The Nuclear Energy Dilemma: Climate Savior Or Existential Threat?

Leslie Alan Horvitz – Photo: http://lesliehorvitz.com

01-05-2024 *Nuclear power has promise and peril, posing many challenging questions for environmentalists.*

With the planet teetering on the brink of climate disaster and the goal of achieving net-zero carbon emissions by 2050 rapidly slipping away, the need for alternatives to pollutive fossil fuels has never been more evident. Should nuclear power be one of those alternatives?

There are many thorny questions. Is nuclear power too dangerous? Is it too expensive? Does it present too much of a security risk? Is the problem of finding a safe way of storing nuclear waste too insurmountable? Is it unfair to kick a clear and present danger down the field to future generations? Is it scalable soon enough to make a meaningful difference in the battle against climate change? Is it a distraction from investing in safer sources of renewable energy?

These are questions that scientists, lawmakers, and pundits have been tackling for years. The argument remains frustratingly unresolved.

The persistent lack of clarity has divided environmentalists. Some say nuclear power is vital to the climate solution because it is a low-carbon energy source. Like wind and solar, it does not directly produce carbon dioxide, the primary greenhouse gas fueling global warming.

Others argue that the dangers of nuclear energy—including meltdowns (a credible threat at Zaporizhzhia, a nuclear power plant in Ukraine—Europe's largest—following its capture by Russian forces in 2022) and the lack of safe disposal of nuclear waste—are simply too grave. Still, others say there is no longer any time left to bring nuclear energy to scale to combat the climate threat effectively.

"The debate over whether we need nuclear power is very polarized," says M.V. Ramana from the University of British Columbia, Vancouver, who specializes in nuclear energy risk.

The World Nuclear Association is one of the foremost proponents of nuclear energy, supporting the global nuclear industry. Based in London, the group argues that nuclear energy is an efficient, effective, and safe solution to the climate crisis. "Nuclear power plants produce no greenhouse gas emissions during operation, and over the course of its life-cycle, nuclear produces about the same amount of carbon dioxide-equivalent emissions per unit of electricity as wind, and one-third of the emissions per unit of electricity when compared with solar," the organization states on its website.

Still, while the statistics sound promising, nuclear may be too late to make a difference, argues Mehdi Leman of Greenpeace International. "Nuclear power is not the way to a green and peaceful zero carbon future," he writes. "According to scenarios from the World Nuclear Association and the OECD Nuclear Energy Agency (both nuclear lobby organizations), doubling the capacity of nuclear power worldwide in 2050 would only decrease greenhouse gas emissions by around 4 percent. But in order to do that, the world would need to bring 37 new large nuclear reactors to the grid every year from now [March 2022], year on year, until 2050."

Leman also notes that nuclear reactors "are easy targets for malevolent acts," from terrorism to acts of war, as Russia's military aggression in Ukraine has illustrated.

Rise of Nuclear Power

As of November 2023, there are 440 nuclear reactors in 32 countries plus Taiwan. The United States has the most reactors, with 93 in operation as of August 2023, accounting for more than 30 percent of the world's nuclear power generation. China is next in production with 13.5 percent, but its 55 reactors are less than France's 56. The latter accounts for 13.3 percent of the total global power generation.

Nuclear power supplies more than eight times as much energy as it did in the 1970s. "The first grid-connected nuclear power plant began operations in the Soviet Union in 1954, and nuclear power reached one exajoule of global supply 19 years later. … (One exajoule is equivalent to 277 terawatt-hours—close to the electricity Mexico consumed in 2019)," according to Electricityinfo.org.

As of November 2023, nuclear power provides the world with approximately 10 percent of its energy needs. Nuclear power plants have a lifespan of up to 80 years.

Nuclear Power: Low-Carbon Energy Source

According to the U.S. Energy Information Administration (EIA), total global energy consumption is expected to rise by nearly 50 percent by 2050; this will make reducing carbon emissions much harder, if not impossible, without nuclear power.

Advocates further say that replacing fossil fuel-based energy with 100 percent renewables would need several scarce elements—from lithium to land space—making it next to impossible to supply the world with its future energy needs—while curtailing climate change's worst effects. In addition, nuclear power is more reliable and consistent since it can provide a steady power supply for days—without wind, sun, or batteries.

"Shutting down nuclear power plants could be a big setback for climate goals," writes Casey Crownhart, a climate reporter at MIT Technology Review.

According to the Nuclear Energy Institute, a nuclear industry policy group, nuclear energy in the United States prevented more than 476 million metric tons of carbon emissions in 2021. The U.S. Department of Energy says that is the equivalent of taking more than 100 million automobiles off the road—and greater than all other clean energy sources combined.

“While Germany has made major progress on installing renewable energy like wind and solar, emissions from its electricity sector have been shockingly slow to fall,” Crownhart notes in an April 2023 article. “The country has pledged to reach net-zero emissions by 2045, but it missed its climate targets for both 2021 and 2022. To reach its 2030 targets, it may need to triple the pace of its emissions cuts.”

Public Opinion

Persuading the public to accept nuclear power is not easy—particularly with nuclear disasters like Three Mile Island in 1979, Chernobyl in 1986, and Fukushima in 2011 still resonating in the public consciousness. Nuclear power rates second only to coal in its unpopularity in the U.S.—with just 16 percent of Americans in favor of keeping existing nuclear plants and building new ones, according to Morning Consult PRO data from 2020.

The association of this energy source with nuclear weapons has led to people harboring a bias against nuclear power, argues Charles Oppenheimer, grandson of Robert Oppenheimer, who oversaw the military effort at Los Alamos, New Mexico, where the atom bomb was developed during World War II. “We must get over our cognitive and political bias: Nuclear energy is necessary and safe, and not the same as nuclear weapons,” he wrote in Time magazine.

However, a 2023 Gallup poll found that 55 percent of American adults say they “strongly” or “somewhat” favor using nuclear energy. This polling data—showing a rise of four percentage points in support of nuclear from 2022—may be tied to Russia’s invasion and occupation of parts of Ukraine, which started in February 2022 and sparked a global disruption in oil and gas supplies.

It makes sense that public opinion toward nuclear energy is tied to the price of gas at the pump. “Throughout the course of Gallup’s trend, Americans have generally been more amenable to the use of nuclear energy as one of the ways to provide electricity for the U.S. when oil prices have been high and less open to it when oil prices are low,” points out Megan Brenan, a research consultant at Gallup.

European nations are more open to nuclear power than the U.S.—but up to a point. In 2022, the European Parliament designated nuclear power as a source of green energy. In the European Union, nuclear power plants operating in 13

countries provide almost a quarter of global electricity, although electricity generation from EU nuclear plants fell by 20 percent between 2006 and 2011. (Germany decided to phase out nuclear energy in 2011.)

And while Germany shut down its three remaining nuclear reactors in April 2023, ending the nation's nuclear era, which lasted more than 60 years, it isn't the first European country to bring an end to nuclear energy: Denmark banned it in 1985, Italy closed all plants in 1990, and in 1999, the Austrian parliament unanimously passed a constitutional law on a "nuclear-free Austria."

Even climate activist Greta Thunberg (who opposes nuclear power and spoke against the European Parliament's "green energy" classification of nuclear) supports keeping nuclear power plants in Germany functional—if the alternative is coal.

But nuclear power still has a lot of ground to make up if it's to become a factor in serving the energy needs of a post-fossil fuel era. In 2021, 95 nuclear plants went online in the previous 20 years, but another 98 have shut down, according to Deutsche Welle (DW). Take China out of the equation, and there are 50 fewer reactors operational in the last two decades, states the 2021 DW article.

"[D]oubling the capacity of nuclear power worldwide in 2050 would only decrease greenhouse gas emissions by around 4 percent," writes Mehdi Leman. "But in order to do that, the world would need to bring 37 new large nuclear reactors to the grid every year from now, year on year, until 2050."

As of November 2023, there are only about 60 new reactors under construction, according to the World Nuclear Association. Doubling nuclear capacity (which would only lead to a minor decrease in carbon emissions) is unrealistic. In contrast, clean, renewable energy sources like solar and wind have grown rapidly.

Proponents of nuclear power are pushing back. In a notable attempt to influence public opinion in its favor, Oliver Stone released a documentary in 2022 called "Nuclear Now," in which the director asserts that opposition to nuclear power has become "glamorous, virtuous, and lucrative all at once."

Well-publicized accidents at nuclear power plants such as Chernobyl and Three Mile Island have only reinforced the idea that nuclear power is too risky to be considered a reliable source of energy.

As Robert P. Crease, a chair of the department of philosophy at Stony Brook University, wrote in a June 2023 edition of Physics World, "No Oliver Stone movie would be complete without a conspiracy theory," which in the case of "Nuclear Now," sees the oil and coal companies as the villains because of their disputable claim that even low levels of radioactive emissions are dangerous.

Stone maintains that because climate change is an existential threat caused by fossil fuels, and given the world's insatiable energy demands, nuclear power should be considered a safer and more essential alternative than its detractors assert.

"Stone's movie forces us to think," Crease argues, because humans can no longer sit back and "ponder and judge nuclear power from a smug and superior distance." With his documentary, Crease adds that Stone has put "nuclear technology back on the table as a possible energy source."

Land Use

How much land an energy-producing installation takes up is often overlooked, but its importance can't be underestimated. Approximately 100,000 square miles of solar panels (an area greater than New England) or more than 800,000 square miles of onshore windmills (the size of Alaska plus California) would be required to meet the energy needs of the eastern United States, according to Armond Cohen of the Clean Air Task Force, writes Jonathan Rauch, a senior fellow at the Brookings Institution, in a February 2023 article in the Atlantic.

By contrast, Cohen says, addressing the same energy needs with nuclear power would take a little more than 500 square miles (roughly equivalent to the size of Phoenix, Arizona).

"Nuclear power is the most land-efficient source, needing 27 times less land per unit of energy than coal and 34 times less than solar [photovoltaic]," writes Hannah Ritchie, a researcher at Our World in Data. But she also points out that "land use of renewable energy sources like wind farms can be co-used with other activities like farming."

The Grid

One advantage of nuclear power, often overlooked by detractors, involves the grid—that is, connecting the power source to the electricity grid systems. Power plants, set up to provide electricity to consumers, can be converted to integrate

nuclear power easily.

This isn't the case with renewable energy sources like solar and wind, which would require the rewiring and transformation of the grid to supply electricity to consumers. This would entail an enormous investment and require zoning boards and regulators' approval.

Despite these advantages, nuclear plants have recorded no more than 10 new grid connections a year in the last decade, states Leman in his 2022 article; in some years, it's many fewer. Scaling that up to meet the demand for capacity in the U.S. is simply not possible, according to skeptics of nuclear power.

Jobs

According to the U.S. Office of Nuclear Energy, the nuclear industry employs nearly half a million workers. Skeptics say this figure is exaggerated and that once the number of 'secondary' jobs (like temporary construction jobs, which may constitute up to 7,000 per plant) is subtracted, the actual number is closer to 45,000. (Each plant employs approximately 500-800 workers.)

However, advocates argue that nuclear energy is a net job creator even though the number of unionized jobs in electricity, gas, water, steam, and nuclear energy only comes to 50,000. Approximately 20,000 unionized workers, or about one-third of the industry's 57,000 workers, are employed by the nuclear power industry.

"The nuclear energy industry employs more workers per megawatt of electricity than any other energy source," said Steven P. Nesbit, then-president of the American Nuclear Society, and Lonnie R. Stephenson, then-international president of the International Brotherhood of Electrical Workers, in an article they wrote for Nuclear Newswire in 2021. "Among all energy sources, nuclear power plants also have the highest labor union membership rates," they added.

By comparison, only "4 percent of solar industry workers and 6 percent of wind workers are unionized, according to the 2020 U.S. Energy and Employment Report," states the Vox. The fastest-growing sector in renewable energy, however, is the solar industry, which provided about 4.3 million jobs in 2021, according to the International Labor Organization. That figure represents more than a third of the worldwide renewable energy workforce.

Deaths

Estimates of deaths attributed to fossil fuels are impossible to pinpoint. However, some researchers believe that about one in five deaths globally were attributed to fossil fuels through air pollution alone in 2018—about 8.7 million fatalities per year, according to a 2021 study conducted by Harvard University in collaboration with the University of Birmingham, the University of Leicester, and University College London.

That estimate doesn't take into account other fossil fuel-related deaths, such as mining accidents, congenital disabilities, early onset dementia, illness, and displacement.

A study published by the Harvard T.H. Chan School of Public Health in 2022 found that people living near an oil or gas operation have a higher chance of dying prematurely. By contrast—despite some major disasters at nuclear plants like Chernobyl—substituting nuclear plants for fossil fuel plants might save millions of lives that would otherwise be lost.

Carbon Emissions

Nuclear power is indeed a low-carbon source of energy. Even so, nuclear power plants emit carbon-14, a radioactive isotope. Moreover, the processes used in all stages of the nuclear power cycle release carbon emissions: "uranium mining and milling, conversion of ore to uranium hexafluoride, enrichment, fuel fabrication, reactor construction and decommissioning, fuel reprocessing, waste management, rehabilitation of mining sites, and transport," all of which require the use of fossil fuels, states an article in the OpenMind.

According to the Intergovernmental Panel on Climate Change (IPCC), the emissions from these processes are close to the emissions produced in constructing facilities for renewables like solar and wind power—an average figure of 65 grams of CO_2 per kilowatt-hour. (Gas and coal, by comparison, produce 450 and 900 grams, respectively, to generate the same amount of energy.)

However, few studies have been conducted on the carbon emissions produced in the entire lifecycle of a nuclear power plant, from uranium extraction to nuclear waste storage. According to one measurement carried out by the state-run German Environment Agency (UBA), as well as figures provided by the

Netherlands-based World Information Service on Energy, nuclear power releases 3.5 times more CO2 per kilowatt-hour than photovoltaic solar panel systems, 13 times more than onshore wind power, and 29 times more than electricity produced by hydropower installations.

It's estimated that each nuclear-generating station discharges about two-thirds of the energy it burns in its reactor core into the environment while only a third is used for energy (and 10 percent of that is lost in transmission)."To produce the 25 [metric tons] or so of uranium fuel needed to keep your average reactor going for a year entails the extraction of half a million [metric tons] of waste rock and over 100,000 [metric tons] of mill tailings," wrote David Thorpe in the Guardian in 2008, then-news editor for the Energy, Resource, Sustainable, and Environmental Management magazine of the UK's Department for Environment Food and Rural Affairs. "These are toxic for hundreds of thousands of years."

Water Usage

The profligate use of water (used as a coolant in nuclear plants) is another concern for skeptics of nuclear power. For example, large reactors like the two at Diablo Canyon, California, individually dump about 1.25 billion gallons of water into the ocean daily. (These are the last reactors still operating in California.)

A statement by the Union of Concerned Scientists warned: "The temperature increase in the bodies of water can have serious adverse effects on aquatic life. Warm water holds less oxygen than cold water, thus, discharge from once-through cooling systems can create a 'temperature squeeze' that elevates the metabolic rate for fish."

Alternatively, many nuclear reactors rely on cooling towers to recycle water, although these, too, can cause an adverse environmental impact by emitting vast quantities of steam and water vapor, warming the atmosphere.

Nuclear Waste

Nuclear waste storage poses even more of a problem than water disposal. According to the EIA, radioactive wastes such as uranium mill tailings, spent (i.e., used) reactor fuel, and other radioactive wastes can remain radioactive and dangerous for millennia.

The environmental group Greenpeace contends that several nuclear storage facilities are on "the verge of saturation," presenting the threat that spent fuel is

at risk of overheating even in plants with no emergency generators available for cooling. The group opposes burying nuclear waste deep underground, too.

As of 2019, "no country has a final disposal site for high-level nuclear waste in operation yet," notes the World Nuclear Waste Report 2019. "Most countries have yet to develop and implement a functioning waste management strategy for all kinds of nuclear waste."

The report goes on to point out that even defining what nuclear waste is can be a problem since countries don't use identical classification systems (with France and the Czech Republic measuring the level of radioactivity, for instance, and the U.S. basing its classification on the origin of the waste and not its radiation).

On the other hand, in a 2022 report, the International Atomic Energy Agency (IAEA) claims that "there is significant progress in the safe and effective management of radioactive waste… including the development of deep geological repositories."

The report states that "95 percent of all existing waste is of low or very low radioactivity, that only 1 percent is high level, and that 80 percent of all solid waste is in safe and sustainable final storage, reports the OpenMind article.

Nuclear fuel comprises metal tubes containing small tubes of uranium oxide, which are then gathered into bundles. These bundles cool off for five to ten years before being placed in concrete or steel storage containers designed to last 100 years and withstand hurricanes, floods, and even missile attacks.

As of April 2023, no deaths or injuries have been reported due to nuclear waste products. After 40 years, the heat and radioactivity of the stored waste will have fallen by more than 99 percent.

In short, say nuclear power advocates, nuclear waste poses less risk than other hazardous industrial materials like ammonia, which have caused injuries and fatalities.

Constructing storage facilities for nuclear waste is well-advanced in Canada, France, Sweden, and Switzerland. Finland has taken the lead in burying nuclear waste deep underground in Onkalo, in a stainless steel room surrounded by concrete walls that are more than a meter thick. The site was chosen in 2000, but

the facility isn't expected to receive a government license to operate until 2024.

All of the spent fuel the U.S. nuclear industry has ever created could be buried under a single football field to a depth of fewer than 10 yards, states the Atlantic, citing a study by the Department of Energy. Unlike coal waste, which is spewed into the air, radioactive waste is stored in carefully monitored casks.

However, getting these storage facilities established has run into significant obstacles. In 1987, Congress authorized a national nuclear waste repository at Yucca Mountain in Nevada, designating it as the only location in the U.S. that could be used for permanent nuclear waste storage. But the repository has never opened because of political reasons, and the radioactive waste intended for it remains at reactor sites scattered around the country.

The problem of finding a secure place to store waste products from nuclear facilities is worldwide. Greenpeace estimates that almost a quarter of a million tons of highly radioactive spent fuel, mostly uranium-238 (the material that forms part of the chain reaction is uranium-235), has accumulated in 14 countries. In addition, there are also discarded materials (tailings) from uranium mining and production, totaling almost 2.4 billion tons.

As of 2019, about 263,000 tons of spent fuel was stored in interim storage facilities worldwide, according to the IAEA. That is a significant amount of radioactive waste waiting for governments to decide where it should be stored permanently.

In 2023, Japan had been scheduled to release up to 1.37 million tons of radioactive waste from the Fukushima Daiichi plant into the sea. In November 2023, the third batch of 7,800 tons of water was safely discharged. The process is expected to last decades.

"Officials say the impact of the water on humans, the environment, and marine life will be minimal and will be monitored before, during, and after the releases, which will continue through the 30-40 year decommissioning process. Simulations show no increase in radioactivity beyond three kilometers (1.8 miles) from the coast," reported Mari Yamaguchi of the Associated Press, whose reporters, in February 2023, visited the failed plant to get an update on the planned release.

When Japan announced the plan in 2011, it was criticized by environmentalists.

“Dumping this nuclear waste directly into the Pacific is dangerous and unacceptable,” said Damon Moglen, then-director of the Climate and Energy Project at Friends of the Earth. “It’s incredible that while an international treaty forbids the dumping of even a barrel of this nuclear waste from a ship, Japan intends to send thousands of tons of that waste into the ocean. This dumping poses a direct threat to humans and the environment, and fisheries and industries depending on a clean Pacific could be devastated.”

Despite approval for the discharge from the UN, noting that all radioactive elements had been removed from the wastewater except for tritium, which is not considered dangerous to health, China announced that it would cease the purchase of any seafood from Japan. However, in August 2023, Japan went ahead with its plan, maintaining that the Fukushima plant no longer can store radioactive wastewater.

Nuclear Disasters

Chernobyl and Fukushima loom large in the minds of people who oppose nuclear plants as a potential solution to climate change. To date, the partial meltdown of Three Mile Island in Pennsylvania in 1979 remains the worst nuclear accident in the U.S., even though it resulted in no injuries or deaths.

Despite the implementation of new training and protocols in Three Mile Island and the unblemished record of the plant’s second, intact reactor, which operated “uneventfully” until 2019, the accident turned the public and environmentalists against nuclear energy.

The meltdown and fire at Chernobyl in Ukraine in 1986 did cause mass fatalities from radioactivity. While 31 people (although some observers put the number at 50) died as a result of the accident, the official casualty rate doesn’t include any of the hundreds of thousands of so-called ‘liquidators’ dispatched to extinguish the fire in the plant without adequate protection, many of whom suffered from radioactive poisoning.

Most experts, though, believe that the Soviet-era plant was in questionable condition and poorly managed to begin with. Proponents of nuclear energy point out that once Chernobyl is excluded, no deaths have been caused due to a failure of a nuclear power plant, attributing the estimated 2,000 deaths in Fukushima in 2011, after that plant was destroyed in a tsunami, to the disarray of the

evacuation of the population from the area, disruptions in medical services, and stress-related factors such as alcoholism and depression.

Several other incidents of deaths at nuclear power plants have occurred, but most are linked to scalding, asphyxiation, and accidental falls, not to radioactive release.

Nonetheless, the disaster at Fukushima propelled Japan into taking almost all of its nuclear plants offline. In August 2022, however, Prime Minister Fumio Kishida announced that "Japan will restart more idled nuclear plants and look at developing next-generation reactors." It also prompted Germany to phase out nuclear power entirely within 10 years (a plan delayed until April 2023 because of the need to compensate for lost fossil fuel imports from Russia after the Ukrainian invasion).

Globally, a capacity of 48 gigawatts was lost after Fukushima because nuclear plants were either shut down or their operational lifetimes weren't extended.

Hazards and Risks
Meltdowns may be rare, but the very existence of nuclear plants poses serious risks.

Because many nuclear plants are built near coasts, climate change makes them vulnerable to rising seas. A rise of about 6 feet (a possibility by the end of the century) could threaten to submerge more than half the interim waste storage sites in the U.S.

In some cases, earthquakes could jeopardize the integrity of the plants. The Diablo reactors in California are located only 3 miles from a fault line, which wasn't detected when they were built.

As storage containers age, toxic leaks pose another risk to the nearby populations' safety. By the end of 2022, the Hanford nuclear site—one of the most polluted places in the U.S.—held some 56 million gallons of nuclear waste as well as leaking storage tanks and contaminated soil.

"About one-third of the nearly 180 storage tanks, many of which long ago outlived their design lives, are known to be leaking, contaminating the subsurface and threatening the nearby Columbia River," according to a 2020 Chemical and

Engineering News report.

The growth of nuclear energy has also increased the likelihood of the proliferation of nuclear weapons. Countries that claim they're constructing nuclear plants exclusively for peaceful energy needs may still use imported uranium to create weapons-grade uranium and harvest plutonium from uranium fuel rods to manufacture nuclear weapons.

Iran, for instance, continues to maintain that its nuclear program is peaceful. Still, the U.S. and Israel strongly suspect that Teheran is secretly engaged in developing the capacity to produce nuclear missiles.

There is also the fear that a nuclear plant might present a tempting target for terrorist threats, cyberattacks, or acts of war. War is no longer a theoretical possibility, either. The nuclear facility at Zaporizhzhia has come under fire from both Ukrainian and Russian forces.

The plant, still managed by Ukrainians but under Russian control (as of March 2022), while no longer producing energy (it's kept operational to prevent a meltdown), remains at heightened risk for a severe accident and meltdown because of shelling and bombing. As the Chernobyl disaster showed, the spread of radioactivity from a meltdown can reach countries well beyond the borders where a meltdown occurs.

Following major incidents and the rise of possible accidents, the hazards and risks of nuclear energy may become a more significant issue among the public, even in nations that have traditionally been very welcoming, like France.

"Even in France, there is strong public pressure following the Fukushima accidents to reduce the share of nuclear electricity, and this pressure was a contributor to the success of the Socialist Party, which promised reduced reliance on nuclear power, in the 2012 elections," writes M.V. Ramana in his 2012 book, *The Power of Promise: Examining Nuclear Energy in India*. "[C]hanging one part [of a reactor] could result in unforeseen impacts on another, especially during unusual operating conditions or accidents… [E]ven familiar systems might fail unless both design and operations are carried out with adequate diligence."

Time and Expense

One of the principal objections to nuclear power as a solution to climate change is

the time it typically takes to build a nuclear plant and the expense involved. Building and bringing each plant online generally takes 15 to 20 years at an estimated cost of $30 billion.

The energy each plant is expected to produce will cost between $112 and $189 per megawatt-hour (MWh), in contrast to $29 to $56 per MWh for wind and $36 to $44 per MWh for solar.

"Most U.S. nuclear power plants cost more to run than they earn," points out physicist Amory B. Lovins. For example, two commercial reactors that began construction in 2009 in Georgia in the U.S. were projected to cost $14 billion each.

As of March 2023, the cost for each had ballooned to more than twice the initial estimates. Unit 3 of Plant Vogtle began commercial operation in the summer of 2023 and can power 500,000 houses and businesses. Unit 4 is scheduled to begin commercial operation by March 2024.

"The reactors that have been built in Europe and North America since 2000, none has taken less than 10 years [to build]," says Stephen Thomas, energy policy expert and emeritus professor at the University of Greenwich. He notes that the cost per kilowatt is currently about $10,000 per kilowatt of capacity, according to an August 2023 article in the Daily Upside.

On the other side of the Atlantic, France started a new reactor in 2007 to be constructed in Flamanville with plans to bring it online in five years, but by 2022, it still wasn't operating, and it was five times over budget in 2020.

Over the past decade, the World Nuclear Industry Status Report 2019 estimates that compared to solar (costs of which have dropped by 88 percent) and wind (costs of which have dropped by 69 percent), the total lifetime cost of building and running a nuclear plant for the entirety of its functional life has *increased* by 23 percent.

Even advocates of nuclear power acknowledge the problem. "Nuclear, as it exists today, is clean, it's reliable, it's safe. But it's not affordable," saysMike Laufer, the co-founder and the CEO of Kairos Power, an energy engineering company. "[A]nd this is what's holding nuclear back from a much bigger role in fighting climate change."

But it may have a more minor role to play than some might argue because we are too far down the emissions path for it to make a difference at this point. "The contribution of nuclear energy is viewed too optimistically," said Ben Wealer, co-author of a 2021 paper on nuclear energy and the climate presented at the COP26 climate summit in Glasgow the same year. "In reality, [power plant] construction times are too long and the costs too high to have a noticeable effect on climate change. It takes too long for nuclear energy to become available."

"If you wanted to power the entire world on nuclear, you'd need about 17,000 large nuclear power plants, each 850 megawatts. And we only have 400 today," said Mark Z. Jacobson, author of a 2017 study published in the journal Cell that outlines a roadmap for 139 countries to power all sectors on 100 percent renewable energy.

"It's cleaner to go wind and solar," said Jacobson, who runs the atmosphere and energy program at Stanford University, to NPR in 2013. "You can put it up faster. There's a larger abundance of it. There's the potential to power the world many times over. And the costs are coming down—whereas nuclear costs are going up."

Looking Ahead

Although nuclear power has run into significant roadblocks, and some countries have announced plans to do without it altogether, there are indications that the energy source is making a comeback.

"As of November 2022, around 140 countries had announced, or were considering, net-zero targets, representing close to 90 percent of global emissions, and many of these countries, including China and India, have announced energy strategies that include a substantial role for nuclear," writes Esin Serin from the London School of Economics and Political Science.

Some advocates believe that innovative designs for reactors will make nuclear energy more popular and less expensive. In 2018, Congress passed several bills intended to innovate the development and implementation of 'advanced' nuclear reactors to overhaul the nuclear business and shift the nuclear paradigm. This goal can be achieved, they believe, by the introduction of the modular reactor. These small modular reactors (SMRs) can be assembled relatively quickly in a factory and transported to the site of operation.

But making these reactors so small and mobile carries a price. They are designed

only to have an output of up to 300 megawatts, a third of the output of current reactors. In theory, it should take only 1.5 to 2.5 years to build an SMR. The reality is quite different.

Many of these companies are also modifying how reactors are cooled. One type relies on convection and gravity, not pumps, so the reactor will stay cool if electricity fails. Others use a fluoride salt-cooled high-temperature reactor because salt-cooled water is considered safer than pure water alone. (Other options are a gas-cooled fast reactor, a supercritical water-cooled reactor, and a lead-cooled fast reactor.)

Admittedly, the companies promoting new designs have "a tendency to overpromise and underdeliver," as John Hopkins, president of a nuclear energy company called NuScale, acknowledged. (NuScale was the first to receive federal approval for its modular design.) "I want to get one module in the ground and prove we're commercially viable and we're going to do it on schedule."

The new models have plenty of skeptics, including Stephen Thomas, who believes their promotion is nothing less than gross arrogance given the failure of larger plants to achieve significant savings, much less lead to a revolution in nuclear energy.

"The claims being made for SMRs will be familiar to long-time observers of the nuclear industry: costs will be dramatically reduced; construction times will be shortened; safety will be improved; there are no significant technical issues to solve; nuclear is an essential element to our energy mix. In the past such claims have proved hopelessly over-optimistic and there is no reason to believe things would turn out differently this time. Indeed, the nuclear industry may well see itself in the 'last-chance saloon.' The risk is not so much that large numbers of SMRs will be built, they won't be. The risk is that, as in all the previous failed nuclear revivals, the fruitless pursuit of SMRs will divert resources away from options that are cheaper, at least as effective, much less risky, and better able to contribute to energy security and environmental goals," Thomas says.

In July 2023, the first new nuclear reactor in more than 40 years in the U.S. was ready to go into full operation at Plant Vogtle in Georgia. A second reactor is scheduled to go online at the same location by March 2024. Each reactor can generate enough electricity to power half a million homes with an estimated cut

of 5 to 10 percent of the state's total carbon emissions once both units are fully functional. But even though they are both small modular reactors, which were promoted for their cost-savings, the price tag has risen to $30 billion for the first reactor, more than double its original estimate.

Efforts to deploy SMRs are by no means confined to the U.S. In the global market, Russia is the leading supplier of nuclear reactors. In 2022, Hungary announced the granting of a construction license for two new, Russian-built nuclear reactors. (European Union sanctions on Russia do not include nuclear energy.) In 2023, Turkey inaugurated its first nuclear plant, also built by Russia. China also plans to get into the game by operating its own salt-cooled commercial reactor around 2030.

Not surprisingly, critics of nuclear power aren't impressed, insisting that even these 'next generation' reactors have suffered delays and cost overruns in France, the UK, Finland, and China. In 2022, Greenpeace said that new nuclear power technologies have been promised as "the next big thing for the last 40 years, but in spite of massive public subsidies, that prospect has never panned out."

Greenpeace's prediction seems to have been borne out. A plan to build a novel nuclear power plant comprising six small modular reactors collapsed in November 2023 when prospective customers for its electricity backed out. The reactors were to be built by NuScale Power, but the estimated cost had risen to more than $9.3 billion—twice what it was initially projected. Utah Associated Municipal Power Systems (UAMPS), a coalition of community-owned power systems in seven Western states, withdrew from the deal, asserting that there weren't enough power systems ready to buy into it.

The plan for the first small-scale U.S. nuclear reactor was initially seen as a way to revive the moribund nuclear power industry when it was announced in 2015. The deal's demise was also a blow to nuclear power advocates who championed the smaller, modular designs. NuScale, a leading manufacturer of SMRs, conceded that the first plant it had proposed as part of the coalition plan known as the Carbon Free Power Project, based in Idaho Falls, hadn't attracted the customers it needed to buy its power. Construction on the plant was supposed to begin in 2026.

"We still see a future for new nuclear," said Mason Baker, CEO and general

manager of UAMPS, which planned to build the plant in Idaho. “But in the near term, we’re going to focus on… expanding our wind capacity, doing more utility-scale solar, [and] batteries.” On a quarterly call with investors, NuScale CEO John Hopkins claimed the project was a “tremendous success” despite the plan’s failure. NuScale is still planning to build reactors in Romania and power data centers in Pennsylvania and Ohio, which a cryptocurrency mining company runs. The company says these plants will be operational “by the mid-2030s.”

In his 2018 book *Fallout: Disasters, Lies, and the Legacy of the Nuclear Age*, longtime environmental reporter Fred Pearce argues that the public’s fear of nuclear threat is real:
“[S]ocieties have a perfect right to turn their back on nuclear technologies if the experts fail to win their trust… if after more than half a century, nuclear protagonists have failed to still that fear, then probably they never will. Maybe we have to concede that this is a dying industry. The atomic age looks like it is over. The future for nuclear energy may be simply for us to see out the lives of existing plants and deal with their environmental legacies as best we can. Oh, and to get rid of nuclear weapons.”

When it comes to nuclear energy, there is both substantial promise and significant peril. As world governments consider the makeup of their current and future energy portfolios—in the face of the climate crisis, jobs and the economy, and the various security risks—one thing is abundantly clear: The decisions on the nuclear energy question made now will impact the planet for generations to come.

By Leslie Alan Horvitz

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