The Future of Electric Power in Arizona

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Increasing Demand for Electric Power

Artificial Intelligence (AI)

(Goldman-Sachs estimates an increase of 100 TWh for AI. In 2023, total generation for the U.S. was 4.237 TWh)

Electric Vehicles

Desalinization Facilities

(As increasing demand for potable water grows)

Crypto Mining

Increasing Demand for Electric Power

New Data Centers

(Microsoft and Constellation Energy re-opening Three-Mile Island nuclear facility that will generate 800 Mwe)

Problems of National Electric Power Grid

Aging Infrastructure: Many grids around the world were built decades ago and in need of significant upgrades and maintenance.

Capacity Issues: Demand for electricity often exceeds the capacity of the grid, especially during peak hours or extreme weather conditions.

Reliability Concerns: Grids can experience frequent outages or instability due to technical failures, weather events, or inadequate maintenance.

Cybersecurity Threats: With increasing digitization, power grids are vulnerable to cyberattacks that can disrupt services or compromise data.

Problems of National Electric Power Grid

Transition to Renewable Energy: Integrating renewable sources like wind and solar into the grid poses challenges due to their intermittent nature and varying energy outputs.

Environmental Impact: Some grids rely heavily on fossil fuels, contributing to environmental concerns such as pollution and climate change.

Financial and Regulatory Issues: Funding constraints and regulatory hurdles can hinder grid modernization efforts and investment in new technologies.

Largest Generating Facilities in the U.S.
(Summer Capacity as of Oct. 2023)

Grand Coulee Dam (Washington)

Capacity: 7,079 MW Type: Hydroelectric

Palo Verde Nuclear Generating Station (Arizona)

Capacity: 3,937 MW Type: Nuclear

West County Energy Center (Florida)

Capacity: 3,777 MW Type: Natural Gas

W.A. Parish (Texas)

Capacity: 3,690 MW Type: Natural Gas, Coal)

Browns Ferry Nuclear Plant (Alabama)

Capacity: 3,662 MW Type: Nuclear

Source: Form EAI-860 database final data for 2022

Largest International Generating Facilities

Three Gorges Dam (China): Hydroelectric facility has an installed capacity of 22,500 MW, making it the largest in the world.

Itaipu Dam (Brazil/Paraguay): Hydroelectric power plant, Itaipu has a capacity of 14,000 MW.

Xiluodu Dam (China): Hydroelectric plant has a capacity of 13,860 MW.

Belo Monte Dam (Brazil): Hydroelectric facility, it has a capacity of 11,233 MW.

Guri Dam (Venezuela): Hydroelectric power plant has a capacity of 10,235 MW.

Sources of Electric Power in U.S. (2023)

- **Natural Gas**: 43%
- **Coal**: 16%
- **Nuclear**: 18%
- **Renewables**: 24% - This includes various sources such as wind, solar, hydroelectric, and biomass.
    - **Wind**: 10% - Wind energy has seen substantial growth over recent years.
    - **Solar**: 5% - Solar power continues to expand rapidly.
    - **Hydroelectric**: 6% - Hydropower remains a stable contributor, though its share fluctuates based on precipitation patterns.
    - **Other Renewables**: 3% - This includes biomass and geothermal energy.
- **Petroleum**: 0.4% - Petroleum is a minor source for electricity generation.
- **Other Sources**: 0.5% - Includes various other sources such as batteries, hydrogen, other.

Sources of Electric Power in Arizona (2024)

- **Natural Gas**: 47.5%
- **Nuclear**: 27.9%
- **Solar**: 9.3%
- **Coal**: 8.5%
- **Hydroelectric**: 4.6%
- **Wind**: 2.2%
- **Biomass**: 0.2%

Source: U.S. Energy Information Administration (EIA)

Bottom Line

- The demand for electric power is growing very rapidly
- To meet the increasing demand, reliance on all sources needs to be examined, with cleanliness as the key driver
- The National power grid is aging and has security concerns
- Nuclear generation is the most salient solution to the problem
- It is estimated that it can take up to 15 years to build a large-scale nuclear facility from start to finish

Department of Energy Newsletter (4/29/2025)

Unleashing American-Made SMRs

In March, DOE re-issued a $900 million solicitation to support the deployment of small modular reactors (SMRs) to better align with President Trump's bold agenda to unleash American energy and AI dominance. The modified solicitation process removed a 20 percent weighting for DEI imposed by the previous administration to ensure potential SMR first-movers are judged only on technical merit. U.S. electricity demand is forecasted to soar in the coming years, and next-generation SMRs could provide flexible, reliable power for energy-intensive sectors like industry and data centers.

https://www.energy.gov/ne/articles/11-big-wins-nuclear-trump-administrations-first-100-days

Small Modular Reactors (SMRs)

Small Modular Reactors (SMRs)

- SMRs typically have a capacity of less than 300 megawatts electric(MWe), which is significantly smaller than conventional nuclear reactors that can have capacities ranging from hundreds to over a thousand megawatts. They can be deployed in various settings, including remote communities, industrial sites, or as part of a larger power grid, providing energy for both electricity generation and other industrial applications.
- One of the key advantages of SMRs is their potential to be manufactured in factories and transported to site, reducing construction time and costs. Additionally, they often incorporate passive safety features that enhance their ability to shut down safely in case of emergencies.
- However, like any nuclear technology, SMRs also face challenges, including regulatory approval, public acceptance, and addressing concerns over nuclear waste management and proliferation risks.

Small Modular Reactors (SMRs)

- **Smaller Size & Modular Design**
  Physically smaller, making them easier to transport and install.

- **Factory-built**
  Shipped to the site, reducing construction time and cost.

- **Enhanced Safety**
  Many SMRs use **passive safety systems** (like natural circulation cooling) to reduce the risk of overheating. Their compact design reduces the likelihood of accidents.

Small Modular Reactors (SMRs)

- **Lower Initial Cost & Scalability**

  Traditional large reactors require **billions of dollars** and over a **decade** to build. SMRs are **cheaper**, can be built in **2-4 years**, and multiple units can be added incrementally.

- **Flexible Applications**

  Electricity generation (for grids, remote areas, and islands)
  Industrial applications (hydrogen production, desalination, district heating)
  Military & space applications (nuclear-powered submarines, space propulsion)

Small Modular Reactors (SMRs)

	SMRs	Large Reactors
Power	10-300 MW	1,000+ MW
Construction	2-4 Years	7-12 Years
Cost	$1 - $3 Billion	$10+ Billion
Deployment	Modular	Single Unit
Cooling Requirements	Lower	Higher

SMR Examples

Company (Ticker)	Model	Capacity
NuScale (SMR)	VOYGR	77-924 MW
GE – Hitachi (GE)	BWRX-300	300 MW
OKLO (OKLO)	Aurora	15-75 MW
NANO Nuclear (NNE)	LOKI	1.5 MW - 5.0 MW

NuScale Power Corporation*

- **Key Features**: Design features a 77 MWe module, with the option to scale up to 12 modules at a single site (for a total of 924 MWe).
- **Power Module:** Is a pressurized water reactor with all the components for steam generation and heat exchange incorporated into a single unit
- **Regulatory Milestone**: In 2020, was the first company to win U.S. Nuclear Regulatory Commission (NRC) design approval for an SMR.
- **Deployment Outlook**: Manufacturing main equipment for the first commercial deployment of a power plant for Utah Associated Municipal Power Systems' Carbon Free Power Project which is to be built at a site at the Idaho National Laboratory in the USA, and expected to be operational by 2029.

* The Ultimate Guide to Small Modular Reactors • Carbon Credits* What is SMR?

NuScale Power Corporation

NuScale Power submitted its 12,000-page application for certification of its SMR design at the end of 2016. In September 2025, the NRC plans to release a final safety evaluation report (SER) for NuScale.

“The Final SER, once issued, will represent approval by the NRC staff of the SMR design, and NuScale can begin commercializing its technology,” NuScale spokesperson Diane Hughes said in an email to Utility Dive.

“NuScale remains the first and only small modular technology in the world to undergo design certification review by the US Nuclear Regulatory Commission,” Hughes said.

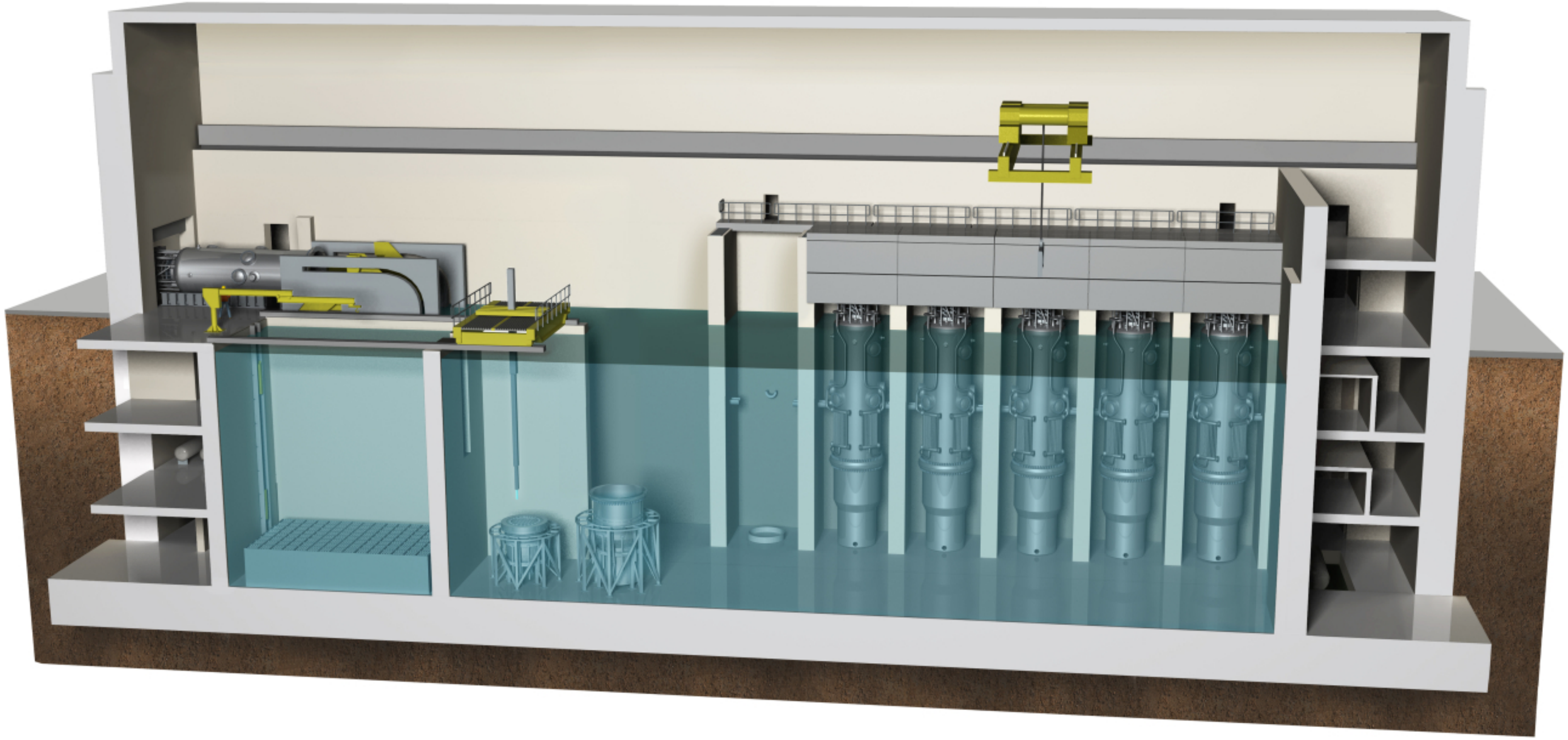
NuScale Safety

NuScale's design employs natural water circulation for the passive cooling of its reactor. The reactor core is contained within a pressurized steel vessel, which is further encased in a steel containment structure, resembling a thermos. Each module is placed underwater to effectively transfer heat away from the reactor during abnormal conditions.

In the event of an emergency requiring cooling, specialized valves automatically open, allowing steam to escape from the reactor vessel into the containment area. This steam condenses, and water is subsequently directed back into the core through a secondary set of valves located at the base of the reactor vessel, aiding in the cooling process.

As the water heats and boils, the resulting steam is recirculated, establishing a passive cooling safety mechanism that persists until the heat and pressure levels stabilize.

NuScale Power Reactor Building



GE-Hitachi BWRX-300 (Japan & USA)*

- **Simplified Boiling Water Reactor**: GE Hitachi's design reduces the number of components. It aims for a lower cost and faster regulatory approval.
- **Project Momentum**: Multiple North American utilities have shown interest. Some Canadian provinces look at the BWRX-300 to replace aging coal facilities.
- **Collaboration**: Works closely with the Canadian Nuclear Safety Commission (CNSC) for design review and licensing.

OKLO*

- **Microreactor Approach**: Oklo's concept focuses on **very small** reactors (around 1-2 MWe) designed for off-grid or remote sites.

- **Fuel Cycle Innovation**: Oklo aims to use **HALEU** and advanced fuel forms, potentially drawing from spent fuel from older reactors.

- **Licensing Path**: In 2020, Oklo received a site permit from the NRC for its Aurora reactor, although licensing processes are ongoing. The company seeks to show that microreactors can be delivered quickly and operate for years without refueling.

NANO Nuclear Energy*

- **Advanced SMR Research**: NNE is working on microreactor and SMR designs that use innovative technology and materials for both safety and efficiency gains.

- **Focus on Modularity**: Like other SMR developers, NNE plans to rely on modular and potentially **additive manufacturing** methods to reduce costs.

- **Market Position**: Targets niche markets, including remote communities, island nations, and industrial sites in need of consistent power but lacking large-scale infrastructure.

TerraPower*

Natrium (USA, Backed by Bill Gates)

- **Coolant Innovation**

  Uses **liquid sodium** as a coolant. Boasting better heat transfer and improved safety over traditional water-cooled designs.

- **Energy Storage**

  Integrates a molten salt energy storage system. This allows the reactor to ramp up power output during peak demand.

- **Timeline**

  Aims to showcase a demonstration plant in the early 2030s. Particularly in regions with high renewable penetration.

Rolls-Royce*

- **Size and Goals**

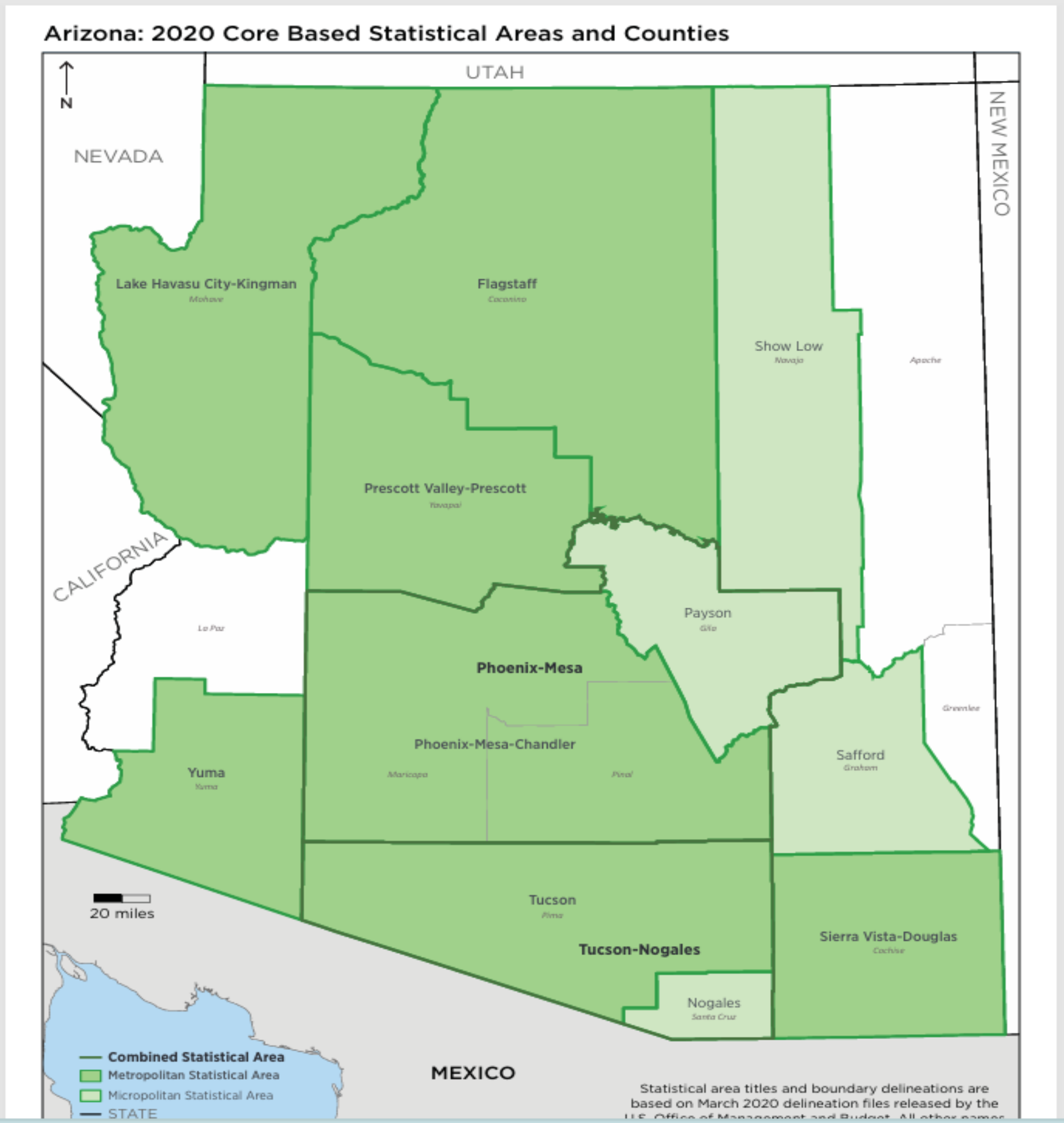
  Rolls-Royce plans a 300 MWe reactor, hoping to deploy in the UK and beyond by the early 2030s.
- **Cost Strategy**

  Leveraging its history in aerospace and advanced manufacturing, Rolls-Royce aims to cut costs and shorten build times with factory-fabricated modules.
- **Focus**

  Compete on both cost and reliability to replace older fossil-fired plants and help the UK achieve net-zero carbon targets.

Arizona Population by Statistical Areas

- Metropolitan Statistical Areas (MSAs) in Dark Shade
- Micropolitan Statistical Areas (MSAs) in Light Shade
- Single County Statistical Areas Without Shading



Meeting Electric Demands

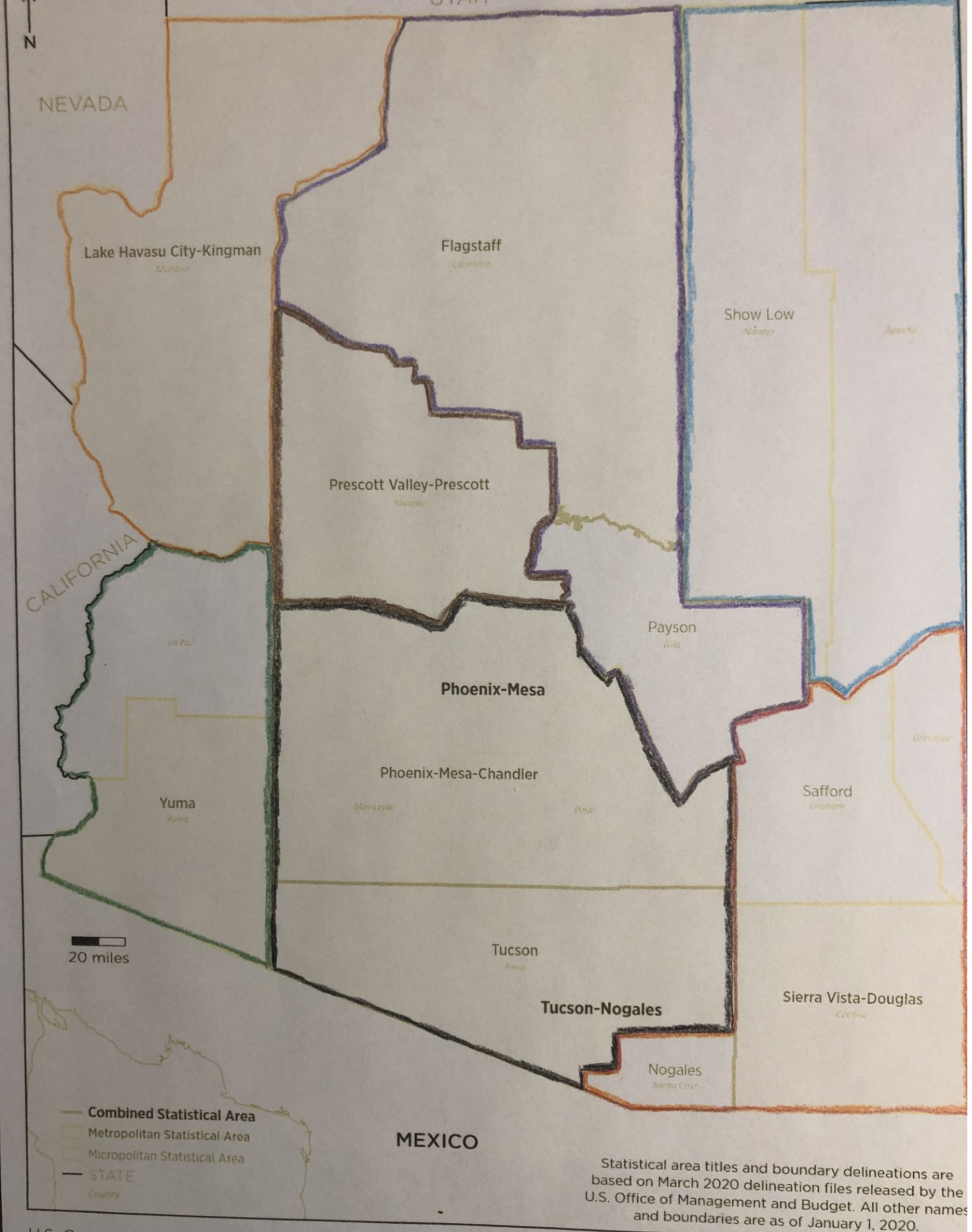
NuScale Power Corporation (NPC) has developed a modularized nuclear generating system with the following characteristics:

Modules	Capacity (MW)
4	293
6	441
12	884

Arizona Power Plan

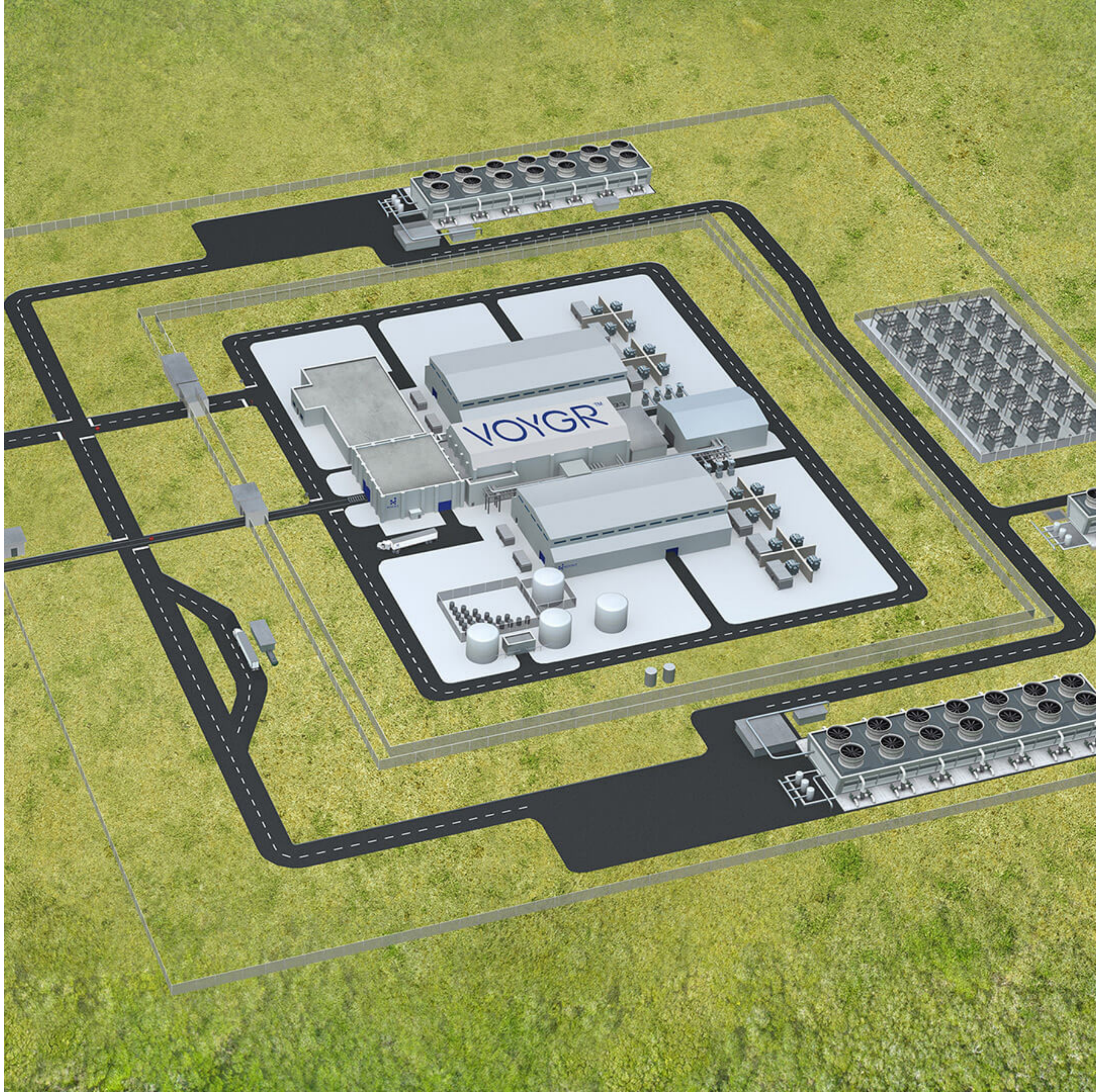
Location	2030E MW *	NuScaleModules	Excess MW	Excess (%)
Show Low + Apache + Greenlee	136	4	157	116.0%
Sierra Vista + Safford + Nogales	141	4	152	108.4%
Flagstaff + Payson	152	4	141	93.3%
Yuma + La Paz	196	6	245	125.3%
Lake Havasu	208	6	233	111.5%
Prescott Valley	221	6	220	99.4%
Totals	1,053		1,149	109.1%

* Determined from U.S. Census housing estimate and EAI data for AZ household consumption



U.S. Census Bureau, Population Division


VOYGR™


VOYGR™

NuScale-Idaho National Laboratory

The U.S. Department of Energy (DOE) approved a multi-year cost share award to a new special purpose entity named Carbon Free Power Project, LLC, an entity wholly owned by Utah Associated Municipal Power Systems (UAMPS), that could provide up to $1.4 billion to help demonstrate and deploy a 12-module NuScale power plant located at Idaho National Laboratory. The agreement serves as a funding vehicle and is subject to future appropriations by Congress. Construction for UAMPS' Carbon Free Power Project is expected to begin in December 2025, with the first power module operating at the lab by 2029. Below is a statement from Dr. Rita Baranwal, the Assistant Secretary for Nuclear Energy.

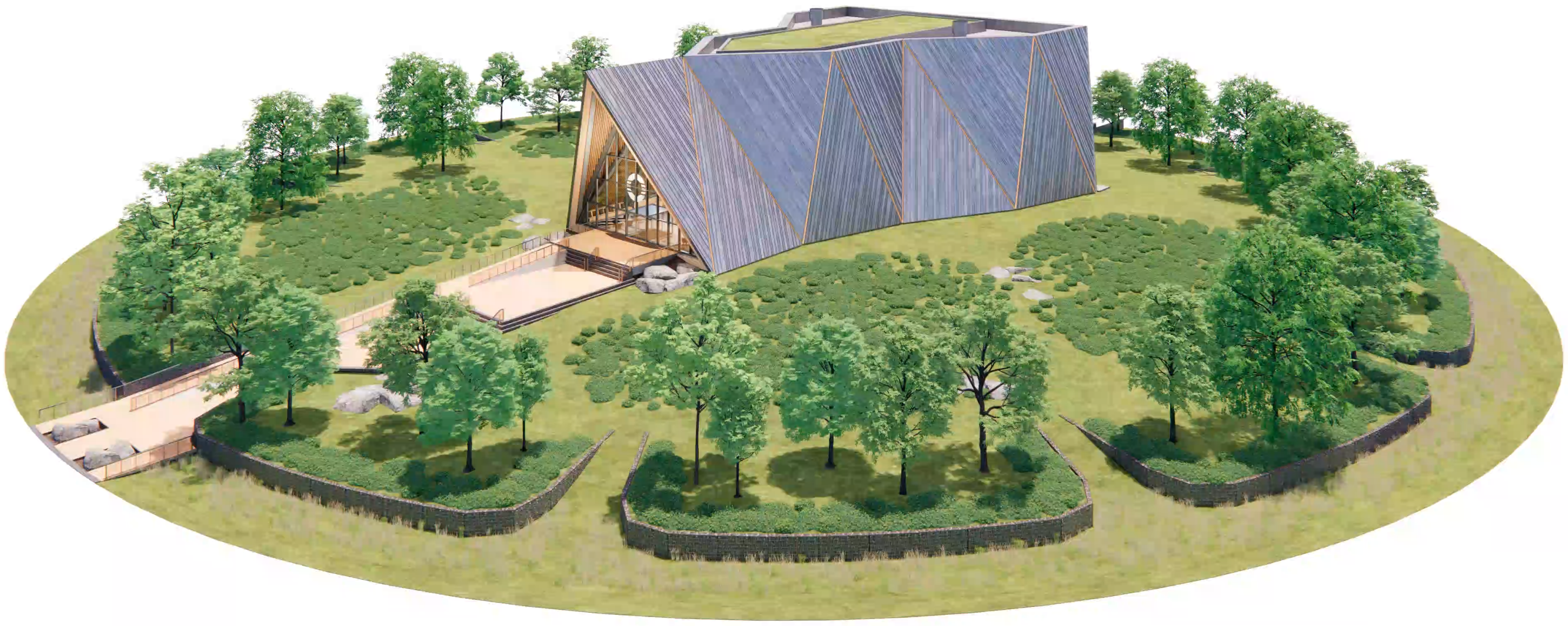
Vision for Electric Power

- The Arizona model would be replicated throughout the U.S. where feasible.
- Major population centers will continue with existing suppliers while waiting for large scale technology to catch up with demand.
- The large number of SMRs throughout the U.S. will be independent of the national grid, each forming a mini-grid that will be capable of accessing the national grid.
- This will require a massive investment in infrastructure but provide security of electricity in the event of a massive grid failure that is increasingly susceptible to hacking and foreign influence.

OKLO, Inc. (NYSE:OKLO)

Developing next-generation fission powerhouses to produce abundant, affordable, clean energy at a global scale – starting with the Aurora, which can produce 15 MW of electrical power, scalable to 50 MWe, and operate for 10 years or longer before refueling. Oklo's fast reactors incorporate inherent safety features and can be fueled by recycled waste.

OKLO, Inc. (NYSE:OKLO)



Nano Nuclear Energy Inc (NASDAQ:NNE)

- Compact
- Produce 1-20 megawatts of thermal energy
- Fabricated offsite
- Portable

Nano Nuclear Energy Inc (NASDAQ:NNE)

GE Verona

GE Verona is jointly owned by GE and Hitachi

BWRX-300 Small Modular Reactor

Using a combination of modular and open-top construction techniques, the Nth-of-a-kind BWRX-300 can be constructed in 24-36 months while achieving an approximate 90 percent volume reduction in plant layout.

In addition, reducing the building volume by about 50 percent per MW should also account for 50 percent less concrete per MW—a significant improvement in both affordability and advantageous size.

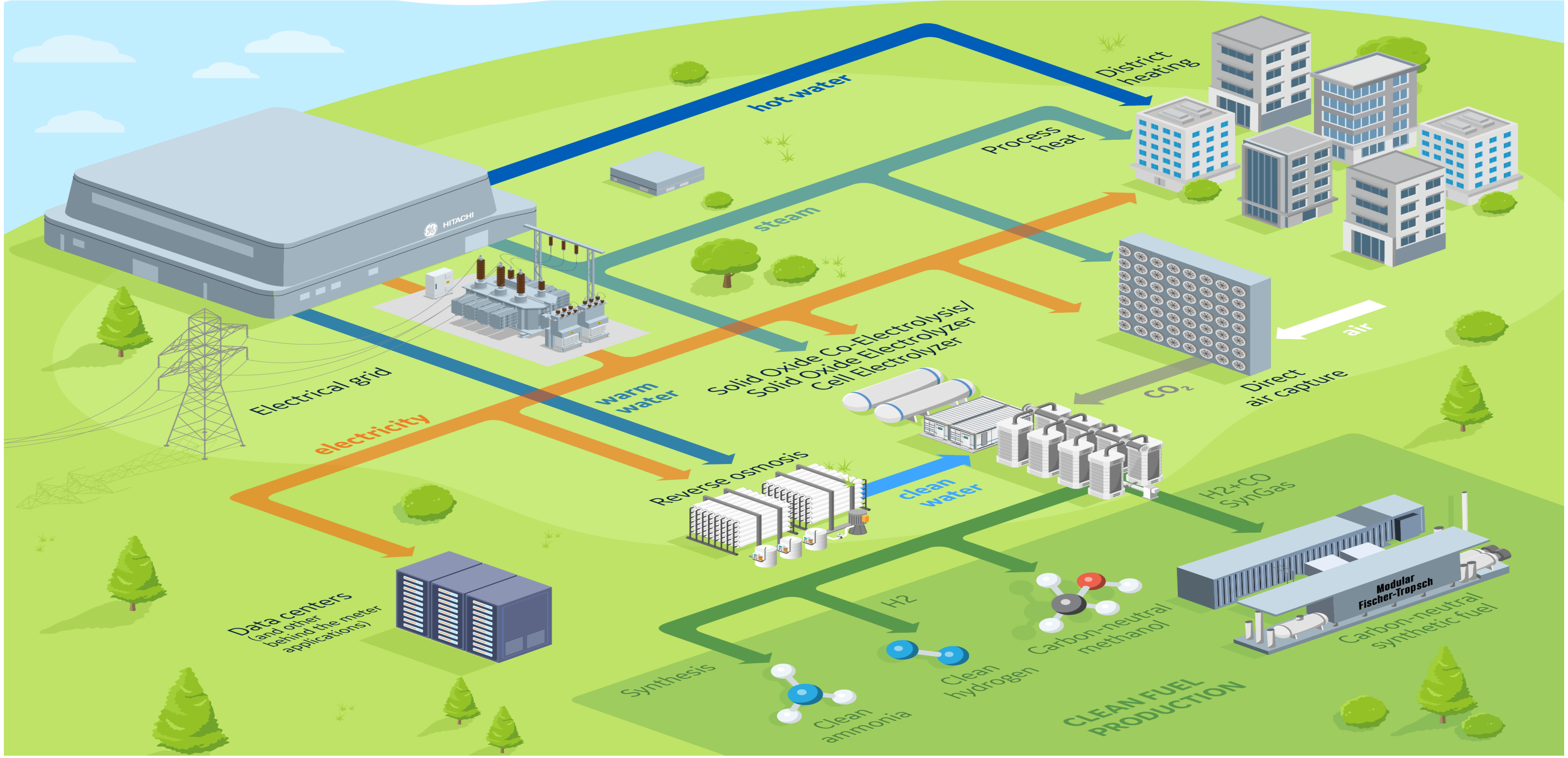
GE Verona

- An advanced reactor, the BWRX-300 uses natural circulation and passive cooling isolation condenser systems to promote simple and safe operating rhythms. In the global race for advanced nuclear power, the BWRX-300 sets itself apart with its proven, less complicated attributes.

- **Reactor type:** Boiling water reactor
- **Electrical capacity:** 300 MW(e) net to the grid
- **Primary circulation:** Natural circulation
- **Fuel enrichment:** 3.81% (avg)/4.95% (max)
- **Refueling cycle:** 12-24 months
- **Approach to safety systems:** Fully passive
- **Design life:** 60 years

GE-Hitachi Vision

BWRX-300 Small Modular Reactor



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Comparisons

Feature	NuScale VOYGR	GE Hitachi BWRX-300	Rolls-Royce SMR	TerraPower Natrium
Type	PWR	Boiling Water Reactor	PWR	Sodium-cooled Fast Reactor
Output	77 Mwe/Module	300 MWe	≈ 470 MWe	345 MWe
Deployment	Modular (4-12 units)	Single Unit	Large Single Unit	Hybrid with Molten Salt
Coolant	Water	Water	Water	Liquid Sodium
Safety	Passive System	Passive System	Passive & Active	Passive + Thermal Storage
Status	NRC-approved Design	NRC-pre Licensing	In Development	Pilot Plant Planned in Wyoming

Pinnacle West Capital

- Main subsidiary is Arizona Public Service (APS)
- News release 02/05/2025

Arizona Public Service (APS), Salt River Project (SRP) and Tucson Electric Power (TEP) announced today they'll be working together to explore adding nuclear generation in Arizona.

Siting work for additional nuclear would consider small modular reactors (SMRs) and potential large reactor projects. SMRs, which are smaller than traditional nuclear power reactors, generate 300 megawatts (MW) or less of energy per unit. For comparison, each unit at Palo Verde Generating Station, located west of Phoenix, is able to generate 1,400 MW. One megawatt of electricity is enough to power about 160 Arizona homes.

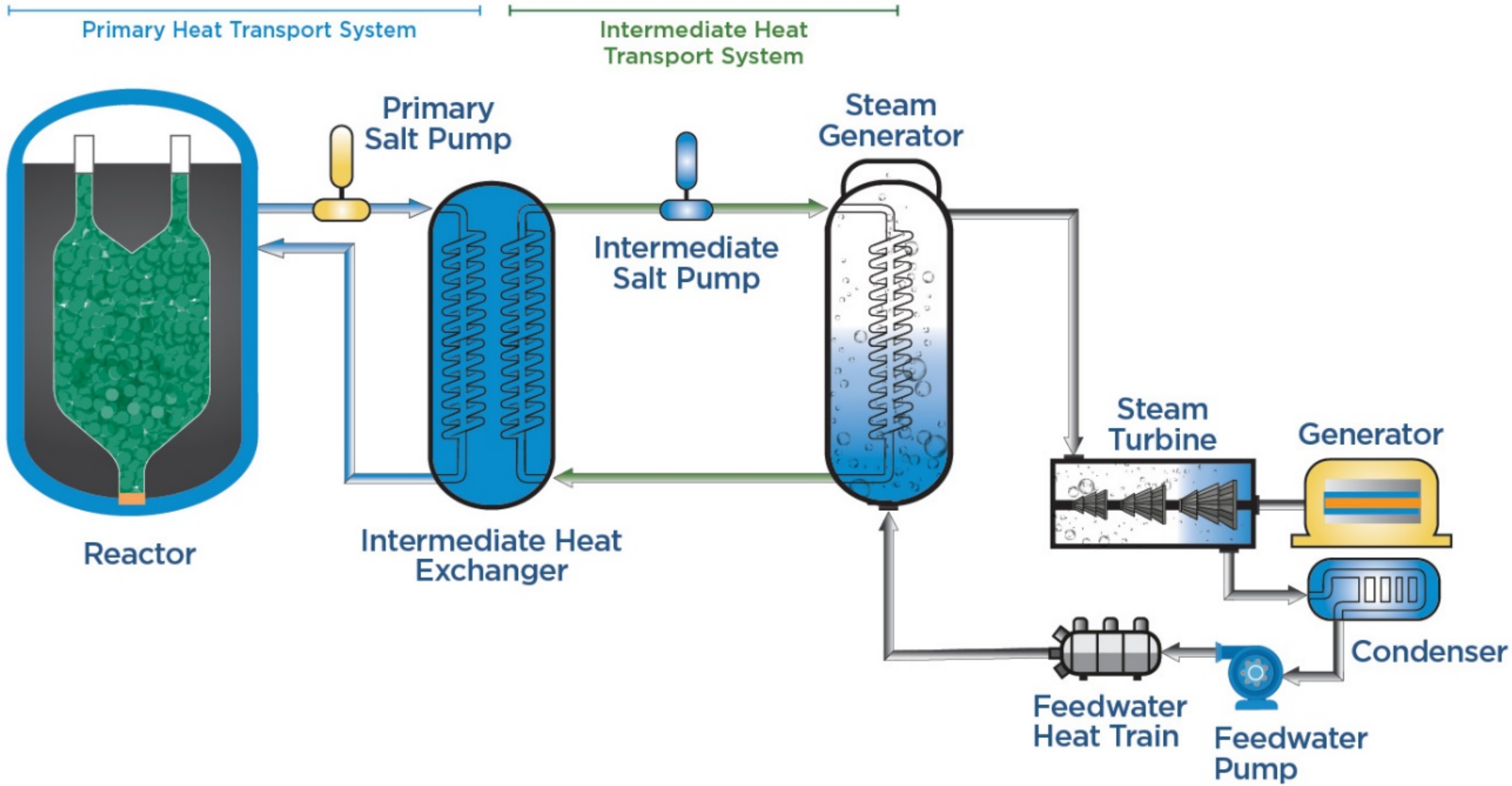
Kairos Power (Google-Backed)

- Developing a fluoride salt-cooled, high-temperature reactor (FHR). The main features of this technology include:
- **Coolant:** The reactor uses a molten fluoride salt mixture as a coolant. This type of coolant has a high boiling point and excellent heat transfer properties, allowing for more efficient and safer reactor operations.
- **Fuel:** The FHR design uses TRISO (Tristructural-Isotropic) fuel particles, which are known for their robustness and high-temperature stability. These fuel particles are encased in a graphite matrix, further enhancing the reactor's safety features.
- **Safety:** The combination of fluoride salt coolant and TRISO fuel provides intrinsic safety features. The reactor can safely shut down and dissipate heat without the need for active cooling systems.

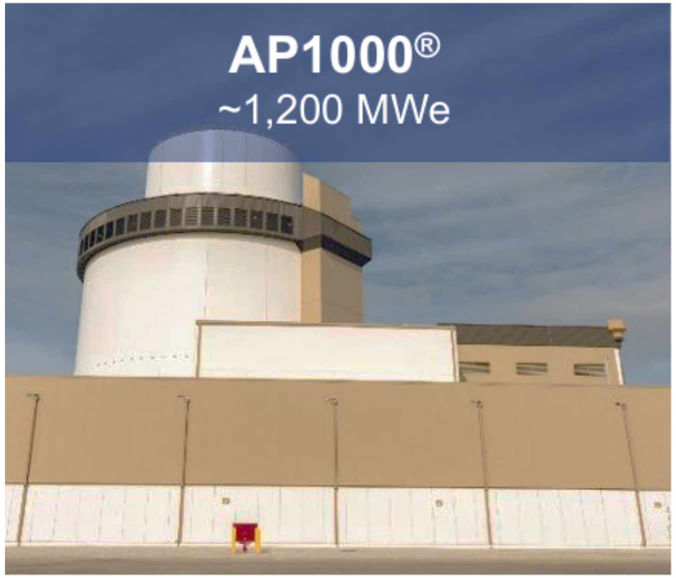
Kairos Power (Google-Backed)

•Technology Specifications

- KP-X Commercial Demo Plant
- KP-FHR Commercial Plant
- Power Output50 MWe
- Deployment Configuration: Single Unit
- Reactor Outlet Temperature: 650°C
- Reactor Operating Pressure: Near Atmospheric
- REACTOR Structural Material: 316H Stainless Steel
- Graphite Grade IBIDEN ET-10
- FUEL ENRICHMENT LEVEL19.75%


Primary Heat Transport System
Intermediate Heat Transport System
Primary Salt Pump
Steam Generator
Intermediate Salt Pump
Steam Turbine
Generator
Reactor
Intermediate Heat Exchanger
Condenser
Feedwater Heat Train
Feedwater Pump

Westinghouse



Holtec

- Plant Type PWR (Proven & Licensable)
- Thermal Power 1050 MWth (nominal) Electrical Power 320 MWe (net)
- Design Life 80 years
- Coolant Water Primary Circulation, Normal
- Fuel Cycle 18 months
- First Commercial Operation 40 acres Est 2030 (Palisades, MI)

X-Energy (Privately-Owned)

- Is focused on developing advanced nuclear reactors and fuel technology to provide safe, clean, and reliable energy. The company's flagship projects revolve around their high-temperature gas-cooled reactor (HTGR) and their innovative TRISO-X fuel. Here's a detailed overview of X-Energy and its key initiatives:
- **Modular Design:** The Xe-100 is designed as a modular reactor, meaning it can be constructed in smaller units (modules) that can be combined to scale up capacity. This modularity allows for flexibility in deployment and reduces construction times and costs.
- **High-Temperature Operation:** The Xe-100 operates at higher temperatures than traditional nuclear reactors, making it more efficient for electricity generation and capable of supporting industrial processes that require high temperatures, such as hydrogen production and desalination.

Department of Energy Newsletter (4/29/2025)

Dow and X-Energy Seek Advanced Reactor Construction Permit

Dow and X-Energy submitted a construction permit application to the U.S. Nuclear Regulatory Commission (NRC) in March for a proposed advanced nuclear project in Seadrift, Texas. The project is part of a demonstration project supported by DOE and includes four Xe-100 reactors at a Dow chemical plant. If approved, it would be the first advanced nuclear facility at an industrial site in the United States.

https://www.energy.gov/ne/articles/11-big-wins-nuclear-trump-administrations-first-100-days

Terminology

A "watt thermal" typically refers to a unit of thermal power or thermal energy, often used in contexts related to heating or energy generation. It represents the rate at which energy is transferred or converted in the form of heat. For instance, when discussing the output of a heating system or the capacity of a power plant to generate heat, watts thermal (Wt) are used to quantify this thermal energy output.

The relationship between **watt thermal (Wt)** and **watt-hour (Wh)** is based on the distinction between power and energy:

- **Watt thermal (Wt)** is a unit of **power**, which measures the rate of energy transfer or conversion. It tells you how much thermal energy is being generated or consumed per second.
- **Watt-hour (Wh)** is a unit of **energy**, which measures the total amount of energy used or produced over time. It is obtained by multiplying power by time.

Terminology

- **MWe (Megawatt electric)** is a unit of **electric power output**, typically used to measure the electrical power generated by a power plant or supplied to the grid.
  - **1 MWe = 1 megawatt (MW) of electrical power = 1,000 kilowatts (kW) = 1,000,000 watts (W) of electricity**
  - It refers specifically to the **usable electrical energy** output rather than the total energy produced.
  - **MWt (Megawatt thermal)** represents **thermal power** (heat energy) generated, often in power plants before conversion to electricity.
  - **MWe (Megawatt electric)** represents the actual **electrical power** delivered after conversion losses.
- For example, a thermal power plant might generate **1,000 MWt** of heat but, due to efficiency losses, only produce **400 MWe** of electricity. The conversion efficiency in this case would be **40%**.

Terminology

Fast Reactors

Allows for operations up to 10 years before refueling and permits running on recycled used nuclear fuel from other nuclear power plants. When a uranium atom's nucleus splits (fissions), it releases energy as well as two or three neutrons with the potential to cause other atoms to fission, and on average one of those neutrons must cause another fission to maintain the chain reaction.

On release, the neutrons are traveling very fast – around 20,000 km per second – but most of today's reactors use water as a moderator to slow the neutrons down to about 2 km per second, because this increases their efficiency to fission uranium isotopes, among certain others.

Fast neutrons gives reactors give the ability to fission a much wider range of fuel isotopes, while also being less sensitive to impurities found in recycled used nuclear fuel.

Terminology

Breeder Reactors

Fast reactors produce fissionable isotopes during operation, which helps extend refueling intervals, but they also efficiently consume these isotopes with the result that they consume more than they produce. Designed to produce more fissionable isotopes than they consume.

This approach contrasts with breeder reactors, which aim to maximize the creation of carbon-free fuel. The configuration of a reactor as a breeder is unnecessary as fast reactors can produce energy from recycled used fuel, with a focus on minimizing carbon emissions.

VOGTLE Unit 4

Vogtle Unit 3 — it's one of the **first new nuclear reactors built in the U.S. in more than 30 years**. It's part of the **Plant Vogtle** site near Waynesboro, Georgia, which already had Units 1 and 2 running since the 1980s.

Here are the key points about **Vogtle Unit 3**:

- **Reactor Type:** AP1000 (a Generation III+ pressurized water reactor by Westinghouse)
- **Capacity:** ~1,100 megawatts (enough to power hundreds of thousands of homes)
- **Fuel Load:** Completed in **October 2022**
- **Commercial Operation:** Officially began **July 31, 2023**
- **Owner/Operators:** Georgia Power (a Southern Company subsidiary), along with Oglethorpe Power, MEAG Power, and Dalton Utilities

VOGTLE Unit 4

- **Reactor Type:** AP1000 (same as Unit 3 — passive safety systems, modular design)
- **Electric Output:** Around **1,100 megawatts**
- **Fuel Load:** Completed **August 2023**
- **First Criticality:** Achieved **February 2024**
- **Connected to the Grid:** March 1, 2024
- **Commercial Operation Target:** Expected **mid-2024**

VOGTLE Unit 4

- Faced **similar delays and cost overruns** as Unit 3 — the whole expansion project started around 2009 and was originally supposed to be done by 2016–17.
- Final price tag: The Vogtle 3 & 4 expansion exceeded **$30 billion**, more than double original estimates.

Top Economies in 2024 Power Generation