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# Small Modular Reactors & Advanced Nuclear Designs

WHITEPAPER


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## The Nuclear Renaissance

# Why SMRs Are Back in the Spotlight

The United States is experiencing a significant strategic shift in its clean energy transition, driven by climate needs, grid reliability, and growing industrial demand. In this environment, nuclear energy is making a comeback, not as the large gigawatt-scale plants of the past, but as small, modular reactors designed with modern efficiency. Small Modular Reactors (SMRs) and advanced nuclear designs are reshaping nuclear power's role in the U.S. energy mix. This emerging view positions these technologies as reliable zero-carbon baseload sources capable of flexible operation, integrating with renewables, and satisfying the increasing demands of energy-intensive sectors such as data centers and AI infrastructure.

Large nuclear projects often face costly overruns, multi-year delays, and complex risk profiles—evidenced by the Vogtle expansion, where projected costs increased and schedules slipped. In contrast, SMRs are built for off-site factory manufacturing, ensuring consistent quality, predictable timelines, and lower capital costs per unit. These reactors usually range from tens to a few hundred megawatts, supporting phased deployment that matches local demand. Fewer onsite complexities and easier deployment logistics decrease both financial risks and regulatory hurdles.

Public policy offers strong support. Over the past two years, more than half of U.S. states have passed laws or issued directives that classify nuclear energy as part of clean energy mandates. For example, several Midwestern states enacted bills defining SMRs as clean sources, making them eligible for financial incentives and procurement alongside renewables. States including Virginia, Michigan, Wyoming, and Utah have lifted moratoria, created SMR-specific regulatory frameworks, or formed task forces to explore deployment options. Some states have increased capacity thresholds or established utility rules that help develop SMRs within existing clean portfolio standards.

At the federal level, the Department of Energy has launched a $900 million solicitation aimed at de-risking Gen-III+ light water SMRs, with funding intended to promote early commercial deployment. Alongside this, bipartisan legislation such as the ADVANCE Act of 2024 directs the Nuclear Regulatory Commission (NRC) to streamline licensing processes for advanced reactors, lower licensing fees, and prioritize HALEU (high-assay, low-enriched uranium) fuel access. Multiple executive orders issued in mid-2025 commit to increasing nuclear capacity by 300 GW by 2050 and establish staged timelines for regulatory approval. These policy actions collectively indicate that federal and state leaders view modular nuclear as vital to energy security and decarbonization efforts.

SMR technology has also started overcoming regulatory barriers. NuScale Power received NRC design certification in July 2022 for its first 50 MWe module, and in May 2025, it gained approval for an upgraded 77 MWe design. As of mid-2025, NuScale remains the only U.S. vendor with fully certified SMR technology. DOE estimates that the deployment of certified SMRs could begin in the late 2020s to early 2030s, depending on favorable policy and funding conditions. Overall, more than seventy SMR designs are actively under development worldwide, with a significant portion aiming for U.S. licensing and grid integration pathways.

Commercial demand supports these developments. Tech giants like Amazon, Google, and Microsoft are starting to anchor SMR projects through power purchase agreements and strategic partnerships. Standard Power, for example, has chosen NuScale's certified SMR technology for nearly 2 GW of planned facilities in Ohio and Pennsylvania, designed to supply low-carbon power to nearby data center clusters. In Texas, X-energy is partnering with Dow to build an Xe-100 reactor that will provide both electricity and steam to a large chemical facility in Seadrift. TerraPower has teamed up with Sabey Data Centers and is actively exploring co-located SMR deployment in multiple states to support AI and industrial electrification.

The convergence of policy momentum, regulatory progress, and corporate offtake commitments has transformed SMRs from academic and niche interests into viable near-term deployments. These advanced nuclear systems are now seen as vital for achieving climate goals, improving grid reliability, and supporting distributed clean energy across the U.S. What sets this moment apart from previous nuclear cycles is the alignment of federal support, state reforms, and customer demand—all combined with inherently safer, smaller reactor designs.

Yet systemic barriers still exist. Public concern over nuclear safety and waste—based on past accidents—remains in some communities, slowing licensing and siting advances. HALEU fuel supply stays limited, which could delay early deployment. The nuclear workforce pipeline must grow quickly to support the expanding SMR sector, and financing models for multi-module projects need to adapt from traditional utility frameworks. Additionally, falling costs for renewables and battery storage continue to make nuclear less competitive financially without ongoing policy support.

Despite these challenges, the strategic calculation favors SMRs as a bridge between renewables and existing nuclear baseload. Smaller footprints, factory fabrication, modular scaling, and passive safety systems give advanced reactors unique advantages in terms of cost predictability, siting flexibility, and risk containment. Energy-intensive industries and regional markets can benefit from localized, uninterrupted, low-carbon power, whether through onsite corporate deployments or utility-scale infrastructure supported by federal incentives and streamlined regulation.

SMR Technology is thus set to play a key role in the future of U.S. power systems. The combined momentum of clean energy policies, strong federal funding, clear regulations, and industrial demand makes advanced nuclear more than just a theoretical concept—it is a practical approach for delivering reliable, carbon-free energy at scale.

The following section will explore the technological foundations behind this resurgence, providing a deeper technical narrative about reactor designs, safety features, and deployment methods that set SMRs apart within the broader Advanced Nuclear Reactors landscape.

**SMRs Rising**

Small Modular Reactors offer flexible, reliable, zero-carbon power for growing U.S. energy needs.

**Strong Support**

Federal and state policies, funding, and streamlined regulations drive SMR deployment.

**Industry Demand**

Tech giants and industries are investing in SMRs to power data centers and heavy facilities.

## SMR Technology Explained

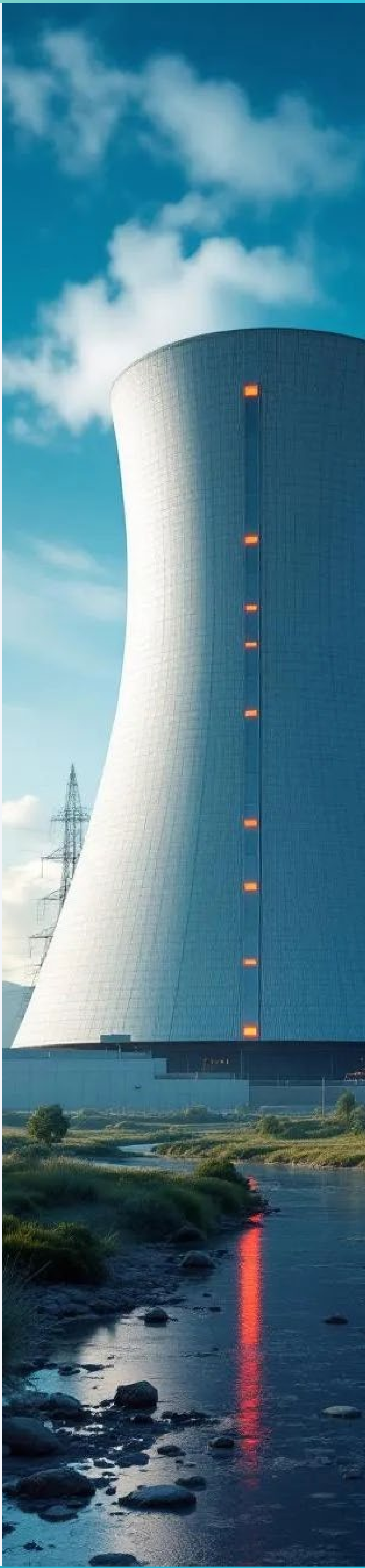
# Small Reactors, Big Potential

Small Modular Reactors (SMRs) mark a significant change in nuclear power in the United States. They feature compact, factory-built reactor modules with improved safety, flexible deployment options, and scalable power capacity. SMRs are defined more by their size—usually up to 300 MWe per module—than by a specific technology. This size allows for modular construction, reduces onsite risks, and enables phased capacity expansion. The main benefit is using series manufacturing to lower costs and minimize schedule uncertainties that have affected traditional gigawatt-scale nuclear projects.

The most advanced SMR designs in the U.S. are based on light water reactors (LWRs). These designs—such as the VOYGR series by NuScale—adapt pressurized water reactor technology into compact, modular units. Each module contains the reactor vessel, steam generator, and pressurizer within a single sealed container, which reduces piping failure risks and simplifies containment. Passive safety systems like natural circulation cooling and gravity-driven emergency heat removal allow the reactors to shut down safely without operator intervention or external power. This design approach speeds up licensing processes and significantly shrinks emergency planning zones.

Beyond LWR-based SMRs, a variety of advanced reactor types are actively being developed in the U.S., broadly categorized as Generation IV technologies. These include high-temperature gas-cooled reactors (HTGRs), sodium-cooled fast reactors, molten salt reactors, and other non-water-cooled systems. Each offers unique benefits and trade-offs. HTGRs—exemplified by Xenergy's Xe100 design—use TRISO-fueled graphite pebbles cooled by helium gas. The modular pebble-bed system provides high thermal efficiency and inherent safety: fuel particles stay intact even under severe heat, and the inert gas coolant cannot cause a significant energy release through phase change. The Xe100 is proposed in 80 MWe modules, scalable in clusters to support larger loads and capable of supplying both electricity and industrial heat via cogeneration.

Sodium-cooled fast reactors are another type of advanced SMR. TerraPower's Natrium reactor, developed with GE-Hitachi, is a 345 MWe sodium-cooled fast reactor combined with a liquid-salt–



based thermal energy storage system. The design enables the reactor to operate on low-carbon electricity and provide stored heat during peak demand. Natrium offers flexibility for grid management and industrial processes. The sodium coolant allows for fast-neutron breeding, which improves fuel efficiency and resource use. Fast reactors also produce less long-lived waste compared to traditional reactors, easing disposal concerns.

Molten salt reactors and other designs, such as lead-cooled or molten chloride systems, are further along the innovation timeline but hold the potential to be game changers, providing passive safety features like freeze plugs and highly modular designs. Although none have been licensed in the U.S., they are part of DOE's Advanced Reactor Demonstration Program (ARDP) and are in early-stage U.S. design efforts.

The diversity in SMR designs meets various needs. Light-water SMRs provide conservative risk profiles and a clear path for near-term deployment. Companies like NuScale benefit from established expertise in LWR construction and streamlined licensing processes. Their certified 50 MWe design and the newly approved 77 MWe versions (VOYGR-4, VOYGR-6) position them for early deployment as America's first SMRs. The integral vessel approach also allows for factory assembly and easier site installation. Advanced reactor developers such as X-energy and TerraPower target specialized uses—industrial heat, fast breeding, or thermal storage—that go beyond the flexibility of LWR systems, although they involve greater technical complexity and longer development timelines.

Current trajectories suggest potential early U.S. deployment between 2028 and 2032 for light-water SMRs, with advanced HTGR and sodium-cooled designs following soon after under ARDP support. DOE funding, licensing guidance, and infrastructure planning all aim to accelerate that timeline. The fuel economy of these systems also varies significantly: fast reactors and TWR-based designs maximize fuel utilization and minimize waste, while TRISO-fueled modules reduce proliferation risks and improve containment integrity. Load following is another feature inherent in advanced SMRs: gas-cooled and liquid-metal systems can adjust output to match grid needs or incorporate variable renewables, further increasing flexibility.

Safety remains a core focus of SMR technology. Lower power densities lead to less decay heat and smaller radioisotope inventories. Using passive cooling and underground containment simplifies safety systems. Factory-made modules are quality-checked in controlled environments before arriving onsite, reducing assembly errors. Integral containment and sealed vessels cut down leak points. Ultra-long fuel cycles—especially in reactor types like

TWRs or fast reactors—limit refueling events and minimize operational disruptions.

Critically, SMRs provide strategic siting flexibility. Smaller reactors can be accommodated on constrained or repurposed sites, such as retired coal plants or remote industrial facilities. Due to their lower cooling requirements and scalable deployment, SMRs may target niche markets like island grids, water desalination, or industrial campuses. Some designs, such as floating marine SMRs, are in conceptual development for off-grid or maritime-focused applications.

Despite the promise, challenges still exist. Advanced reactors need new fuel supply chains—for example, producing HALEU or TRISO fuel particles, which are currently operated at a limited scale in the U.S. Licensing pathways vary by reactor type and complexity, meaning each design faces its own regulatory challenges. Supply chains for specialized parts—such as large forgings, coated particle fuels, and heat exchangers—must expand to meet deployment goals. Financing models must also adjust for modular multi-unit construction in contrast to traditional utility ownership and rate-based cost recovery.

Nonetheless, SMR technology marks a significant shift in the U.S. nuclear industry. The combination of LWR-based SMRs providing conservative, near-term deployment potential and advanced reactor designs offering flexibility, efficiency, and industrial applications creates a diverse and strong technological foundation. Together, these technologies form the core of advanced nuclear reactors set to deliver scalable, safer, and more adaptable nuclear power for the U.S. grid.

The following section will outline the current U.S. deployment pipeline—from demonstration projects to regulatory milestones—highlighting the evolving role of SMRs and the Advanced Nuclear Reactors driving the next wave of nuclear energy.

**SMRs represent a major shift in U.S. nuclear power,**

offering safer, factory-built, modular reactors with scalable capacity, lower costs, and flexible siting options for electricity, industrial heat, and niche applications.

**Light-water SMRs lead near-term deployment**

while advanced designs like HTGRs, sodium-cooled fast reactors, and molten salt reactors promise higher efficiency, fuel economy, and grid flexibility—though they face fuel, licensing, and supply chain challenges.

## From Labs to Grid

# The State of US Deployment

The deployment landscape for Small Modular Reactors and advanced nuclear projects in the United States is rapidly evolving and faces complex realities. Demonstration programs, regulatory milestones, and industry consortium plans are actively shaping the industry, even as high-profile setbacks highlight the challenges of pioneering new nuclear ventures.

Regulatory progress truly took off when the U.S. Nuclear Regulatory Commission granted standard design certification to NuScale Power's SMR in 2022 and then approved its uprated 77 MWe design in May 2025. NuScale remains the only U.S. company with formal NRC design approval as of mid-2025. Its VOYGR-4 and VOYGR-6 configurations now provide modular plants with capacities of up to 462 MWe, and the company expects commercial deployment by 2029–2030, given favorable market and regulatory conditions.

The flagship deployment effort—the Carbon Free Power Project (CFPP) near Idaho Falls, Idaho—initially planned a six-module NuScale plant to serve the Utah Associated Municipal Power Systems (UAMPS). That facility was designed to generate 462 MWe from light-water SMR modules. Despite DOE cost-share support estimated at over one billion dollars, the project faced escalating cost estimates, increasing per-megawatt prices, and declining utility partnerships. The price forecast rose from $58/MWh to $89/MWh, prompting withdrawals by UAMPS members. In November 2023, the utility consortium withdrew from the project, resulting in its cancellation. Although initially seen as a milestone for the American SMR sector, CFPP's failure demonstrated the financial fragility of early deployments and forced NuScale to revise its commercialization timeline.

Still, NuScale maintains regulatory momentum and seeks to reengage partners and investors. Its design remains available for licensing, and the company has signaled interest in export markets and alternative U.S. sites. DOE's ongoing $900 million solicitation for Gen-III+ SMR deployment aims to support these efforts across multiple states and locations.

Beyond NuScale, other U.S. utilities and developers are advancing SMR integration plans. The Tennessee Valley Authority (TVA) has designated the Clinch River Nuclear Site in Oak Ridge, Tennessee, as its first SMR location. In collaboration with GE Hitachi, TVA is pursuing licensing for the BWRX-300, a 300-MWe boiling-water SMR that features passive safety through natural circulation cooling. If approved, TVA's application would mark the first construction-permit proposal for a GE-Hitachi SMR in the U.S., with operational timelines extending into the 2030s.

Holtec International is leading one of the most ambitious efforts in the U.S. to revitalize an existing nuclear plant and deploy SMRs. Holtec has initiated the regulatory process and received NRC approval to start loading fuel at the Palisades Nuclear Generating Station in Michigan. The company aims to restart the 800-MWe conventional reactor by late 2025 and add two SMR-300 reactors by 2030. Backed by a $1.5 billion DOE loan and state funding from Michigan, this integrated restart and expansion project exemplifies a hybrid approach: utilizing existing nuclear infrastructure while introducing modular SMR capacity for steady zero-carbon growth.

Parallel to government and utility-led developments, private developers such as Xenergy, TerraPower, Kairos Power, and Oklo are progressing with demonstration and pilot-scale initiatives. Many of these companies have secured funding backed by interest from the tech sector. Overall, SMR and advanced reactor developers in the U.S. raised about $1.5 billion in investments over the past year, including nearly $700 million for Xenergy, with significant support from Amazon. Google has made power purchase commitments through Kairos Power, and Microsoft authorized Constellation Energy to restart Three Mile Island units under extended agreements. These capital investments and PPA frameworks support early-stage development and reflect growing private-sector confidence.

A key upcoming project is TerraPower's Natrium demonstration at a retiring coal-fired site in Wyoming, in partnership with GE Hitachi. TerraPower has submitted its construction permit to the NRC and has begun initial onsite preparations. Natrium is designed as a fast reactor with integrated molten salt thermal energy storage, providing dispatchable power and flexibility. Although this project faces advanced licensing scrutiny and fuel access challenges, it exemplifies next-generation U.S. advanced reactors supported by federal demonstration funding.

Despite these high-profile pipelines, significant obstacles persist. The U.S. still lacks the streamlined regulatory framework found in state-led markets like China or Russia, and licensing for advanced reactors remains slow and resource-heavy. A new AI-driven licensing effort led by Oak Ridge National Laboratory and Atomic Canyon aims to speed up regulatory review through simulation and automation, but such systems are not yet fully integrated into NRC procedures. Supply constraints for high-assay low-enriched uranium (HALEU) and TRISO fuel create additional challenges. Although the ADVANCE Act and DOE directives aim to support domestic fuel production, commercial-scale supply remains limited into the late 2020s.

Many project timelines now aim for first operations between 2029 and 2032. NuScale, TerraPower, GE Hitachi (via TVA), Holtec, and Xenergy all have realistic deployment goals within that window, but none have started full commercial operations yet. The collapse of the CFPP delayed NuScale's launch until at least 2029. GE Hitachi's BWRX-300 at Clinch River might receive construction permits by the mid to late 2020s, but actual energy generation probably won't begin until the early 2030s. Holtec's Palisades restart could deliver its first energy by late 2025, with SMR additions following by 2030. Oklo and other developers are further from commercialization, still working on early licensing and financing stages.

Many developers still argue that these companies serve as credible pilot efforts to demonstrate regulatory frameworks and deployment logistics. The DOE's Advanced Reactor Demonstration Program and Gen-III+ solicitation, along with state-level policy changes and federal support, provide a foundation for reducing deployment risk and scaling up gradually.

In summary, SMR and advanced nuclear deployment in the United States is supported by design approvals, federal funding initiatives, and emerging commercial partnerships but is also challenged by project cancellations, fuel and workforce limitations, and slow regulatory processes. The outlook remains cautiously optimistic. The network of demonstration projects—NuScale's VOYGR, TVA's BWRX-300 efforts, TerraPower's Natrium, and Holtec's Palisades restart—together chart a course from lab-scale design to grid-scale deployment by the early 2030s. The success of these projects, along with regulatory innovation and supply chain development, will determine whether SMR technology can effectively transition from promise to operational power generation.

The following section will examine the policies and financial tools driving this resurgence, including state clean energy designations, federal legislation, tax credits, and licensing reforms under the ADVANCE Act and Inflation Reduction Act frameworks.

**U.S. SMRs advance with NuScale, TVA, Holtec, and TerraPower, backed by DOE and tech investors but slowed by costs, fuel limits, and regulation.**

**With setbacks like NuScale's Idaho cancellation, key projects now target 2029–2032 for first operations.**

POLICY POWER

# The Regulatory and Financial Push Behind SMRs

Policymakers at both the federal and state levels have substantially restructured regulatory and financial frameworks to support Small Modular Reactors and advanced nuclear energy. The combination of congressional legislation, executive orders, and state reforms has shifted nuclear power from a marginal part of clean energy strategy to a viable, incentivized sector aligned with renewables.

Central to this shift is the Inflation Reduction Act of 2022, which introduced the zero-emission nuclear power production credit under Section 45U. This production tax credit can reach up to 0.3 cents per kilowatt-hour, adjusted for inflation, and can increase up to five times for projects that meet prevailing wage and apprenticeship requirements. Most notably, it is transferable or eligible for direct payment, making it highly valuable to project developers without large tax burdens. Complementing this is a technology-neutral investment tax credit (ITC) under Section 48E, offering up to a 30 percent base credit, which can rise to 50 percent with additional incentives for siting in energy-impacted communities. Analysts at Idaho and Argonne National Laboratories have modeled scenarios demonstrating that these credits significantly improve SMR economics—especially in competitive markets like ERCOT—enhancing net present value and reducing the levelized cost of energy in real-world operating environments.

Beyond tax incentives, the Infrastructure Investment and Jobs Act (also called the Bipartisan Infrastructure Law) dedicates several billion dollars to support nuclear and advanced reactors. The law allocates nearly $2.4 billion specifically for microreactor and SMR development, along with additional funding through 2027 via its Civil Nuclear Credit Program and HALEU fuel production grants. DOE's Loan Programs Office has used this legislation to back a $1.52 billion conditional loan to Holtec International for restarting the Palisades Nuclear Generating Station in Michigan. While the traditional reactor restart is included, Holtec also plans to deploy SMR-300 units onsite, indicating potential for future modular capacity expansion.

Congress further accelerated reform with the passage of the ADVANCE Act in 2024. This bipartisan legislation requires the Nuclear Regulatory Commission to simplify licensing processes for advanced reactor technologies, reduce fees, and prioritize review of HALEU use and advanced fuels. The act also includes a licensing fee incentive to encourage faster permits for SMR or advanced reactor projects—especially at pre-approved former coal or fossil fuel sites—and directs federal agencies to make export procedures for U.S. nuclear technology more straightforward. Overall, these measures shift the regulatory environment from passive oversight to active support for modular nuclear deployment.

State governments have complemented federal initiatives with customized legislation and regulatory designations. Over twenty-five U.S. states enacted advanced nuclear bills in 2024 alone, with many officially recognizing SMRs as clean energy sources eligible for renewable portfolio standard (RPS) incentives. Indiana passed a series of laws in early 2025 establishing a State Nuclear Planning Agency, granting tax credits to developers, and allowing utilities to recover exploration costs even for projects that may never come to fruition—policy moves aimed at attracting developers and speeding up siting. At the same time, Indiana's legislation was structured to require large energy users, such as data centers, to carry most of the cost risk, making sure ratepayers are protected from early financial exposure.

Virginia advanced its efforts through comprehensive energy legislation that includes SMRs as part of a clean energy standard, engaged industry task forces, and set goals for hosting commercial SMR capacity within the next decade. Wyoming utilized energy authority grant programs to co-fund feasibility studies for SMR deployment, while South Carolina's nuclear advisory council is developing strategic plans to lead deployment and resilience initiatives. State actions vary from executive orders to incentive programs and utility regulatory rule adjustments, aligning local markets with federal momentum.

Despite these favorable policy environments, uncertainty persists. In Congress, new proposals could phase out key federal credits by 2029. Industry groups—including NuScale Power, TerraPower, Oklo, and the Nuclear Energy Institute—have ramped up lobbying efforts early in 2025, warning that the expiration of tax credits could threaten emerging SMR projects and U.S. leadership in advanced nuclear technology. While some developers believe that phasing out these credits might boost private investment and financial innovation, most advocates emphasize that ongoing incentives are essential for reducing project risk, securing financing, and maintaining a competitive edge over solar, wind, and battery storage.

The cumulative effect of these policies is clear: technology-neutral tax credits created level economic opportunities across different types of generation; direct funding and loan guarantees reduced barriers to access capital; licensing reforms shortened approval timelines; and state-level clean energy designations unlocked incentives that traditionally favored renewables. Together, these strategies have greatly enhanced SMR viability in the U.S., drawing in venture capital, corporate partnerships, and utility involvement.

However, challenges persist within this evolving framework. The potential reversal of IRA credits risks undermining long-term project economics. Domestic HALEU production, although supported by DOE grants, still lacks the scale needed for widespread use. While many jurisdictions have enabled state-level policies, some remain inconsistent or contested. Indiana's exploration-cost recovery provisions, for example, raise concerns about shifting financial risk to consumers in fragmented markets. Additionally, SMR developers argue that capital infrastructure still faces local siting obstacles, environmental reviews, and public hearings—areas where regulatory streamlining is still incomplete.

Nonetheless, the alignment of federal law (IRA, INFRASTRUCTURE law, ADVANCE Act), state-level statutes, and DOE financing creates a policy ecosystem that did not exist a decade ago. These reforms serve as a foundation enabling SMR Technology to transition from pilot projects to commercial deployment. Future deployment depends on maintaining stable incentive frameworks, ensuring that fuel and workforce supply chains keep pace, and executing cost-effective licensing and planning across jurisdictional boundaries.

The following section will examine corporate involvement and Big Tech's role in driving demand for SMRs, including power purchase agreements, data center power sourcing strategies, and the emerging connection between corporate sustainability and advanced nuclear procurement.

CORPORATE CATALYSTS

# Big Tech's Nuclear Bet

Technology giants are emerging as key drivers in the U.S. SMR ecosystem. Their growing need for reliable, baseload zero-carbon power to support AI and data center operations has led to unprecedented corporate involvement in nuclear procurement and financing. These partnerships serve two primary purposes: ensuring long-term clean energy and giving early credibility to SMR technology and advanced nuclear projects.

Microsoft's 20-year power purchase agreement (PPA) with Constellation Energy for the restart of Three Mile Island Unit 1 exemplifies innovation. Valued at approximately $16 billion, the agreement encompasses the entire output of the renewed 835 MW reactor, which is scheduled to begin operation in 2028 at the Christopher M. Crane Clean Energy Center in Pennsylvania. Microsoft will utilize this full supply to power its AI-driven data centers across PJM-region facilities in states like Pennsylvania, Ohio, and Virginia. This agreement not only solidifies the financial foundation for the reactor's restart but also signals that hyperscale power users are willing to support nuclear projects aligned with their sustainability goals. Constellation's restart plan also promotes job creation and increases tax revenue in the region, while highlighting the flexibility of nuclear infrastructure for modern corporate energy sourcing. Microsoft's involvement through an FTM (front-of-the-meter) PPA marks a significant milestone in corporate-nuclear partnerships, advancing grid-scale nuclear power procurement for clean energy portfolios.

Google has also positioned itself at the forefront of advanced nuclear procurement. In October 2024, it announced the world's first corporate PPA specifically tied to SMR development by agreeing to purchase up to 500 MW of power from Kairos Power's planned molten salt reactors. The initial phase aims to bring the first reactor online by 2030, followed by additional SMR deployments through 2035. Kairos Power, which received the first new advanced reactor construction permit from the NRC in 2023 and began its Hermes demonstration in Tennessee, now serves as a prominent corporate anchor as it advances toward commercialization.

Beyond Kairos, Google publicly committed early-stage funding to support Elementl Power's development of three advanced nuclear project sites, each targeting at least 600 MW of generation. Google's capital support aims to fund site planning, regulatory preparation, and utility partnership outreach. Elementl Power plans to bring over 10 GW of advanced nuclear online by 2035. Although designs may vary, this implicit commitment demonstrates demand-side power for multiple high-capacity reactors aligned with Google's goal of sourcing 24/7 carbon-free power for AI workloads.

Amazon is also making waves with investments in Xenergy to develop up to 5 GW of SMRs by 2039. Xenergy's HTGR (high-temperature gas reactor) Xe100 design aligns with Amazon's industrial and data infrastructure goals. These efforts collectively show that Big Tech firms see nuclear power as a key part of their decarbonization plans, especially where intermittent renewables and battery storage can't meet near-real-time baseload demands.

These corporate engagements have an additional purpose: they demonstrate investor and market confidence in SMR Technology. Venture capital investments in developers like Xenergy, TerraPower, Kairos Power, and Elemental Power surpassed $1 billion in the past year. Google's support for multiple companies and Microsoft's high-profile agreement enhance credibility, reducing perceived risk for other investors, utilities, and regulators.

Although these PPAs and investments depend on project completion, they establish a long-term demand anchor that allows developers to proceed with licensing, financing, and early construction preparations. These arrangements strengthen the connection between corporate decarbonization goals, energy resilience strategies, and SMR deployment. The participation of hyperscale users significantly reduces timelines from concept to commercial operation, providing actual commercial off-takers where utility demand may lag or be disjointed.

Challenges persist. Corporate PPAs mainly apply to projects in regions serving hyperscale users. Not all U.S. grid markets match data center clustering. Integration with utility procurement rules, transmission access issues, and interconnection queue delays can create friction, especially for behind-the-meter or campus-based deployments. Moreover, developers still need to overcome fuel supply, licensing, and site-specific regulatory hurdles. Corporate demand can help reduce early-stage risks, but cannot eliminate construction complexity or workforce limitations.

Nevertheless, the combined strategic efforts of Microsoft, Google, Amazon, and other corporate players represent a significant shift in nuclear industry dynamics. SMR technology is no longer developed solely for utility rate-based customers; large corporate entities now set deployment schedules and support financial viability. The following section will explore public perception and safety framing, examining how these corporate-backed developments affect community acceptance, transparency, and trust in advanced nuclear deployment.

PUBLIC PERCEPTION & SAFETY

# A Trust Issue to Solve

The deployment of Small Modular Reactors (SMRs) and advanced nuclear technologies in the United States mainly depends on public perception, safety confidence, and social trust. Past nuclear incidents—Three Mile Island, Chernobyl, and Fukushima—still influence public attitudes, especially in communities near proposed reactor sites. Ongoing concerns about safety, radioactive waste, and emergency preparedness show that technology alone is not enough without credible public engagement and transparent processes.

One of the main features of SMR Technology is its reliance on passive safety systems—designed mechanisms that need no external power or manual intervention. These systems utilize natural gravity, convection, or pressure differences to keep the reactor safe, even without active controls. According to the International Atomic Energy Agency, many SMR designs depend more on passive safety features and inherently safe traits than their larger predecessors. Similarly, assessments by the U.S. Department of Energy confirm that SMRs reduce reliance on active electrical safeguards, significantly improving resilience during power outages.

Engineering evaluations support these claims. Smaller reactor cores have higher surface-area-to-volume ratios, which help with passive heat dissipation and increase safety margins. The OECD Nuclear Energy Agency has observed that SMRs generally feature simpler design architectures and fewer potential failure modes. However, critics warn that in extreme scenarios—such as prolonged loss-of-cooling events—some passive features might not work as intended, highlighting the importance of extensive testing and triage protocols.

Public awareness remains low but crucial. A 2023 survey by Bisconti Research found that only about 20 percent of U.S. adults had heard of SMRs. Interestingly, among respondents living within ten miles of existing nuclear power facilities, awareness was still low, but support increased to approximately 78 percent after hearing descriptions emphasizing higher safety and lower environmental impact. These findings indicate that informed and engaged communities are more open to SMR siting when relatable benefits and safety features are clearly explained.

Community engagement has become a key part of SMR trust-building strategies. Developers such as TerraPower in Wyoming and Holtec in Michigan have launched public outreach efforts, including town halls, advisory councils, and partnerships with local organizations. These forums aim to educate citizens about passive safety, emergency response plans, and waste management strategies, while gathering local feedback on siting choices. Engagement that offers economic benefits—especially in areas shifting from fossil fuel jobs—has been shown to increase local acceptance.

Waste management continues to present a reputational challenge. Although SMRs generally produce less waste per megawatt-hour compared to gigawatt reactors, differences in fuel types and refueling cycles can lead to more long-lived radioactive by-products in some setups. Without a permanent national repository or a clear long-term storage plan, communities stay cautious. Developers emphasize interim solutions and recycling research, but broader public trust depends on federal action toward creating a permanent disposal infrastructure.

Liability frameworks also influence public trust. SMRs generally need less insurance coverage due to smaller inventories, but all projects are covered by the Price–Anderson Act, which limits industry liability and ensures federal support in case of an incident. As SMR deployments increase, legal and regulatory experts suggest adjusting emergency preparedness measures—including planning zone sizes—to better match the features of modular designs and passive systems.

Media framing plays a significant role in shaping public sentiment. Stories focused on protests, cost overruns, or project cancellations often reinforce skepticism. In contrast, coverage emphasizing zero-carbon operations, passive safety design, and local economic revitalization encourages more positive attitudes. Recognizing this, developers now invest in education programs—such as interactive site tours, classroom outreach, and simulation tools—to promote scientifically grounded understanding rather than superficial marketing.

Comparative risk framing further promotes acceptance. Many industry and academic studies confirm that nuclear power produces significantly fewer fatalities per unit of energy compared to fossil fuels. Showing these comparison stats helps put nuclear risk into perspective alongside common energy sources, encouraging rational public discussion.

Despite design improvements and outreach efforts, widespread social acceptance remains conditional. Any jurisdiction with veto powers, binding referenda, or strong community opposition can delay or halt projects, even if they comply with federal and state regulations. In such situations, consistent safety performance, transparent communication, and active local presence become crucial.

Building public trust in SMR technology requires a multi-faceted approach: excellent passive safety engineering, transparent stakeholder engagement, clear waste management and liability pathways, and contextualized risk communication. When combined with economic incentives, science-based education, and community dialogue, advanced nuclear reactors can gain the social acceptance needed to support renewables in powering a decarbonized and resilient U.S. grid.

The following section features case studies of U.S.-based SMR and advanced reactor projects—including Natrium, NuScale's Carbon-Free Power Project, Holtec's Palisades SMR plans, and TVA's BWRX-300 at Clinch River—covering their engineering, financial, regulatory, and community aspects.

# Case Studies

Real Projects Shaping the Future

- **TerraPower Natrium Demonstration**
  Kemmerer, Wyoming
- **NuScale Carbon Free Power Project (CFPP)**
  Idaho Falls, Idaho

CASE STUDY # 1

# TerraPower Natrium Demonstration

## Kemmerer, Wyoming

TerraPower's Natrium project in Kemmerer, Wyoming, is an advanced initiative showcasing fourth-generation reactor technology in a practical grid setting. The system combines a sodium-cooled fast reactor with molten salt energy storage, allowing for dispatchable electricity during peak demand, even if the reactor's output is temporarily reduced. This model enhances grid reliability and supports zero-carbon energy objectives.

Regulatory and permitting milestones highlight the project's progress. The Wyoming Industrial Siting Council granted initial commercial siting approval in early 2025, marking the first such decision on a U.S. fast reactor. Simultaneously, the Nuclear Regulatory Commission adopted a faster review schedule, aiming to finish environmental and safety assessments by December 2025—about seven months ahead of initial plans. This coordinated regulatory pace indicates federal and state agreement on advanced reactor timelines.

From a technical perspective, the design prioritizes passive safety and efficient operation. The reactor sits within a below-grade containment vessel to aid heat dissipation and lower surface risk exposure. A freeze-plug cooling system melts under high temperatures, triggering natural convection and aiding heat removal without external power. Sodium coolant allows for fast-neutron operation, enhancing fuel use and reducing waste volume. The integrated molten salt storage module buffers generation timing, providing operators with flexibility to adapt to real-time grid changes.

Community engagement demonstrates a strong alignment with local transition goals. Kemmerer was selected as the siting community after evaluating former coal plant towns; local support was high due to the potential for economic revitalization. The project plans to employ around 1,600 workers during construction and retain approximately 250 once full operations begin. Outreach strategies included public forums, advisory groups involving tribal leadership, and partnerships with community colleges for workforce development. These efforts aimed to foster goodwill, transparency, and inclusion.

Financially, Natrium is backed by federal cost-sharing through the Department of Energy's Advanced Reactor Demonstration Program. This support helps reduce risks associated with early capital costs. Additional funding from state economic development agencies and private investors further strengthen its financial stability. The project's structure shows how aligned federal, state, and community incentives can support the deployment of advanced nuclear technologies. Construction is expected to start in mid-2025, with the first energy production projected in the early 2030s.

The project's broader importance lies in its approach: the smooth integration of technical innovation, faster permitting, thoughtful community planning, and federal incentives. By combining storage-enabled dispatchability with passive safety and national support systems, the Natrium model provides a repeatable template for future demonstrations and deployments. It shows how modular reactor technology can go beyond traditional light-water SMRs, especially in regions shifting economically from fossil fuel generation to clean energy jobs.

CASE STUDY # 2

# NuScale Carbon Free Power Project (CFPP)

## Idaho Falls, Idaho

The Carbon-Free Power Project (CFPP), based at Idaho National Laboratory, aimed to demonstrate light-water SMR deployment in partnership with NuScale Power. The plan included six upgraded VOYGR 77 MWe modules—totaling approximately 462 MWe—serving the Utah Associated Municipal Power Systems (UAMPS). The project was designed to showcase modularity, factory-based construction, and simplified licensing made possible by NRC certification.

CFPP initially estimated levelized costs at around USD 58/MWh, supported by Department of Energy cost-sharing agreements and backed by municipal utility commitments. NuScale had obtained NRC certification for its VOYGR design, boosting confidence in regulatory predictability. The plan was to combine several integrated reactor modules to reach operational scale within a collaborative offtake model.

However, during pre-construction, projected costs started rising, eventually reaching USD 89/MWh. Site-specific construction and licensing complexities, higher contingency estimates, and the lack of alternative demand arrangements contributed to budget instability. Once several UAMPS members withdrew support, the project's economics fell apart. NuScale and the consortium officially terminated CFPP in November 2023, and the NRC paused its combined license application.

Despite its cancellation, CFPP remains important as a pioneering example of regulatory and engineering groundwork. Its VOYGR modules are still NRC certified, and pre-application licensing activities maintain essential technical and regulatory data that could be reused for future projects. NuScale has since shifted its strategy toward states with clean energy nuclear eligibility mandates, seeking partnerships with utilities and large industrial buyers.

The case highlights key themes in SMR deployment: early cost estimates must consider first-of-a-kind uncertainties, and combining offtake across multiple buyers is essential to support capital-intensive infrastructure. The CFPP's failure shows that certified designs alone are not enough without diversified demand and strong project governance.

Under revised deployment plans, NuScale aims for late-2020s or early-2030s timelines, contingent on offtake and financing agreements. The company is continuously refining construction logistics, cost estimation models, and export strategies. CFPP provides a regulatory legacy and a cautionary tale, highlighting that deploying advanced nuclear requires credible stakeholder support, transparent budgets, and flexibility to adapt as commercial conditions change.

The Road Ahead

# Challenges to Commercial Viability

While Small Modular Reactors and advanced nuclear reactors hold transformative potential for the U.S. energy system, significant strategic barriers still exist before widespread commercial deployment becomes feasible. Key challenges include fuel supply limitations, financing complexities, supply chain readiness, workforce capacity, and regulatory and market stability.

A primary obstacle is securing affordable access to high-assay low-enriched uranium (HALEU) or TRISO fuel in sufficient quantities. Most advanced reactors—especially fast reactors like Natrium and TRISO-based high-temperature gas systems—depend on HALEU fuel, which is currently produced in limited domestic amounts. The Department of Energy has initiated production incentives, but private infrastructure remains limited, which puts early projects at risk if production is delayed or costs rise. Light-water SMRs such as the VOYGR design may temporarily ease these concerns by using conventional low-enriched uranium, but their scalability will ultimately depend on expanding the domestic HALEU fuel industry.

Financing and capital cost challenges present a major obstacle. SMR projects must balance high upfront costs with long asset lifetimes and uncertain early-stage economics. Cost control becomes even more vital when there are no strong offtake agreements, as shown by the cancellation of the Carbon-Free Power Project. Developers typically depend on a combination of federal cost-sharing, production tax credits, and state clean energy incentives; however, the potential expiration of key federal incentives—such as the Inflation Reduction Act or ADVANCE Act licensing benefits—creates financial uncertainty. Without demand aggregation from utilities, data center users, or industrial companies, project budgets can quickly become unsustainable.

Supply chain readiness—including reactor module manufacturing, specialist heavy forgings, TRISO fuel fabrication, and thermal storage systems for integrated projects—lags behind the projected deployment pace. The current U.S. industrial infrastructure for specialized reactor components remains limited, forcing reliance on overseas suppliers or costly domestic ramp-up. Scaling manufacturing for modular construction across multiple reactor types will require significant investment and coordination, which could delay subsequent deployments unless capacity growth accelerates in parallel.

Workforce planning and talent availability are also critical constraints. Many nuclear engineering and operations professionals are nearing retirement, and existing training pipelines—including specialized skills in advanced reactor operations and TRISO fuel handling—must expand quickly. Community engagement and workforce development programs that connect local training institutions to skilled construction and operations roles can help bridge the gap, but training timelines might extend beyond planned reactor commissioning windows.

Regulatory uncertainty still makes commercialization planning difficult. Although there has been progress—primarily through the ADVANCE Act's directives and NRC's design certification processes—licensing timelines remain long. This is particularly true for non-light water reactor types, where regulatory standards are still developing and review capacity is limited. States without clear nuclear siting rules or post-closure funding plans add logistical challenges. In some cases, local veto powers or atomic safety referenda can cause delays despite federal approvals.

Market integration and grid access present operational challenges. Delays in the interconnection queue, transmission constraints, and limited wholesale pricing mechanisms in some regions can hinder the timely integration of reactors into load-serving contexts. SMR and advanced reactor models may succeed in industrial microgrids or data center campus environments, but connecting to regional utility markets often involves complex policy and contract negotiations. Additionally, cost competition from declining renewables and storage continues to erode nuclear's strict economic advantage unless there is ongoing policy parity.

Addressing these challenges requires deliberate coordination across multiple sectors. Long-term incentive frameworks—such as renewable portfolio standards that include SMRs and extending federal tax credits—can offer stability. Federal investments in HALEU production, fuel cycle infrastructure, and domestic manufacturing are crucial. Increasing licensing and regulatory capacity at NRC or via state-federal coordination mechanisms will help shorten permit timelines. Partnering with educational and workforce institutions can ensure training pipelines meet future demand. Finally, stronger cooperation among corporate offtake partners, utilities, and regional planners can help pool demand and reduce risk exposure.

Overcoming these barriers is crucial not only for flagship projects like Natrium and VOYGR SMRs but also for developing a sustainable U.S. advanced nuclear sector. With ongoing innovation, structural support, and stakeholder collaboration, SMR technology and advanced reactors can transition from demonstration projects to significant contributors to America's clean energy economy.

**Key Barriers**

Fuel, finance, supply chain, workforce, regulation, market.

**Critical Needs**

Stable policy, HALEU, manufacturing, training, faster licensing.

**Path Forward**

Government, industry, and utilities must collaborate.

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