.

United Kingdom. Matrix Renewables signed a full engineering, procurement,

3. This is a rendering of the 500-MW/1-GWh standalone BESS being constructed in Eccles, Scotland. Courtesy: Matrix Renewables

4. Inside a high-density data hall, racks of servers push power demand to new highs—underscoring why grid-connected energy storage is essential to keep artificial intelligence (AI), cloud computing, and wider electrification reliably online. Source: Envato Elements

and construction (EPC) agreement with Tesla for a 500-MW/1-GWh standalone BESS in Eccles, Scotland (Figure 3)—the company's first standalone storage project in the UK. Meanwhile, Jinko ESS announced expansion of its UK portfolio with a second 140-MWh phase, bringing combined deployment to 280-MWh. Although the location of the system was not disclosed, the initial press release noted the deal was with AGR Renewables and that the system was engineered specifically to handle challenging environmental conditions, including –10C temperatures, which can be found in "high-latitude areas."

Northern Ireland. SSE took final investment decision on the 100-MW/200-MWh Derrymeen BESS in County Tyrone, with construction to follow in 2026. The project will be located beside the Tamnamore 275/110-kV substation, near Dungannon, and has secured a 10-year Capacity Remuneration Market contract beginning in October 2028.

Africa. Jinko ESS secured 15 MWh of SunGiga liquid-cooled energy storage systems for deployment across 45 remote villages in Senegal, bringing reliable nighttime electricity to tens of thousands of residents in distributed off-grid applications.

Data Center Growth Reshapes Storage Strategy

The explosion of AI applications (Figure 4) is creating unprecedented electricity demand that is fundamentally reshaping how utilities and storage developers approach project planning. According to a report issued by the U.S. Department of Energy (DOE) in July 2025, substantial load growth coupled with the retirement of firm power capacity could increase the risk of power outages by 100 times by 2030.

"Data centers require very high up times and, as such, they need both [storage and solar], and they need short-term and long-term reliability," said Waranch of Spearmint Energy. "We're seeing more and more RFPs [requests for proposals] from tech companies of all types, not just the big data companies."

Baclig agreed that data center integration rules will become a major force shaping energy storage deployment. "FERC [the Federal Energy Regulatory Commission] and DOE are actively taking up this topic," he told *POWER*. "PJM's response to dwindling capacity reserve and rising capacity prices—driven in large part by data center demand—is a key region to watch," he said.

The investment bank source interviewed by Troutman Pepper Locke noted that the data center industry's willingness to pay premium prices strengthens the case for storage even amid tariff-driven cost increases. Notably, the argument for battery storage is not just decarbonization-focused but also based on grid reliability concerns. "It's not unreasonable to expect that there would be some appetite to continue to support it [battery storage] even if there are price increases," the investment bank source said.

Looking Ahead: The Storage Landscape in 2030

Industry executives and analysts are cautiously optimistic about the sector's trajectory, even as significant challenges remain. The DOE projects that reaching future U.S. grid requirements will necessitate more than 225 GW of long-duration energy storage by 2050—far beyond what Inlyte and other industry observers say current lithium-ion technologies can economically deliver.

Baclig offered his prediction for the U.S. market: "8-hour duration battery storage will be standard for new projects and it will likely still be majority provided by LFP in 2030. However, long-duration energy storage, like iron-sodium battery storage, will constitute a growing share as the needs for infrequent winter peak responses of 24+ hours become clear in the evolving grid."

In Europe, ENTSO-E emphasized that storage deployment must be targeted to system-relevant locations where flexibility delivers the highest value. "Storage assets will be an essential element of the generation mix in any decarbonised power system," the organization concluded. To that end, it said conditions that allow private investors in these capital-intensive technologies to achieve a fair and predictable return should be established as a prerequisite for deployment.

The path forward involves navigating policy uncertainty, supply chain restructuring, and rapidly evolving technology options. But the fundamental drivers—falling costs, rising demand, and the essential role of flexibility in modern grids—suggest energy storage has moved from the periphery to the center of power system planning. The question is no longer whether storage will transform the grid, but how quickly that transformation will unfold. ■

*—**Aaron Larson** is POWER's executive editor.*

ADVERTISERS' INDEX

Shared Power: Building Data Centers That Serve Everyone

Yash Hurkat

The unprecedented revolution in digital infrastructure, driven by the explosion in artificial intelligence (AI) services and cloud computing, is fueling an economic boom. However, this wave of technological innovation is hiding rising ratepayer burden and mounting reliability risks to the electric grid.

Data centers consumed 184 TWh in 2024. McKinsey projects this to increase by 230%, to 606 TWh by 2030. New upcoming hyperscale facilities with proposed loads of 100 MW to 200 MW are key drivers of this growth.

Government policies and private investments are increasingly prioritizing rapid permitting and interconnection, not recognizing the long-term risks and impacts of adding such large loads on our electrical grids in such a short timeframe. The burden of this unprecedented, geographically concentrated demand is being disproportionately allocated to consumers and utilities.

Rising Costs and Reliability Risks

Rapid load growth is already driving up consumer electricity costs. A Carnegie Mellon University study estimates that large-scale transmission and grid expansion investments to support data center growth could raise the average U.S. electricity bill by 8% by 2030. Rate increases in high-demand markets like northern Virginia could even exceed 25%.

Grid reliability risks are also escalating. The North American Electric Reliability Corporation (NERC) warned that rapid addition of large, voltage-sensitive data center loads threatens grid stability.

To rectify this growing structural inequity, regulators must evolve from simply accommodating fast data center growth to promoting integrated, shared-value solutions that ensure mutual benefit for consumers, utilities, and developers. Waste heat recovery and grid-interactive assets are key solutions to democratize benefits from this rapid growth.

Integrating Thermal Energy Networks

Data centers release nearly all the electricity they consume as low-grade heat, representing a significant untapped energy potential. When harnessed with heat pumps, this heat can be upgraded for use in district and industrial heating applications.

This concept is not theoretical. Large-scale heat recovery is already operational in Scandinavia—the 25-MW Nebius facility in Finland heats the equivalent of 2,500 homes. Successful domestic pilot projects include the National Laboratory of the Rockies' campus in Golden, Colorado, and Amazon's Seattle, Washington, headquarters.

This solution also addresses the massive upcoming challenge of heating electrification. With an increasing number of jurisdictions mandating all-electric heating, utilities face yet another surge in electrical consumption. Water-source heat pumps in thermal networks outperform air- and ground-source alternatives. Waste-heat integration can help accelerate decarbonization while simultaneously creating a new revenue stream for utilities.

Waste heat recovery must be integrated into planning for all upcoming data centers. The primary obstacle is not technical feasibility, but rather the conflict between rapid construction timelines and the lengthy planning required for utility-scale thermal networks. Large-scale implementation plans often face business-related barriers (such as the lack of well-defined business models), underscoring the need for regulatory intervention. Permitting bodies must utilize the power of their approval process to bridge this gap. Expedited permits and interconnections should require waste-heat recovery feasibility studies, installation of piping and heat-exchange infrastructure, and coordination with local utilities or industries needed for future thermal network integration. This mechanism leverages the developer's need for speed to secure a lasting and valuable community asset.

Enabling Grid-Interactive Assets

Uninterrupted power is essential for data center reliability. Data centers are increasingly being built with considerable onsite generation capacity and battery energy storage systems (BESS) to ensure 24/7 operation. While essential for backup and redundancy, these assets typically remain idle. With a proper incentive structure and mandatory participation requirements, these assets can be leveraged as dynamic grid resources to reduce operational stress on local utilities.

By participating in ancillary grid services like frequency regulation, spinning reserve, and strategic load smoothing, data center assets can support grid operations. NERC's recent assessments confirm improved grid reliability in areas with high BESS concentrations. Ireland has already demonstrated how transmission operators can utilize data center BESS for frequency stabilization and improved renewable penetration.

The shift toward AI processing also creates new opportunities in load flexibility. Regulators must transition from voluntary participation to mandatory enrollment in demand response (DR) programs as a prerequisite for fast-track interconnections. According to the Rocky Mountain Institute (RMI), curtailing new data center load by just 0.5% annually could unlock nearly 100 GW of new load, without expanding existing generation capacity. This incentivization allows local utilities to mitigate their capital costs and operational risks while allowing data centers to monetize backup assets.

A Path Forward

The data center boom is largely beneficial and inevitable. However, we must not allow short-term economic gains to create long-term inequity in our grid infrastructure. These strategies can transform data centers into grid and community assets.

Regulators must adopt clear, mandatory requirements to incorporate these shared-value solutions linking rapid development with broader benefits. The growth and benefits of the digital economy must be harnessed to create a more stable, affordable, and decarbonized grid for everyone. ■

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