Big Wins for Nuclear Energy

By John Benson

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1. Introduction

Most of my readers are aware that photovoltaic (PV) and wind turbine electric generation are (1) the most popular renewables and (2) intermittent. Although energy storage can be used to mitigate their intermittency, it would be better if they were not intermittent. Actually, there are two renewables that can be dispatched, these are still at least somewhat intermittent: small hydro and geothermal. The former is generally run-of-the-river (no reservoir) and thus dependent on stream-flow, and the latter is dependent on the amount of underground heat. Large hydro is not considered a renewable (mainly because of the large cost and secondary environmental impacts of building a large dam and the reservoir), but is considered "zero-greenhouse gas (GHG). There is one other zero-GHG electric generation technology, and from the above title, you can probably guess what that is, and that this is the subject of this post.

2. Recent Big Wins

Did nuclear power just have its best year ever?[1]

From welcoming a new reactor online for a second straight year to seeing two retired units pursuing historic restarts, nuclear power is definitely making a comeback in the United States.

2.1. Vogtle 4 Enters Commercial Operation

Vogtle 4 entered commercial service on April 29 to wrap up the power plant's expansion project in Waynesboro, Georgia.

Plant Vogtle is now the largest clean power generator in the country and is home to two AP1000 reactors, which are the first new builds in the United States in more than 30 years.

The expansion project received approximately $12 billion in loan guarantees from the U.S. Department of Energy (DOE) and played a crucial role in helping to retrain the workforce — supporting 9,000 jobs at peak construction…

2.2. Reactor Restarts

DOE closed a $1.52 billion loan to repower and upgrade the Palisades nuclear power plant in Michigan. The single-unit 800-megawatt reactor shut down in May 2022 and would be the first reactor ever recommissioned in the United States, if approved by the U.S. Nuclear Regulatory Commission (NRC).

The project is expected to support or retain up to 600 high-quality jobs and is the first loan closed through DOE's Energy Infrastructure Reinvestment program created under the Inflation Reduction Act.

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[1]US Department of Energy, Office of Nuclear Energy, "11 Big Wins for Nuclear Energy in 2024," December 31, 2024, https://www.energy.gov/ne/articles/11-big-wins-nuclear-energy-2024

Holtec plans to bring the plant back online in 2025.

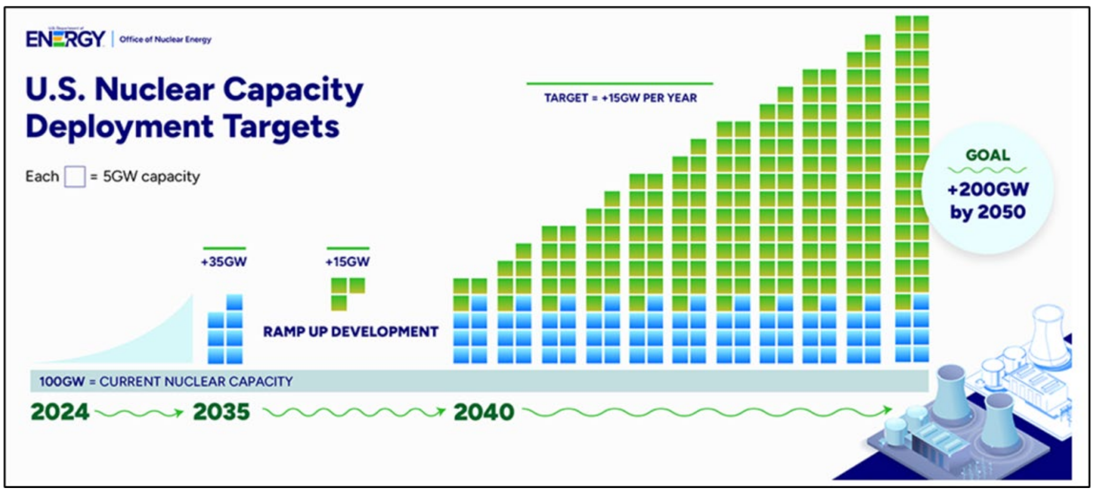
Constellation also announced its plans to restart Three Mile Island Unit 1 in Pennsylvania thanks to a 20-year power purchase agreement with Microsoft to power its data centers.

The plant will be renamed the Crane Clean Energy Center and is expected to be online in 2028, pending regulatory approval.

2.3. Nuclear Power Growth Targets

Last year, the United States joined more than 20 countries in pledging to triple global nuclear energy capacity by 2050, and now we have a plan to get there.

The White House released nuclear deployment targets this year to expand domestic capacity by 200 gigawatts (GW). See image below.



The plan outlines more than 30 actions the U.S. government can take to add 35 GW of new capacity by 2035 and achieve a sustained pace of 15 GW per year by 2040.

Most of that capacity could come from existing power plant sites.

Preliminary research shows that a majority of our nuclear power plants could host up 95 GW of new capacity. An additional 174 GW could also be built near U.S. coal plants, depending on the reactor type.

2.4. Securing Domestic Nuclear Fuel

DOE is working to grow our domestic nuclear fuel supply chain by selecting multiple companies to participate in low-enriched uranium and high-assay low-enriched uranium capacity building programs. The $3.4 billion effort will allow the awardees to bid on future task orders to produce, store, and recover material that can be fabricated into fuel for current and future reactors.

The funding underpins the nation's contributions to a multilateral commitment made at COP28 between the United States, Canada, France, Japan, and the United Kingdom to mobilize $4.2 billion in government-led investments to establish a global uranium supply market that is free from Russian influence.

The United States also took crucial steps toward strengthening our domestic energy security by issuing a ban on imported uranium products from Russia.

The move is a key piece to a larger strategy to build new production capacity in the United States and transition away from Russian-sourced fuel, which currently makes up more than 20 percent of our enriched uranium imports for nuclear fuel.

2.5. Smaller Factory-Built Reactors

Several DOE-supported projects started construction in 2024, bringing the United States one step closer to the deployment of new advanced small modular and microreactor systems.

2.5.1. Natrium

TerraPower started non-nuclear construction on a sodium test facility in support of its Natrium reactor in Kemmerer, Wyoming.

The 345-MWe sodium-cooled fast reactor and energy storage system is being built near a retiring coal plant to leverage the available infrastructure and workforce in the area.

The NRC accepted the company's construction permit application in May for review, which is being implemented through a modernized licensing framework methodology to streamline the review process for non-light-water reactor designs.

2.5.2. Project Pele

The Department of Defense broke ground on its Project Pele microreactor at Idaho National Laboratory.

DoD is planning to design, build, and demonstrate a transportable high-temperature gas reactor that will operate at the lab's Critical Infrastructure Test Range Complex. The Pele reactor is being authorized and approved by DOE's Idaho Operations Office.

The demonstration is being led by DoD's Strategic Capabilities Office and could be one of the first advanced reactors to operate in the United States as early as 2026.

2.5.3. Hermes

Kairos Power also started construction on its Hermes reactor in Oak Ridge, Tennessee.

The project is one of several projects being supported through DOE's Advanced Reactor Demonstration Program.

The low-power reactor is being used to inform the development of the company's commercial fluoride salt-cooled, high-temperature reactor.

The NRC also cleared a second plant, Hermes 2, for construction in late November.

2.5.4. Deployments

DOE launched a $900 million program to demonstrate up to two advanced light-water small modular reactor systems in the United States.

The new program encourages a consortium-based approach to lower the risk of deploying new reactor technologies. It will also facilitate multi-reactor order books and provide additional support to build out the advanced light-water reactor supply chain.

Advanced light-water systems incorporate enhanced safety features and modern instrumentation and controls to improve performance while offering the potential to reduce construction, operations, and maintenance costs.

The two first-mover projects will be managed by DOE's Office of Clean Energy Demonstrations, while the Office of Nuclear Energy manages the siting, supply chain, and cost estimating initiatives.

2.6. Accelerating Future Reactors

This summer, President Biden signed another key bipartisan bill known as the ADVANCE Act to help speed up the deployment and licensing of new reactors and fuels.

The new bill builds on the successes of previous legislation to develop a modernized approach to licensing new reactor technologies.

It also introduces prize competitions for the first time to cover licensing fees for first adopters and makes strides to develop guidance for smaller reactor technologies and advanced fuel cycles.

2.7. Spent Nuclear Fuel

After years of negotiating with the state of Idaho, and dozens of deliverables achieved by the U.S. government to manage the state's legacy waste, Idaho National Laboratory received its first shipment of spent fuel since the 1990s.

The data generated from the 25 fuel rods will be crucial to developing and licensing new fuel technologies designed to enhance safety performance and operate for longer periods of time in a reactor — ultimately saving customers money on their energy bills.

3. More on Future Advanced Reactors

The workings of nuclear power plants have always fascinated me. They're massive, technically complicated, and feel a little bit magic (splitting the atom—what a concept). But I've reached new levels of obsession recently, because I've spent the past week or so digging into advanced nuclear technology.[2]

Advanced nuclear is a mushy category that basically includes anything different from the commercial reactors operating now, since those basically all follow the same general formula. And there's a whole world of possibilities out there…

In nuclear power plants today, there are basically two absolutely essential pieces. First, the fuel, which is what feeds the reactions. (Pretty obvious why this one is important.) Second, it's vital that the chain reactions happen in a controlled manner, or you can get into nuclear meltdown territory. So, the other essential piece of a nuclear plant is the cooling system, which keeps the whole thing from getting too hot and causing problems. (There's also the moderator and a million other pieces, but let's stick with two so you're not reading this newsletter all day.)

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[2] Casey Crownhart, MIT Technology Review, "The next generation of nuclear reactors is getting more advanced," January 18, 2024, https://www.technologyreview.com/2024/01/18/1086753/advanced-nuclear-power/

In the vast majority of reactors on the grid today, these two components follow the same general formula: the fuel is enriched uranium that's packed into ceramic pellets, loaded into metal pipes, and arranged into the reactor's core. And the cooling system pumps pressurized water around the reactor to keep the temperature controlled.

But for a whole host of reasons, companies are starting to work on making changes to this tried-and-true formula. There are roughly 70 companies in the US working on designs for advanced nuclear reactors, with six or seven far enough along to be working with regulators.[3]

Many of these so-called advanced technologies were invented and even demonstrated over 50 years ago, before the industry converged on the standard water-cooled plant designs. But now there's renewed interest in getting alternative nuclear reactors up and running. New designs could help improve safety, efficiency, and even cost.

3.1. Coolant

Alternative coolants can improve on safety over water-based designs, since they don't always need to be kept at high pressures. Many can also reach higher temperatures, which can allow reactors to run more efficiently.

Molten salt is one leading contender for alternative coolants, used in designs from Kairos Power, Terrestrial Energy, and Moltex Energy. These designs can use less fuel and produce waste that's easier to manage.

Other companies are looking to liquid metals, including sodium and lead. There are a few sodium-cooled reactors operating today, mainly in Russia, and the country is also at the forefront in developing lead-cooled reactors. Metal-cooled reactors share many of the potential safety benefits of molten-salt designs. Helium and other gases can also be used to reach higher temperatures than water-cooled systems. X-energy is designing a high-temperature gas-cooled reactor using helium.

Author's comment: See the earlier post from January 2024 on liquid metal fast breeder reactors summarized and linked below.

Nukes Part 8 - Fast Breeders: *Many times, I thought I had left my history in the dust, only to have a new team bring it back to me. In case you are wondering about the title of this paper, it is a type of nuclear fission reactor that was in my deep past. I graduated from college (BSEE) in 1975. My first job out of college was with Rockwell Atomics International. The projects I worked on there all involved a type of reactor called a Liquid Metal Fast Breeder Reactor.*

The "Liquid Metal" was its heat-transfer fluid: either liquid sodium or a sodium-potassium alloy (NaK). "Fast" refers to the neutrons emitted by the nuclear reaction that are "fast" (high-energy), and remain fast until they undergo additional reactions. In a standard water-cooled fission reactor, the neutrons are moderated (have their energy reduced) before additional reactions. "Breeder" means that the LMFBR breeds its own fuel.

This report is also about Oklo, who wanted to focus on the technology with the most demonstration history, with inherent safety, while having the capability to use waste as fuel. All of these capabilities were demonstrated by LMFBRs well before my history with this technology.

[3] Per Jessica Lovering, cofounder and co-executive director at the Good Energy Collective, https://www.goodenergycollective.org/

https://energycentral.com/c/cp/nukes-part-8-fast-breeders

3.2. Fuel

Most reactors that use an alternative coolant also use an alternative fuel.

TRISO, or tri-structural isotropic particle fuel, is one of the most popular options. TRISO particles contain uranium, enclosed in ceramic and carbon-based layers. This keeps the fuel contained, keeping all the products of fission reactions inside and allowing the fuel to resist corrosion and melting. Kairos and X-energy both plan to use TRISO fuel in their reactors.

Other reactors use HALEU: high-assay low-enriched uranium. Most nuclear fuel used in commercial reactors contains between 3% and 5% uranium-235. HALEU, on the other hand, contains between 5% and 20% uranium-235, allowing reactors to get more power in a smaller space.

3.3. Size

I know I said I'd keep this to two things, but let's include a bonus category. In addition to changing up the specifics of things like fuel and coolant, many companies are working to build reactors of different (mostly smaller) sizes.

Today, most reactors coming on the grid are massive, in the range of 1,000 or more megawatts—enough to power hundreds of thousands of homes. Building those huge projects takes a long time, and each one requires a bespoke process. Small modular reactors (SMRs) could be easier to build, since the procedure is the same for each one, allowing them to be manufactured in something resembling a huge assembly line.

NuScale has been one of the leaders in this area—its reactor design uses commercial fuel and water coolant, but the whole thing is scaled down. Things haven't been going so well for the company in recent months, though: its first project is pretty much dead in the water, and it laid off nearly 30% of its employees in early January. Other companies are still carrying the SMR torch, including many that are also going after alternative fuels and coolants.

Author's comment: I just looked at a recent Motley Fool review of NuScale, and it was, at best, mixed (go through the link referenced here[4]). Also, see my earlier post from November 2024 summarized and linked below.

Nuclear Power Partnerships: *I have covered several emerging nuclear power technologies in the past. Since the nuclear industry has a long history (the first fission reactors were built during WWII, in the early 1940s), there have been many flavors of advanced reactors. In this post we will look at Kairos Power, who is developing a "Pebble Bed" Reactor using an advanced "Flibe" coolant/heat transfer fluid. This ends up being an ideal design for future Artificial Intelligence (AI) server farms. Thus, Kairos Power, a US-based nuclear engineering company, recently inked a long-term deal with Google to develop and bring the company's first SMR online "quickly and safely by 2030," with continuing rollouts planned through 2035.*

https://energycentral.com/c/gn/nuclear-power-partnerships

[4] https://www.fool.com/investing/2024/12/27/where-will-nuscale-power-stock-be-in-10-years/?msockid=234c177cbb1d6cca0f6904bcba996d70