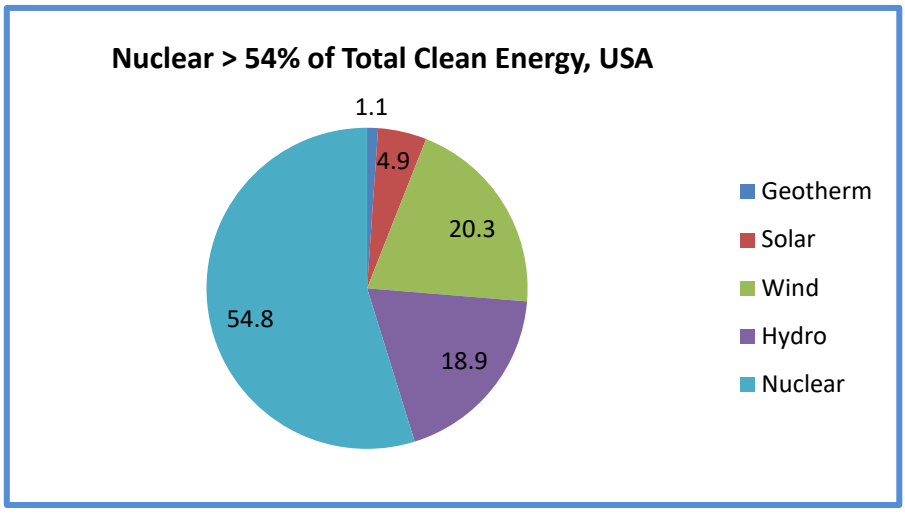
THE FUTURE OF NUCLEAR ENERGY IN THE USA

THE GOOD NEWS = THE USA HAS THOUSANDS OF YEARS OF URANIUM FUEL AVAILABLE

THE BAD NEWS = EVERYTHING ELSE?

NUCLEAR REACTORS generate 19.7% of the USA's electricity now, after Natural Gas (38.4%) and Coal (23.5%). Nuclear provides by far the largest source of USA's low carbon "clean energy".



Source: NEI (Nuclear Energy Institute), March 2020

The US is still the largest producer of nuclear power in the world (though France gets a much larger 75% of its energy from nuclear). But only one new US nuclear plant has been commissioned since the 1980's (Watts Bar **TVA reactor**, **Tennessee** 2016). Most of our fleet of nuclear plants is aging! Unfortunately, they are gradually being decommissioned, with few replacements. So this lowest carbon-footprint fuel is scheduled to decrease as a percent of our generation capacity over the next three decades.

DECOMMISSIONING: the real money will be made here in the next couple of decades. Dozens of plants could be decommissioned (though some may earn a 20 year life extension at high retrofit costs).

"Of the 98 nuclear reactors currently operating in the U.S., 92 of them, or 94%, are over 30 years old, while 48 (or 49%) are over 40 years old. Six of the current power reactor licenses will terminate within the next five years, 17 within the next 10 years, and 53 within the next 20 years (NRC, 2019d). Regardless of whether these plants will renew their licenses, the United States has an aging nuclear fleet that must look towards life after operation."

> *Source: "An Analysis of United States Nuclear Power Plant Decommissioning Policy and the Public Participation Process", Alexis Stabulas, Clark University, 2019*

Eleven US reactors have been decommissioned. Another 21 are planning for or in decommissioning process. However some states have supported (and some received) first or second license renewal to delay decommissions for 20 years; they need low cost power to stay competitive and prevent outages.

Providers: electric utilities don't want to get into the radioactive waste or hazardous scrap business (decommissioning is effectively that). So private companies have arisen to purchase and decommission old nuclear plants. They get legal access to "decommissioning funds" set aside by each reactor owner over the life of the asset (currently around $70 Billion nationally). Can be a lucrative business, but there is concern that these companies' main objective is profits, not long term safe disposal of nuclear waste.

Another concern: where to store used fuel. Holtec, for example, uses temporary storage sites in NM and TX (against local opposition) as Congress has yet to approve the Yucca Mountain NV geologic storage facility, or any alternative. So: will "temporary" storage sites become de facto permanent sites?

Some key players in the US decommissioning market:

HOLTEC, Camden NJ: earlier this century was charged with bribery by the TVA, and disbarred from providing any services – but only for a few months - along with a $2 million fine. Still going strong.

NORTHSTAR, New York NY: strong business in decommissioning nuclear plants but also nuclear research sites, nuclear medicine facilities and laboratories. Also does other hazmat abatement.

ENERGY*SOLUTIONS,* Salt Lake City UT: in 1990's did an early nuclear plant decommissioning (Zion Nuclear Station in Utah), has built a business from that base for over two decades in USA and globally.

THE FLIP SIDE: FEW NEW PLANTS ARE UNDER CONSTRUCTION OR IN PROCESS

Plant Vogtle, GA: two new Nuclear reactors are now being built, at great cost (with overruns too).

> *"The two most recent nuclear projects in the US illustrate this point. The construction of two Westinghouse AP1000 reactors at the Virgil plant in South Carolina was abandoned . . . after massive cost overruns and $9bn in expenditures, contributing to the bankruptcy of Toshiba subsidiary Westinghouse – with knock-on-impacts for nuclear projects around the world.*
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> *The construction of another **two AP1000 reactors at the Vogtle plant in Georgia** is still ongoing, but the company expects the project to cost at least $25bn, more than $10bn over budget. Duke Energy recently cancelled plans to build new nuclear plants in South Carolina and Florida."*
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> Source: CarbonBrief "Mapped: the US Nuclear Power Plants at Risk of Shutting Down" 7/24/2018
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> Of note, the TVA's Watts Bar Nuclear Plant was the first to be commissioned (2016) in USA since the 1980's.
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> And another TVA nuclear project, Bellefonte 1 and 2 (two reactors in Alabama) started in 1988 but were never completed; auctioned off in 2018 for $111 Million – not bad when you consider the TVA had already spent $6 billion on Bellefonte! The private investor who bought it agrees to complete construction within two years (famous last words?) Delaying legal actions have been taken, though it seems the project may go forward.

The Blue Castle Project, Utah, another new nuclear plant scheduled for completion this decade, will not be built by a traditional utility, but by another group of private investors. It is permitted and scheduled to begin construction in 2023 (based on the same Westinghouse reactor used at Vogtle).

Blue Castle's objective is to **provide electricity to a specific target market** - **data centers used by bitcoin miners**, through a distribution arm, ***Power Block Coin***. This could be a potential new market for nuclear, provided investors keep construction costs under control and offer competitive electricity costs.

Generally however, in the USA, the economic case for nuclear power is less compelling than before: with "fracking" and US energy independence, in the past decade nuclear has become less competitive vs low-cost Natural Gas for electricity generation. Plus there are many legal, regulatory, financial and political (NIMBY, others) obstacles to overcome. For example, Vogtle's reactors were initially requested (planning, permitting) in 2006, construction started 2013, commissioning is projected for 2022.

The Environmental Case may be stronger, but is it enough to trump economics or bridge the cost issues? – Not necessarily. Nuclear fuel has a much lower carbon footprint [zero per supporters] than NG or any other fossil fuel, or even most 'green' energy sources – raising a debate: should the USA give carbon / tax credits to nuclear generators for the lower carbon footprint of Nuclear vs alternatives, if we truly prioritize "decarbonization" of our energy production fleet?

1 Nuclear Fuel pellet (about the size of a pencil's eraser) provides as much energy as:

1 Ton of Coal
149 Gallons of Oil
17,000 FT^3 of Nat Gas

Source: NEI, 2020

The Trump administration has provided carbon offsets for nuclear energy. Besides Trump's tax credits, the Obama administration earlier provided Federal loan guarantees backing $8.3 billion of Southern Company debt to support launch of construction on the two Vogtle reactors. So there is some Federal government support from both major parties, but no apparent long term strategy.

Even many green-leaning scientific and conservation groups, including *The Union of Concerned Scientists*, *The Nature Conservancy* and *The MacArthur Foundation* see a role for nuclear in their 'decarbonization' models, and agree that it is among the 'greenest' of all fuels available to us.

A negative Side Effect: shrinking Nuclear power talent pool? Baby boomer retirements, limited career paths in nuclear for younger workers as few new US plants will be built soon, plus bad PR (and some real failings by the nuclear industry, e.g. Fukushima): *"What happens to the safety of the existing fleet as the*

top power generation talent shifts to other fields – leads to more and earlier plant decommissioning?"
- Gregory Jaczko (ex-NRC Chair), Decommissioning: The Future of the Nuclear Industry, May 2019.

New Nuclear technologies/markets: the hope of tomorrow? Some of these:

- NuScale Power's SMR (Small Modular Reactor) received a demo permit for Idaho Nat'l Labs site. Applications: On-site Industrial Power, Water Desalination, Military Base power gen, Hybrid.

- Terrapower: Bill Gates, Chairman. Research on lower cost, safer nuclear energy applications. *"On paper really works well"* – Bill Gates (I think he said that about Power Point too?) See:

  https://www.youtube.com/watch?v=_HxI3-DzPWU

- Kilopower Reactors: NASA and the DOE are working on small inexpensive reactors to power (very) long term space exploration, power for establishment of a Mars or Moon base, etc.

- Nuclear Fusion: touted by some (for years) as the ultimate solution, but there are still no real results. Because input costs/requirements far exceed value of the energy potentially generated.

- Electric Vehicles! If electrification of transportation increases exponentially as projected we'll need new battery / energy storage technologies, new nuclear plants, or some other low carbon alternatives (not fossil fueled plants – which defeat the purpose of electric vehicles).

A good summary of the future of US Nuclear Energy is this 6-page article by specialists at Carnegie Mellon, Harvard and the U of California published in the Proceedings of the National Academy of Sciences. Though not hopeful regarding the economics of traditional nuclear vs NG, or even the latest Small Modular Reactors (SMR's), they advocate that policy makers take steps, including some funding, to help industry test and deploy more nuclear technologies to decarbonize energy production and encourage new applications:

https://www.pnas.org/content/115/28/7184

Here's a more cheerful 45 minute YouTube of MIT Prof Jacopo Buongiorno on MIT's 2018 "Future of Nuclear Energy" study. He's a fan! Buongiorno demonstrates there are **thousands of years of uranium available** for nuclear energy, while (Big Foot!) solar and wind require vastly larger foot prints for comparable output, and nuclear has the lowest mortality rate (seriously? Yes Bill Gates agrees too). So:

> If all else fails
> There'll still be U
> Element 92

https://www.youtube.com/watch?v=35TjfnV-_9w