Seven Reasons Why New Nuclear Energy is an Opportunity Cost That Damages Efforts to Address Climate Change and Air Pollution

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A small group of scientists has proposed replacing 100% of the world's fossil fuel power plants with nuclear reactors as a way to solve climate change (*1*). Many others propose that nuclear should satisfy up to 20 percent of all our energy (not just electricity) needs. They advocate that nuclear is a "clean" carbon- free electricity source, but they don't look at the full scope of impacts of nuclear. Let's look at the facts.

All nuclear reactors in history have taken 10 to 22 years from the planning phase to operation (*2*). Recently, the range has increased to 17 to 22 years in North America and Europe (*2*). According to the World Health Organization, about 7.4 million people die from outdoor plus indoor air pollution each year, with more than 90 percent of these deaths from energy-related combustion (3). So, switching the world's energy to nuclear would result in at least 113 million people dying as we wait at least 17 years for all the new nuclear reactors to be built in an all-nuclear scenario.

On top of that, as we wait until 2041 (17 years) for even a single new reactor to operate, global temperatures will accelerate beyond 1.5°C above the 1850-1900 average. The 1.5°C threshold is considered dangerous for the planet by the Intergovernmental Panel on Climate Change (*4*). Based on the remaining carbon budget, 80% of the chemicals that cause warming must be eliminated by 2030 and 100% by 2035-2050 to avoid 1.5°C (*5*). As such, new nuclear is not useful at all for solving the climate and air pollution problems we face.

Utility-scale wind and solar farms, on the other hand, take an average of only one to five years from planning to operation. Rooftop solar PV projects are down to only a six-month timeline. So, transitioning to 100% clean, renewable energy for all purposes as soon as possible would result in tens of millions fewer deaths than a nuclear scenario, and may also avoid 1.5°C warming.

This illustrates a major problem with nuclear energy and why renewable energy -- in particular Wind, Water, and Solar (WWS)-- avoids this problem. Nuclear, though, doesn't have just one problem. It has seven. Here are the seven major problems with nuclear energy:

1. Long Time Lag Between Planning and Operation

The time lag between planning and operation of a nuclear reactor includes the times to identify a site, obtain a site permit, purchase or lease the land, obtain a construction permit, obtain financing and insurance for construction, install transmission, negotiate a power purchase agreement, obtain permits, build the reactor, connect it to transmission, and obtain a final operating license.

The planning-to-operation (PTO) times of all nuclear reactors ever built have been 10-22 years. For example, the Olkiluoto 3 reactor in Finland was proposed to the Finnish cabinet in December 2000 to be added to an existing nuclear reactor. It began generating electricity in 2022, giving it a PTO time of 22 years.

The Hinkley Point C nuclear reactor was planned in 2008. It has an estimated completion year of 2028, giving it a PTO time of 20 years.

The Vogtle 3 and 4 reactors in the U.S. state of Georgia were first proposed in August 2006 to be added to an existing site. Vogtle 3 was connected to the grid in 2023 and Vogtle 4 is expected to be connected in 2024, giving them PTO times of 17 and 18 years, respectively.

The Flamanville, France, Unit 3 reactor was planned in 2004. The reactor is expected to be completed in 2024, for a PTO time of 20 years.

The Haiyang 1 and 2 reactors in China were planned to start in 2005. Haiyang 1 began commercial operation on October 22, 2018. Haiyang 2 began operation on January 9, 2019, giving them PTO times of 13 and 14 years, respectively.

The Taishan 1 and 2 reactors in China were bid in 2006. They began commercial operation in 2018 and 2019, respectively, giving them PTO times of 12 and 13 years, respectively.

Planning and procurement for four reactors in Ringhals, Sweden started in 1965. One took 10 years, the second took 11 years, the third took 16 years, and the fourth took 18 years to complete.

Many claim that France’s 1974 Messmer plan resulted in the building of its 58 reactors in 15 years. This is not true. The planning for several of these nuclear reactors began long before. For example, the Fessenheim reactor obtained its construction permit in 1967 and was planned starting years before. In addition, 10 of the reactors were completed between 1991-2000. As such, the whole planning-to-operation time for these reactors was at least 32 years, not 15. That of any individual reactor was 10 to 19 years.

There is no evidence that small modular reactors (SMRs) will reduce PTO times compared with large reactors. Indeed, no commercialized SMR exists worldwide. In the United States, the only company building an SMR with its design approved by the Nuclear Regulatory Commission lost its main purchaser, lost 84% of the value of its stock from its peak, was sued by its shareholders for securities fraud, and laid off 28% of its full-time staff, all near the end of 2023. Their test reactor, if it will be built at all, is not anticipated to be available until after 2030, far too late for it to be an effective solution to air pollution or global warming.

2. Cost

The levelized cost of energy (LCOE) for a new U.S. nuclear reactor in 2023, based on Lazard (*6*) is $181 (1141 to 221)/MWh. This compares with $49.5 (24 to 75)/MWh for onshore wind and $60 (24 to 96)/MWh for utility-scale solar PV from the same source.

This nuclear LCOE range is an underestimate for several reasons. First, Lazard assumes a construction time for nuclear of 5.75 years. However, the Vogtle 3 and 4 reactors, the only ones built in the U.S. in the past 20 years, took 9 and 10 years, respectively for construction. Lazard also assumed a mean capital cost of $11.2/W. However, the Vogtle reactors cost $15.7/W ($35 billion for 2.23 GW). These changes alone suggest an LCOE of nuclear that is 3 to 14 times that of onshore wind.

Next, the LCOE does not include the cost of the major nuclear meltdowns in history. For example, the estimated cost to clean up the damage from three Fukushima Dai-ichi nuclear reactor core meltdowns, was $460 to $640 billion (*7*). This is $1.2 billion, or 10 to 18.5 percent of the capital cost, of every nuclear reactor worldwide.

In addition, the LCOE does not include the cost of storing nuclear waste for hundreds of thousands of years. In the U.S. alone, about $500 million is spent yearly to safeguard nuclear waste from about 92 civilian nuclear reactors. This amount will only increase as more waste accumulates. After the nuclear reactors retire, the spending must continue for hundreds of thousands of years with no revenue stream from electricity sales to pay for the storage.

There is no reason to think SMRs will be less expensive than large reactors. Indeed, SMRs were developed before large reactors, but large reactors took over because they were less expensive due to economies of scale. Small reactors generally require more material per unit energy produced than large reactors.

3. Weapons Proliferation Risk

The growth of nuclear reactors for electricity generation and research has historically increased the ability of nations to obtain or harvest plutonium or enrich uranium to be used in nuclear weapons. The Intergovernmental Panel on Climate Change (IPCC) recognizes this fact. They concluded in the Executive Summary of their 2014 report on energy (*9*), with "*robust evidence and high agreement*" that nuclear weapons proliferation concern is a barrier and risk to the increasing development of nuclear energy:

> "Barriers to and risks associated with an increasing use of nuclear energy include operational risks and the associated safety concerns, uranium mining risks, financial and regulatory risks, unresolved waste management issues, ***nuclear weapons proliferation concerns***, and adverse public opinion."

The building of a nuclear reactor for energy in a country that does not currently have a reactor allows the country to import uranium for nuclear energy production. If the country so chooses, it can also secretly enrich the uranium to create weapons-grade uranium and harvest plutonium from uranium fuel rods for use in nuclear weapons. This does not mean any or every country will do this, but historically some have and the risk is high, as noted by IPCC. The link between nuclear energy and weapons is clarified further as follows (*10*):

> "Peaceful nuclear cooperation and nuclear weapons are related in two key respects. First, all technology and materials related to a nuclear weapons program have legitimate civilian applications. For example, uranium enrichment and plutonium reprocessing facilities are dual-use in nature because they can be used to produce fuel for power reactors or fissile material for nuclear weapons. Second, civilian nuclear cooperation builds-up a knowledge-base in nuclear matters."

Several countries, including Pakistan, India, Iraq (prior to 1981), Syria (prior to 2007), Iran, and North Korea, among others, have developed or attempted to develop weapons secretly under the guise of peaceful civilian nuclear energy or nuclear energy research programs. Today, 32 countries have nuclear energy facilities. Building and spreading SMRs into countries without nuclear energy will likely only increase this risk further because SMRs are modular.

4. Meltdown Risk

To date, about 1.5 percent of all nuclear power reactors ever built have melted down to some degree. Meltdowns have been either catastrophic (Chernobyl, Russia in 1986; three reactors at Fukushima Dai-ichi, Japan in 2011) or damaging (Three-Mile Island, Pennsylvania in 1979; Saint-Laurent France in 1980). Nuclear energy developers, including developers of SMRs, have proposed new reactor designs that they suggest are safer. However, these designs are generally untested, and there is no guarantee that the reactors will be designed, built, and operated correctly or that a natural disaster or act of terrorism, such as an airplane flown into a reactor, will not cause the reactor to fail, resulting in a major disaster.

5. Mining Lung Cancer Risk

Underground uranium mining (which comprises over one-third of all uranium mining) causes cancer in many miners because uranium mines contain radon gas, which is a radioactive decay product of uranium. Some of radon's decay products, such as polonium, are carcinogenic. The risk of radon-related cancers (including lung cancer, leukemia, and extra-thoracic cancer) from underground uranium mining is high (*11*). The reason is that

> "Radon gas is soluble in water, so inhaled radon progeny enters the bloodstream close to the airway and can cause leukemias through irradiation of T lymphocytes. Radon gas is also soluble in fat, so radon progeny reaches organs through proximity to adipose tissue. Dosimetric models show that the liver, kidney, stomach and red bone marrow receive doses of radon progeny,…" (*11*)

Clean, renewable energy does not have this risk because (a) it does not require the continuous mining for fuel of any material, only one-time mining to manufacture the energy generators; and (b) the mining usually does not occur in the presence of uranium, thus radon. Because SMRs require uranium just as large reactors do, cancer risk from underground uranium mining extends to SMRs as well.

6. Carbon-Equivalent Emissions and Air Pollution

There is no such thing as a zero- or close-to-zero emission nuclear reactor. Even existing reactors emit due to the continuous mining and refining of uranium needed for the reactor. Emissions from new nuclear are 78 to 178 g-CO_2/kWh (*12*), not close to 0. Of this, 64 to 102 g-CO_2/kWh over 100 years are emissions from the background grid while consumers wait 10 to 22 years for nuclear to come online or be refurbished, relative to 1 to 5 years for wind or solar. In addition, all nuclear reactors emit 4.4 g-CO_2e/kWh (where CO_2e means carbon-dioxide-equivalent emissions) from the water vapor and heat they release. This contrasts with solar panels and wind turbines, which reduce heat or water vapor fluxes to the air by about 2.2 g-CO2e/kWh for a net difference from this factor alone of 6.6 g-CO_2e/kWh (*12*). The rest of the emissions associated with nuclear are due to the CO_2e emitted during the construction and decommissioning of the reactor and due to producing the energy needed to mine and refine uranium.

Because of its long PTO time and its construction emissions, a nuclear reactor may take decades after it starts running to offset the emissions it allowed from the grid during its PTO phase and from its construction.

The delays also cause additional deaths. For example, China's investment in nuclear reactors that take so long between planning and operation, instead of wind or solar, resulted in China's CO_2 emissions increasing by 1.3 percent from 2016 to 2017 rather than declining by about 3 percent. The resulting difference in air pollution emissions may have caused 69,000 additional air pollution deaths in China in 2016 alone, with additional deaths in years prior and since.

SMRs face similar carbon-equivalent emissions and air pollution mortality problems as large reactors.

7. Waste Risk

Last but not least, consumed fuel rods from nuclear reactors are radioactive waste. Most fuel rods are stored at the same location as the reactor that consumed them. This has given rise to hundreds of radioactive waste sites in many countries that must be maintained and funded for at least 200,000 years, far beyond the lifetime of any nuclear reactor. The more nuclear waste that accumulates, the greater the risk of radioactive leaks, which can damage water supply, crops, animals, and humans. SMR designs do not eliminate waste. Some reduce it, but those that reduce it do so at the expense of developing more refined uranium that can be used to develop nuclear weapons.

Summary

To recap, new nuclear electricity costs about 3-14 times that of onshore wind per unit electricity generated. Nuclear also takes 7 to 21 years longer between planning and operation than wind, and produces, 9 to 37 times the emissions per unit electricity generated as wind. In addition, nuclear creates risk and cost associated with weapons proliferation, core meltdown, underground uranium mining lung cancer, radioactive waste, and carbon-equivalent emissions. Thus, nuclear has seven major problems. Clean, renewables avoid all such problems.

Nuclear advocates claim nuclear is still needed because wind and solar are intermittent and need natural gas for backup. However, nuclear itself never matches power demand so it needs backup. Even in France, which has the world's highest-penetrating nuclear energy programs, the maximum ramp rate is 1 to 5 % per minute, which means they need natural gas, hydropower, or batteries, which ramp up 5 to 100 times faster, to meet peaks in demand. Today, in fact, batteries are beating natural gas for wind and solar backup needs throughout much of the world. Dozens of independent scientific groups have further found that it is possible to match intermittent power demand with clean, renewable supply and storage, without nuclear or fossil fuels, at low cost (*5*, *13*).

Finally, many existing nuclear reactors are so costly that their owners are demanding subsidies to stay open. For example, in 2016, three existing upstate New York nuclear reactors requested and received subsidies to stay open using the argument that the reactors were needed to keep emissions low. However, subsidizing such reactors may increase carbon emissions and costs relative to replacing the reactors with wind or solar as soon as possible (*14*). Thus, subsidizing nuclear would result in higher emissions and costs over the long term than replacing nuclear with renewables.

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