Policy Topics 09-18-23

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2025 Apr, Jun, Nov; 2026 Apr

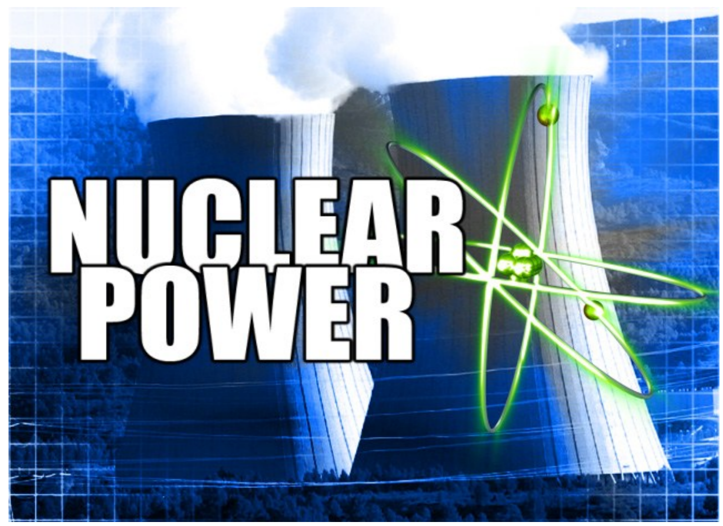
CliSciPol

Climate Science and Policy for Nonscientists

One picture is worth a thousand words.

Nuclear Power is the Best Hope for Reliable Energy Without CO2 Emissions

Nuclear energy can provide immense amounts of electricity. One pound of natural uranium emits as much power as 20,000 pounds of coal. Nuclear plants are incredibly reliable, operating at an average of 93% capacity in the US, as opposed to around 35% for wind farms and around 25% for solar farms. Nuclear plants emit virtually no CO_2 or any other pollutants and can operate for 60-80 years. So nuclear deserves serious consideration. Bill Gates has said, "We need more nuclear power to zero out emissions and to prevent a climate disaster."



Environmentalists point to a long list of disadvantages with nuclear. The three most significant ones over the years have been (1) safety, (2) radioactive waste disposal, and (3) cost.

The US now has a long history with nuclear power. In 1954 construction started on the first US nuclear power plant at Shippingport, Pa. The plant went on line in 1957, only three years later. It was a PWR plant, using a Pressurized Water Reactor (water cooled). This has been the design for about three-quarters of the over than 1,000 nuclear plants that have been built ever since around the world, but not for Chernobyl (graphite cooled).

Global starts on nuclear power plants increased dramatically in the 1960s and reached a peak in the mid-1970s. At the time nuclear power was cheaper than fossil power, particularly after the OPEC oil embargo of 1973. Environmental organizations tended to prefer nuclear power to coal, because of the reduced pollution, but oil companies started making large gifts to such organizations to oppose nuclear power. In 1974 the Sierra Club switched to opposing nuclear, because it led to "unnecessary economic growth."

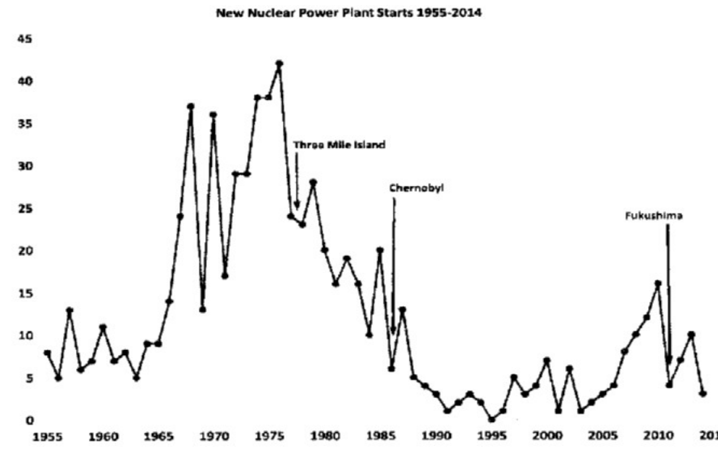
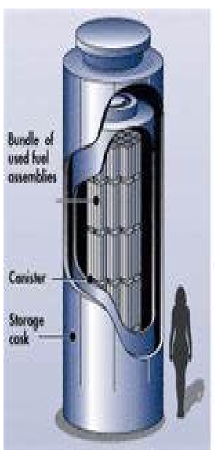
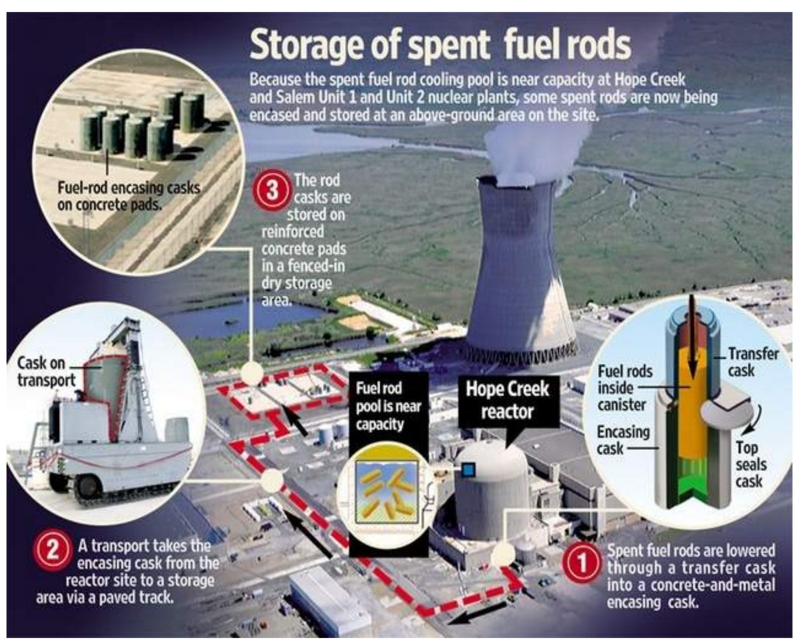


Figure 9.2 Global nuclear reactor construction starts, 1955 to 2014. Note that the industry collapse began *before* Three Mile Island, and despite the 1974 oil price rise that made it *more* competitive. (Adapted from IAEA data[9])



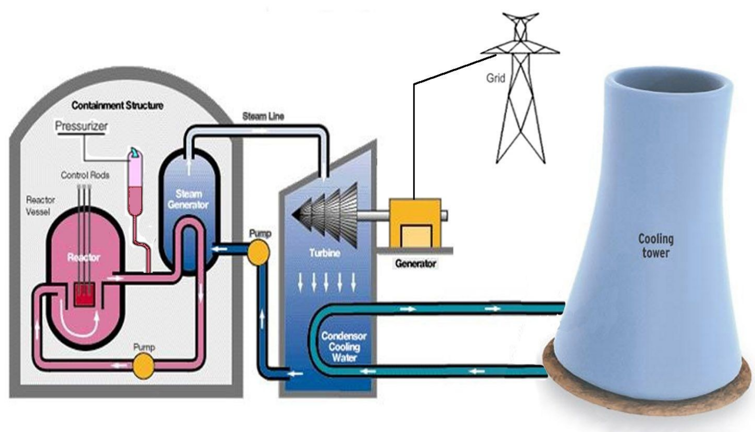
In the 1970s environmental opposition focused on the waste disposal issue. But the volume of such waste is remarkably small, because so little nuclear fuel actually exists at each plant. Coal plants generate 30 times more waste every day than the entire nuclear fleet has produced over the last 45 years. Presently nuclear waste is stored for a year or two in an on-site cooling pool, which allows radioactivity to decay to a low level. It is then encased in concrete casks, which are lined with stainless steel and then stored on-site on concrete pads. All the nuclear waste from all US plants since the 1950s could be safely stored on one football field with the casks piled 30 feet high. This storage should suffice for over 100 years. There is no immediate need for underground or other storage.

The procedure for on-site storage has been well worked out over the years. The US military and other government agencies have stored without incident their nuclear waste underground at the Waste Isolation Project Plant near Carlsbad, New Mexico. But the best solution to handling waste is to reprocess it. Waste is not waste if it is used. Advanced reactors can recycle a majority of fuel "waste." At present France gets over 70% of its power from nuclear, and 17% of that comes from reprocessed fuel. Reprocessing is not presently legal in the US, because of a Carter administration rule promulgated in 1977.

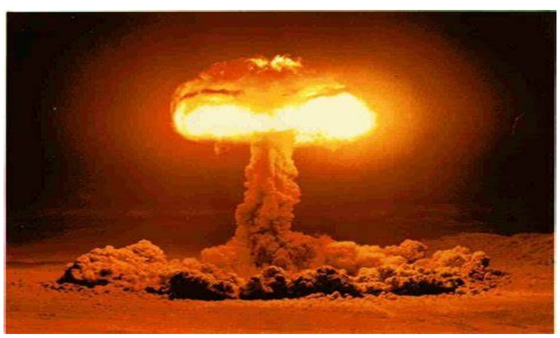


In 1979 Unit 2 at Three Mile Island had its meltdown. The movie, The China Syndrome, had opened 12 days before, suggesting that a meltdown could go clear through to the opposite side of the world. What actually happened at Unit 2 was that the turbine tripped, and the emergency cooling system was activated, but then operators erroneously turned off the cooling system, causing the meltdown.

In the US all the nuclear fuel is contained in a reactor vessel made of steel, typically about 8" thick. The reactor vessel is placed in a containment building made strong enough to protect against ramming by an airplane. The TMI meltdown only melted about 1" into the reactor vessel, so it came no where near even reaching the concrete reinforced floor of the containment building. Virtually no radiation was released. No one died.

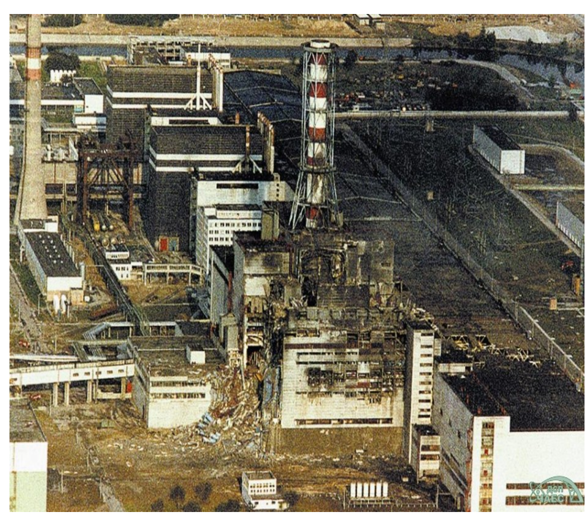


After TMI the NRC regulation of nuclear power was significantly strengthened and designs have been improved to prevent reoccurrence of similar accidents. Unit 1 at TMI was undamaged and has operated safely ever since it went back into operation after the meltdown. But the unfavorable publicity led to over 100 planned plants being cancelled, and the number of global starts declined markedly over the 1980s.



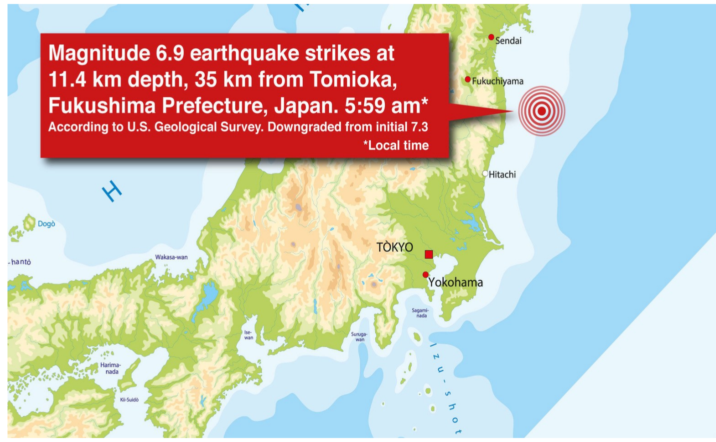
Environmentalists suggest that nuclear plants pose a danger of a nuclear explosion, but naturally occurring uranium is only 0.7% radioactive U-235. The uranium fuel in a power plant is enriched only to the point that it is 3-4% U-235. To cause a nuclear explosion the U-235 must be at least 80% pure, and preferably over 90%. It is impossible for the U-235 at a power plant to increase its concentration above 3-4%, and therefore it is impossible for a nuclear explosion to occur.

In 1986 the disaster at Chernobyl occurred, caused as with TMI Unit 2, by operator error. Obvious design defects also contributed significantly. The unit was not water cooled, as virtually all US units are, but was graphite cooled. Graphite is flammable and unstable in some circumstances. When the core melted, the graphite caught fire, leading to a conventional explosion equivalent to a medium-sized conventional bomb. The image shows the unit after the explosion and after the fire was extinguished. Since the unit had no containment, the explosion blew the roof off the building and caused a massive release of radiation. The Chernobyl design would never have been proposed, let alone licensed, in the US.



Some 40-50 firefighters at Chernobyl died from radiation poisoning. Initial estimates were that hundreds of thousands of people would die from the radiation released, but to date fewer than a hundred deaths have been attributed to the release. A major learning from the Chernobyl disaster is that radiation at low levels is a lot less harmful than was feared. At high levels, of course, radiation is deadly.

Six nuclear units were built at Fukushima and went online from 1971-1979. Fukushima was known to be exposed to earthquakes and tidal waves. In 2011 the largest earthquake in Japanese recorded history caused a tidal wave of 46 feet to hit the plant. The sea wall protecting the plant was only about 20 feet high. The wave knocked out the cooling system for 3 of the units. The neighboring Onagawa nuclear facility had a sufficiently high sea wall and suffered no damage.



The reactor vessel of one of the units was breached, and some of the contents leaked onto the floor of the containment building but was contained there. Some radiation was released within the plant site but not enough to cause any deaths. Virtually no radiation was released outside the plant site. The tidal wave killed between 18,000 and 28,000 people. The unnecessary evacuation that followed may have killed between 1,000 and 2,000. The radiation released killed zero.

Japan and other countries such Germany and Italy decided to close down all of their nuclear plants, which has caused CO2 emissions to increase in those countries. Japan has recently reconsidered and is planning to reopen 8 of its nuclear plants. Just this month (May 2023) the Italian Parliament has voted to reopen some of its closed nuclear plants.

Just how dangerous is nuclear radiation? The US Nuclear Regulatory Commission was established in 1974, and much of its regulatory apparatus was established during the Carter presidency, which was very anti-nuclear. At the time there was much uncertainty as to the danger of radiation, so the NRC adopted a "Linear No Threshold" (LNT) policy, which means that there is no such thing as a safe radiation exposure. So plants are required to this day to be designed so that the risk of radiation exposure is "As Low As Reasonably Achievable" (ALARA), an extraordinary difficult, vague, and changing standard

Our present scientific knowledge shows that the LNT/ALARA policy is unwarranted. The average American is exposed to about 6.2 millisieverts of radiation per year. A single CT scan exposes the patient to about 10 millisieverts of radiation. Many places around the world, such as the Colorado plateau, including Denver, have much larger background radiation activity because of the prevalence of radioactive materials in the earth's mantle. Those living in Denver have not been harmed by the higher radiation level, and it has been discovered that human cells are constantly repairing themselves from radiation damage so the damage from radiation exposure is not cumulative.

The NRC has strangled (Alex Epstein says "criminalized") nuclear construction in the US. The amount of electricity in the US produced by nuclear is declining. The leadership in nuclear construction has shifted from the US to China, Russia, and India. Worldwide there are presently 436 operating nuclear plants and 452 in various stages of planning and construction, most all outside the US.

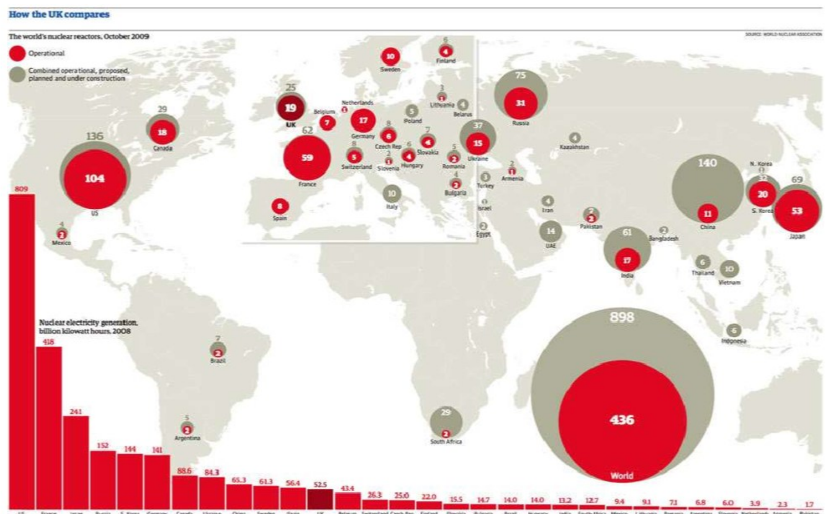
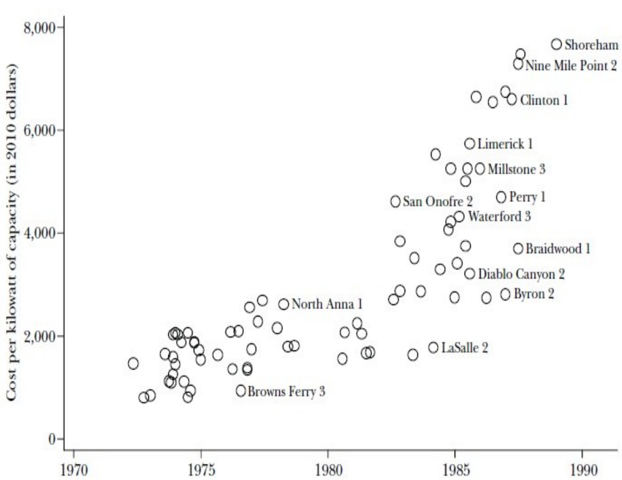


Figure 3

Construction Costs for U.S. Nuclear Reactors by Year of Completion

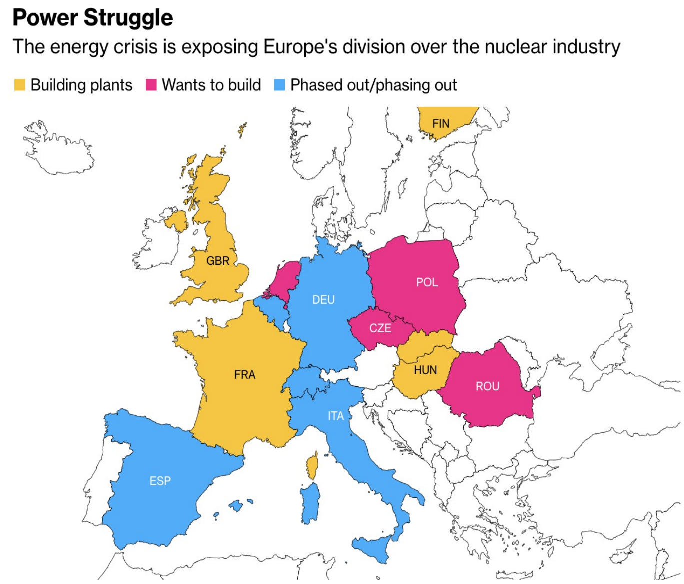


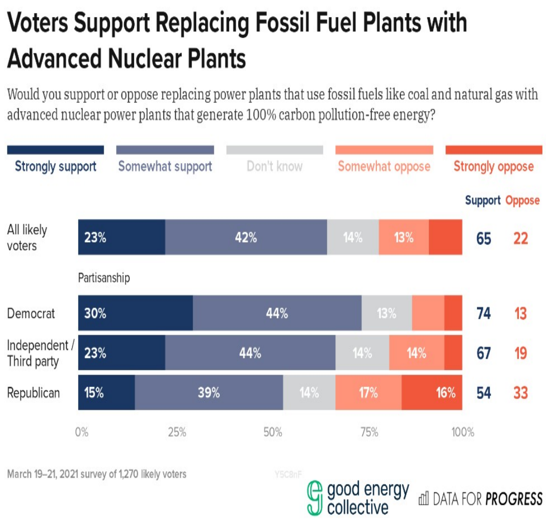
Source: U.S. DOE (1986), table 4.

Notes: Figure 3 plots "overnight" construction costs for selected U.S. nuclear power plants from the U.S. Department of Energy (1986). The figure includes *predicted* costs from the same source for a handful of reactors that were under construction but not yet in operation in 1986.

The cost of nuclear plant construction in the US has risen dramatically since the 1970s, mainly due to the length of time it takes to complete a project. In South Korea it now takes 4 years and in France 5 years. In those countries costs have been declining. In the US it currently is taking about 16 years (7 years to get the initial license and then 9 years to build the plant). It has been estimated that the cost of a plant varies with the square of the time it takes to complete. The length of time in the US is mostly due to the practices and procedures of the NRC, which have been described as "inefficient and antiquated" and a "maze of confusing red tape." Upon completion a plant still has to receive a license to operate. Due to the opposition of NY Governor Andrew Cuomo the Shoreham nuclear plant, completed in 1984, was denied its operating license and never went on line.

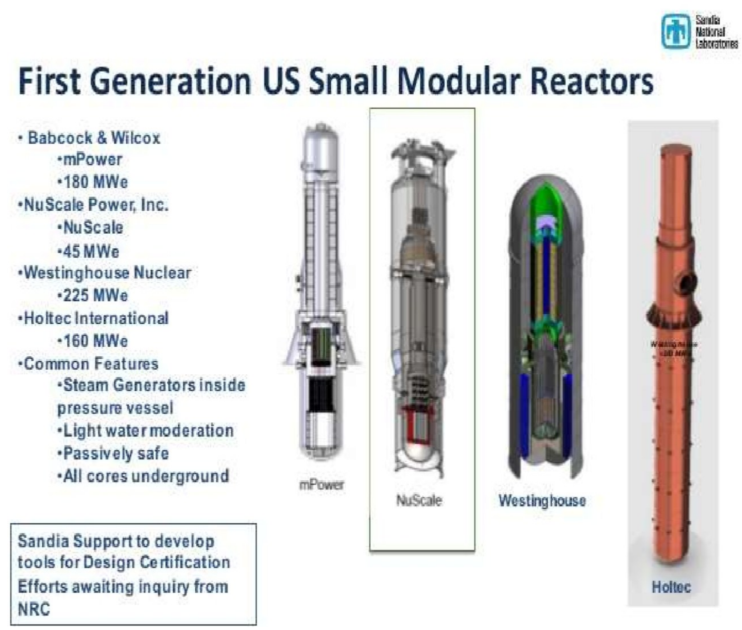
There is great disagreement about nuclear policy around the world. The image shows the splits in Europe. Attitudes towards nuclear power are becoming more favorable. As mentioned, Italy has just reversed its opposition. In the US the Democratic Party 2020 platform for the first time acknowledged nuclear power, saying that the party favored a "technology-neutral" approach to energy that includes advanced nuclear power. President Biden has appointed Kathrun Huff as head of the Office of Nuclear Energy in the Department of Energy. She views it as "imperative" that the US develop a new generation of nuclear power plants.

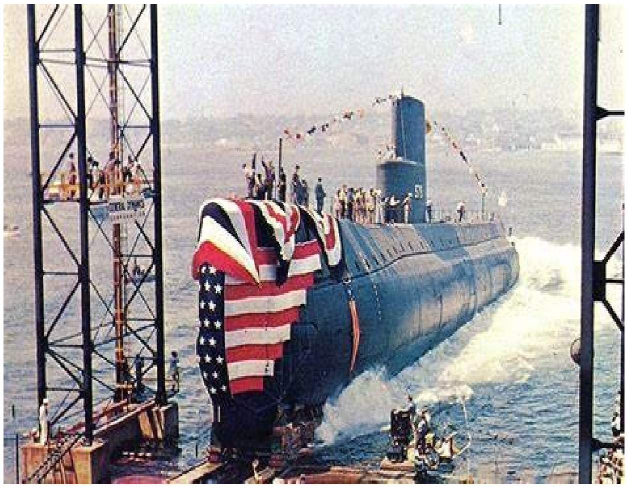




One commentator has observed that environmentalists "hate nuclear power, because it solves problems they need to have." Despite environmentalist opposition and negative press, US voters show surprising receptivity to nuclear power plants, particularly when they are presented as an alternative to fossil fuel plants. By displacing the emissions that come from fossil and biomass power plants, it has been estimated that nuclear power plants have saved over two million lives over the period that nuclear plants have been operating. It is estimated that the present rate of saving lives is 76,000 per year.. Particulate emissions from coal-fired power pants kill a huge number of people per year worldwide. Numbers estimated range from over 200,000 to over one million per year.

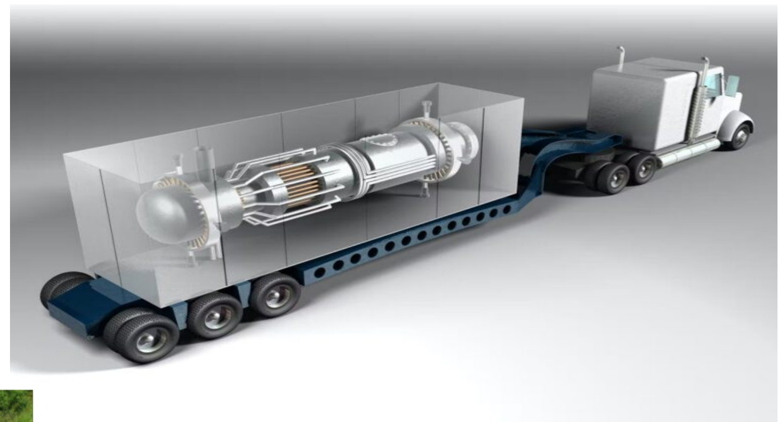
The future of nuclear in the US is tied to the future of "advanced" (Generation IV) nuclear plants and in particular Small Modular Reactors (SMRs), pictured in this image. Most nuclear plants now operating in the US (like TMI) are Generation II. All modern SMRs have fail-safe design unlike TMI, Chernobyl, and Fukushima. They are modular so they can be fitted to the need at a particular site. If 600 mw are needed, then 3 200 mw or 4 150 mw reactors can be installed. Reactors can be individually shut down, which greatly facilitates maintenance and refueling. Most designs reprocess their spent fuel, which significantly reduces the amount of nuclear waste.

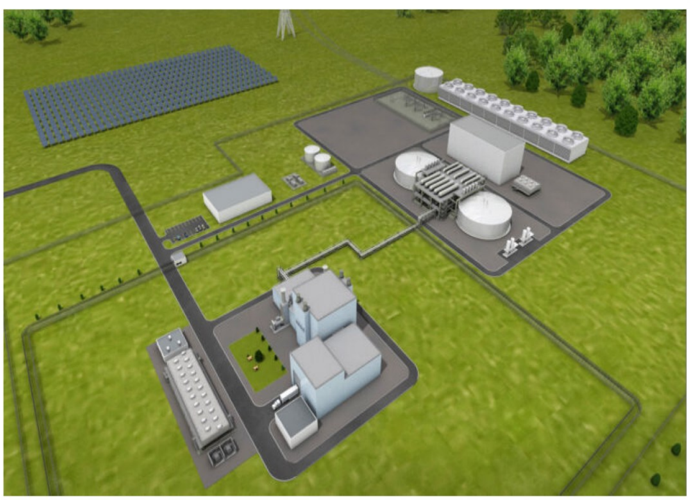




The US Navy launched its first nuclear powered ship, the submarine Nautilus, in 1954, and has been operating numerous submarines (there are presently 68 nuclear powered submarines), aircraft carriers, and other types of ships, powered by SMRs, for 69 years. These ships have no containment building and a minimal containment vessel compared to that required by the NRC for standard nuclear power plants. They routinely dock in the ports of major cities around the world, and there have been no significant nuclear accidents involving Navy SMRs.

Once a SMR design is approved by the NRC, it can be mass produced, and the appropriate number of reactor units delivered to each site. The approval of the basic design should greatly speed the approval of subsequent reactors of the same design. Mass production at just one, or a very small number of sites, should significantly reduce construction time and cost.

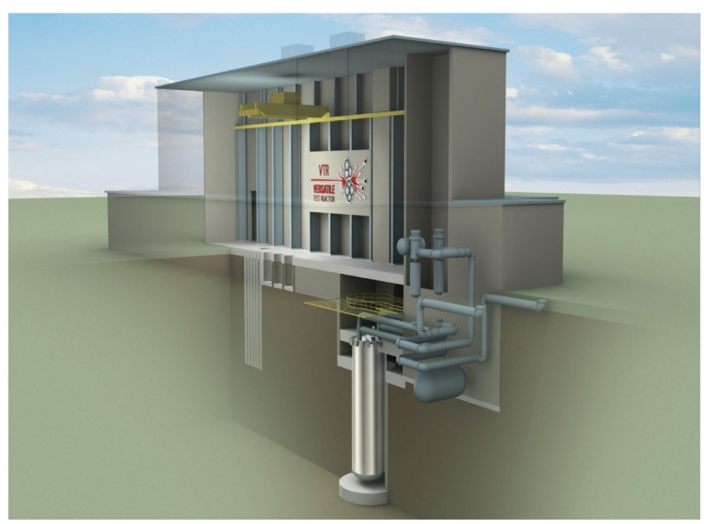


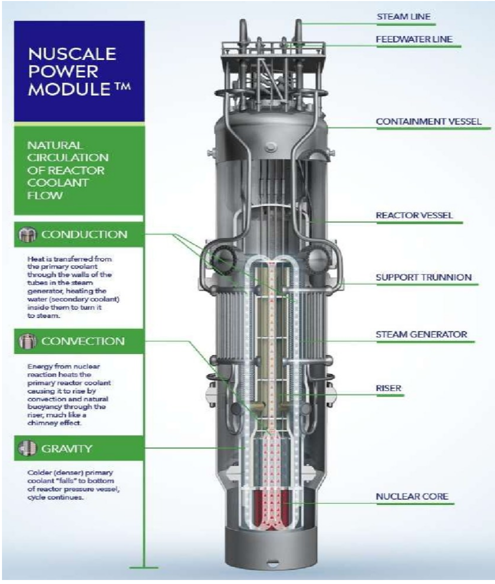


Enlarge / In TerraPower's design, the nuclear reactor is separated from the power generation process by molten salt heat storage.

Bill Gates founded TerraPower in 2008 and is in the process of building this SMR plant, which is set to open in 2030. Many SMR designs do not use water as a coolant. This eliminates problems caused by heating the water used for cooling. The TerraPower SMR uses liquid sodium, so it does not need to be located near the ocean or a lake or river. Gates is confident that the TerraPower SMR will be safe and practical. "We've solved all the areas where there have been safety challenges and we have dramatically less waste."

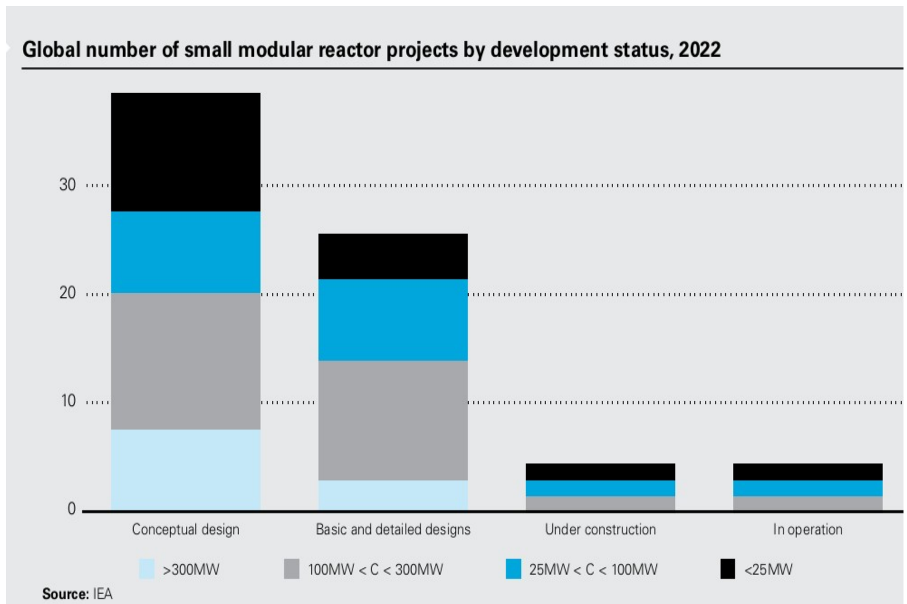
A SMR reactor can be located below ground level, which is an important safety feature. The size of a SMR facility is relatively small. The US Department of Energy has identified 157 retired coal plant sites and 237 operating coal pant sites as "potential candidates" for coal-to-nuclear transition. Great advantages of such sites are that (1) they have already been assembled, (2) they have previously received all required approvals for electricity generation, (3) they tend to be near the places where the electricity produced is needed, and (4) they already have transmission lines connecting the site to the local grid.





The NuScale design shown here was approved by the NRC in 2022. The company is presently building a demonstration project (6 reactor units to produce 462 mw) at the Idaho National Laboratory with a planned 2030 completion date. The US Department of Energy is providing significant financial support for this plant and other SMRs. Dept. of Energy Assist. Sec. Kathryn Huff says that, “This is innovation at its finest and we are just getting started here in the US.” The Biden Inflation Reduction Act provides production tax credits for next generation reactors such this.

SMR designs are attracting widespread interest. The image shows the status of SMRs by size around the world in 2022. NuScale, for example, hopes to build SMRs in Romania, Poland, and Kazakhstan in addition to in the US.



Conclusion

66 years of nuclear power plant operation in the US and the rest of the world have demonstrated that such plants are significantly safer than coal-fired power plants. Nuclear waste disposal can be readily handled, given the very small volume of such waste, particularly if reprocessing is allowed. Cost remains a significant problem in the US, but this problem is due to the excessive regulation of the licensing and construction process by the NRC and the EPA. In the US SMRs offer the possibility of providing massive amounts of safe, reliable, zero-CO2-emissions electricity. With reasonable cooperation of government regulators, we can make SMR power cheap as well as safe and environmentally friendly.

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