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Small Modular Nuclear Reactors are a Dead End

The nuclear power industry is currently promoting designs for small modular reactors (SMRs) that will supposedly be cheaper, safer, and faster to build than older nuclear power plants. Bill Gates and Amazon are investing in the technology. Moreover, some environmentalists, including Mark Lynas and Bill McKibben, support SMRs in the hope that they can lower carbon emissions. And, according to polls, far more Americans now approve of the development of nuclear energy than was the case just a decade or two ago.

This year, the world has been plunged into a global energy crisis: with the closure of the Strait of Hormuz, nearly a fifth of world oil shipments have been held up, with economic impacts likely to reverberate for months or years. World leaders are suddenly desperate for energy alternatives, and are turning to solar, coal, and nuclear. At the same time, electricity demand for data centers is exploding, and builders of those centers hope to use SMRs to power artificial intelligence (AI).

In short, it looks like a great moment for the nuclear industry.

Yet Indigenous peoples, technology critics, and old-school environmentalists still oppose nukes—even in new, highly touted forms. I agree with their critiques. In this article, we'll look at the current nuclear revival and see why it may end up being a zombie attack.

Nuclear Renaissance?

Before looking at SMRs specifically, it's helpful to understand the status of the nuclear industry in more general terms. The industry's potential resurgence comes after three decades in the doldrums following the Chernobyl catastrophe in 1986. Today, roughly 440 nuclear power plants, spread across 30 countries and with a combined net capacity of around 400 gigawatts (GW), provide about 10 percent of the world's electricity. The US, which has the largest number of plants of any country (96), is seeing a slow phase-out of old reactors (average age 44 years), but has commissioned three new ones during the last decade. China is now operating 60 reactors, with up to 40 others under construction. India is likewise hoping to grow its nuclear industry rapidly and is experimenting with fast breeder reactors.

Globally, the International Energy Agency (IEA) forecasts total nuclear power capacity to grow to over 700 GW by 2050, and small modular reactors are expected to make up a significant share of this growth. A year ago, the Trump administration unveiled an ambitious nuclear strategy that includes a goal to quadruple the United States' nuclear capacity by 2050, with SMRs playing a key role.

The principal drivers of renewed interest in nuclear power are climate change (globally), the Trump administration (in the US), tech companies' voracious demand for electricity, and Asian nations' hunger for more industrial power. Most nations want to limit their carbon emissions, and the main low-carbon alternatives to fossil fuels are solar, wind, hydro, and nuclear. Solar and wind are intermittent ("variable") sources, requiring energy storage to align electricity supply with demand. Hydro has limited potential for growth. That leaves nuclear power, which has the advantage of being reliable and steady, and has possibilities for expansion.

If it's helpful to understand why the industry is growing again, it's just as important to know the reasons for its long period of dormancy:

- *Cost:* Nuclear power plants are complex and expensive, employing technology that's internationally regulated due to concerns about the proliferation of nuclear weapons. Despite over 80 years of the industry's development, nuclear plants still take a long time to build and are often plagued with cost overruns.
- *Fuel:* Uranium, the fuel for nearly all existing nuclear power plants, is a depleting nonrenewable resource, and supplies are running short. Uranium mining is a dirty, expensive process, and mine closures, mostly due to resource depletion, are expected to lead to fuel shortfalls by 2035. While geologists have identified more uranium resources, opening new mines will entail further environmental destruction and harm to human communities, of which the uranium mining industry already has a grim history.
- *Waste:* Despite decades of research, the global nuclear industry still has found no good place to put the 300,000 tons of nuclear waste—as well as 480,000 tons of depleted uranium in the US alone—that it has produced in the last 80+ years.
- *Safety:* While nuclear accidents are relatively rare, they can be devastating and expensive when they occur. The Fukushima disaster of 2011 resulted in direct cleanup costs of up to $180 billion as of 2016, but the damage still has not been completely contained, and indirect costs to human health have been estimated at half a trillion dollars. Further, nuclear power technology is still tied to the threat of nuclear weapons proliferation.
- *Water issues:* Nearly all nuclear power plants use water as a coolant and are highly vulnerable to droughts and floods. Droughts reduce the availability of water for cooling, while floods (nuclear plants are generally built next to rivers, lakes, and other bodies of water) damage safety infrastructure and risk contaminating water sources.

If the nuclear industry can overcome its historic obstacles, a door is open. According to the industry, small modular reactors are the main way forward.

SMRs: Promise or Hype?

The main arguments for SMRs are that they would be cheaper and faster to build than conventional power plants; that they would be safer; and, being smaller, that they could be installed to power remote towns or data centers. The idea is to build components in a centralized factory and then assemble those components at power generation sites.

“Small” is defined as 300 megawatts of electrical power or less. While most existing nuclear plants are in the one-gigawatt (1,000 MW) range, some proposed SMRs are 20 megawatts or less; these are called “micro” reactors.

For the most part, SMRs are still at the design stage. China has one SMR under construction. In the United States, TerraPower, founded by Microsoft’s Bill Gates, has received a permit to build a 345-megawatt (not exactly “small,” but close) sodium-cooled reactor in Kemmerer, Wyoming.

Clearly, it is possible to get funding and approval for these new-generation power plants. The big question is, can SMRs deliver on their promises to overcome the historic drawbacks of conventional nuclear power?

- *Cost:* SMRs will only be cheaper to build if large numbers are ordered; the first prototypes may be even more costly than conventional plants. Meanwhile, construction costs *per MW of capacity* will likely be higher, and operating costs are largely unknown until real-world data can be collected. The cost of electricity from SMRs is therefore also yet to be determined, but preliminary estimates put it much higher than solar or wind.
- *Fuel:* Most proposed SMRs use uranium, but some designs on the drawing boards would use depleted uranium or thorium as fuels (see below). For now, however, the uranium fuel constraint looming over the nuclear industry remains in place. SMRs also won’t use their fuel more efficiently than conventional reactors, despite some claims to the contrary.
- *Uranium from Seawater:* The supply limits of uranium could be greatly expanded by harvesting it from seawater, where the potential resource is enormous—albeit at a concentration of about 3.3 parts per billion. The total oceanic uranium resource is estimated at 4.5 billion tons, over 500 times all identified land-based uranium resources. However, extracting the uranium will take a lot of energy: the best existing technology using absorbent materials will offer an energy return on energy invested (ERoEI) of about 4:1, which is lower than the ERoEI for solar, wind, hydro, fossil fuels, or conventional uranium mining.
- *Waste:* Some proposed SMR designs would be breeder reactors that could get rid of depleted uranium or even nuclear waste by using them as fuels—but this technology has faced significant challenges (see below). Otherwise, SMRs will do nothing to solve, and may actually worsen, the nuclear waste dilemma.
- *Safety:* SMRs are designed to be safer than conventional nuclear plants, using passive, gravity-driven cooling systems that don’t require electricity or human intervention to shut down. However, their overall safety is controversial. There is still no real-world data to support the industry’s promises. And having lots of smaller nuclear plants dotted across the landscape could make it easier for nuclear materials to end up in the hands of bad actors.

> The resilience of SMRs in the face of more frequent and more severe natural disasters is also controversial; a 2021 study concluded that storms, droughts, and higher ambient temperatures linked to climate change are likely to pose operational risks to *all* nuclear power plants.

The biggest remaining advantages of SMRs are the speed with which they *could* be deployed once the manufacturing infrastructure is in place, and the prospect of providing non-grid-tied dedicated power sources for data centers.

What about further technological advances?

When confronted with the limits of one technology, nuclear advocates often shift the conversation to another. However, close examination usually shows that each technological "solution" has its own problems:

- *Fast breeder reactors:* If nuclear fuel is scarce, why not develop fast breeders, which produce more nuclear fuel than they consume? Currently, Russia operates two fast breeders and India's first one reached criticality in late April. China has a fast breeder reactor for research. The US, France, and Japan operated breeders in the past but have shut down research along these lines due to high capital and operational costs, safety risks related to sodium coolant, and nuclear proliferation concerns.
- *Alternative cooling systems:* Water-cooled reactors (a category that includes nearly all existing commercial nuclear plants) pose risks of loss-of-coolant accidents due to pipe breaks, high-pressure operation failures, age-related component deterioration, and earthquakes or other natural disasters. The industry's solution: use sodium or helium as a coolant. Unfortunately, sodium is highly chemically reactive and ignites upon contact with air and reacts explosively with water, while helium is a depleting non-renewable resource that is becoming economically scarce at a rapid rate.
- *Thorium reactors:* If uranium is scarce and might lead to weapons proliferation, why not use more-abundant thorium? China already has an experimental two-megawatt thorium reactor in the Gobi Desert. However, thorium reactors have steep development costs and produce a highly radioactive byproduct, uranium-232, which decays into isotopes that emit penetrating gamma rays, making fuel handling and maintenance more hazardous and costly. Also, thorium reactors require a "driver" fuel: thorium-232 is fertile, not fissile, meaning it needs a different radioactive fuel (like uranium or plutonium) to initiate the chain reaction. Therefore, proliferation concerns remain.

Currently, there is little real-world data regarding these "new" nuclear technologies, even though all have been discussed or experimented with for decades. The nuclear industry hasn't actually solved its many dilemmas, and the current nuclear renaissance isn't being driven by novel solutions so much as by the rapid worsening of society's energy-related problems, primarily climate change: world leaders are now so desperate for reliable low-carbon energy sources that they are willing to overlook substantial risks, if only the nuclear industry will put a shiny gloss on its latest iteration of products. And leaders of the tech industry, keenly aware of the soaring electricity demand from AI, are even more desperate for ways to power the exponential growth of their companies without risking a backlash from the rest of society, which may suffer from higher electricity prices or shortages.

If not SMRs, then what?

Nuclear power is a product of high-tech modern industrialism. The proponents of nuclear power assume—and nuclear reactors rely on—global supply chains, uninterrupted grid power, reliable water resources, and functioning political systems. The future that's unfolding around us is a polycrisis in which supply chains, grid power, water, weather, and politics-as-usual are all threatened. In these unfolding circumstances, the only solutions that make sense are ones that are small-scale, local, low-risk, and nature-based.

What to do about carbon emissions? Yes, we need to replace fossil fuels with low-carbon energy sources—but these should be as low-tech as possible, and we should aim to reduce overall energy usage.

What to do about AI data centers? That's easy: don't build them. We are rushing headlong into an AI-managed future without an adequate understanding of what AI is, does, or is likely to do in the future. Besides, AI appears to be perhaps the biggest investment bubble in history.

Most political and economic leaders have taken the attitude that we must go to any possible lengths to save industrial modernity. But industrial modernity is the essence of our problem: it is a crisis-generating machine—and one that, prior to its inevitable self-destruction, is creating enormous wealth for a small minority of people, while entrapping everyone else in dreary systems of employment, payment, debt, dependency, and distraction that leave little time for reflection on the futility of it all.

Moreover, SMRs will do nothing to solve our immediate global energy crisis. The oil shortages that are already sweeping over the world in the wake of the US-Iran war cannot, in most cases, be offset with electricity—at least not right away. While electrification is a good interim energy strategy for gradually winding down modernity with minimal casualties, it's one that will take time, and some things will be hard or impossible to meaningfully electrify—including heavy manufacturing and air travel. Meanwhile, the world needs gasoline, diesel, and jet fuel *now*; SMRs will take decades to deploy.

The opinion you hold about SMRs will have a lot to do with your general attitude toward technology. If you think humanity's fate and future rest with high tech (including AI and advanced rockets to enable colonization of other planets), then you're almost guaranteed to believe that SMRs will help us get there. But if you think, as I do, that the global polycrisis is an inevitable outgrowth of industrialism and its consequences (resource depletion, pollution, and overpopulation), then you're likely to view SMRs as a pointless and dangerous waste of resources.

Once we see why industrial modernity is unsustainable, the most important question becomes: what is a viable exit strategy? On our way out the door of modernity and back toward simplicity, we need to minimize the creation of new problems and re-learn nature's elegant solutions. When our priorities are thus reoriented, nuclear power makes no sense.