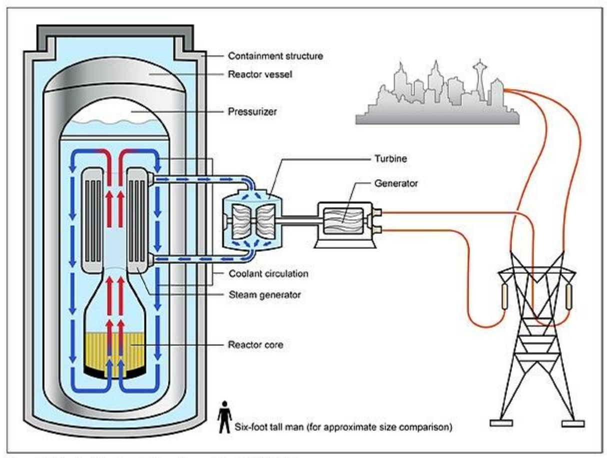
Small Modular Nuclear Reactors (SMRs); too costly, too slow to deploy, inherently dangerous, with an outsized waste problem[1]

What are Small Modular Nuclear Reactors (SMRs)?

According to the International Atomic Energy Agency, "small modular reactors (SMRs) are advanced nuclear reactors that have a power capacity of up to 300 MW(e) per unit…about one-third of the generating capacity of traditional nuclear power reactors."[1] Unlike the traditional nuclear power plant which is used only to supply electricity to the grid, SMRs built to various size are being considered "for power generation, process heat, desalination, or other industrial uses."[2]

SMRs can be used to incrementally to build a larger nuclear power plant with the smaller, modular operating units through serial production of many small and prefabricated components (think assembly line).[3]



Source: GAO, based on Department of Energy documentation. | GAO-15-652

"Small" and modular might sound like a good thing when it comes to talking about nuclear power, but the many major concerns regarding SMRs are not that much different from traditional, commercial nuclear power plants of the late 50s.

Moving too slowly to quickly reduce greenhouse gas emissions

With a variation in design, to date, not a single SMR has been built in the US, and so far**, only one company's design has received the green light from the Nuclear Regulatory Commission** in September 2020—spearheaded by the public power consortium Utah Associated Municipal Power Systems (UAMPS) and built by NuScale, an Oregon-based company.[4] According to NuScale's website, "By the end of this decade, the first NuScale small modular reactor (SMR) power plant will begin operation in the United States in Idaho Falls, Idaho."[5] So the first SMRs design approved by the NRC is projected for completion in the next 8 years, barring setbacks.

However, shortly after its approval, eight of the 36 public utilities that had signed on to help build the plant have backed out. "The withdrawals come just months after the Utah Associated Municipal Power Systems (UAMPS), which intends to buy the plant containing 12 small modular reactors from NuScale Power, announced that completion of the project would be delayed by 3 years to 2030. **It also estimates the cost would climb from $4.2 billion to $6.1 billion.**"[6]

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[1] https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs
[2] https://www.energy.gov/ne/advanced-small-modular-reactors-smrs
[3] https://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx
[4] https://www.energy.gov/ne/articles/nrc-approves-first-us-small-modular-reactor-design
[5] https://www.nuscalepower.com/projects/carbon-free-power-project
[6] https://www.science.org/content/article/several-us-utilities-back-out-deal-build-novel-nuclear-power-plant

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Too expensive to compete with wind and solar

A perpetual concern of nuclear power in general and SMRs in particular is economic competitiveness.[7] "Proponents for small modular nuclear reactors claim that modularity and factory manufacturing would compensate for the poorer economics of small reactors."

To be price competitive, **several hundreds or even thousands of these SMRs would need to be manufactured** to compete with larger, traditional reactors on a per kilowatt basis.[8] Will there ever be enough customers? The **high cost of SMRs** makes the cost of battery storage for wind and solar extremely attractive to compensate for their variability.[9]

How safe are SMRs? Does anybody really know?

Safety concerns around SMRs are numerous, despite the "assuring" use of terms like "small," "modular," and "inherently safe." In the interest of space, only some will be listed here:

Mass production: What happens if an error occurs during the mass manufacturing of reactor components which results in a safety issue? It happened to the Boeing 737 Max airliner. Can a radioactive reactor be recalled (or multiple ones)? What happens to the electricity supply at that location? Does the industry have an answer to these questions? If an SMR design includes pressurized water reactors (as is common), a **continuing issue is the need to replace the steam generator** well before the end of the licensing period—a problem that still has not been resolved over at least two decades.[10]

Engineering challenges regarding cooling: Just like traditional nuclear reactors, SMRs require systems "to ensure that heat generated by the reactor core is removed both under normal and accident conditions at a rate to keep the fuel from overheating, becoming damaged, and releasing radioactivity." [11] Some developers suggest that "passive natural convection" used for cooling in some models of SMRs, will keep pumps from overheating, and that might be true for some cases; however, this wouldn't be the case under all accident scenarios.

For example, according to the Union of Concerned Scientists, in the case of the NuScale design, "a large earthquake could send concrete debris into the pool, obstructing the circulation of water or air."[12] They further state, no design "can shut itself down and cool itself in every circumstance without the need for intervention,"[13] suggesting that passive systems can only address conditions for

[7] https://thebulletin.org/premium/2021-07/can-small-modular-reactors-help-mitigate-climate-change/#.YyC2I__-aLc.mailto
[8] Ibid.
[9] Ibid.

[10] Ibid.
[11] https://www.ucsusa.org/resources/small-modular-reactors
[12] Ibid.
[13] Ibid.

which they have been designed. That brings us back to costs. The more back-up systems that are built into the design, the great the cost.

Underground, yet risks remain: Additionally, reduced containment structures which can decrease costs, may not be robust enough (with sufficient strength and volume), to prevent a hydrogen explosion. While some suggest that an underground reactor might provide greater safety, this, too, comes with its own set of concerns, including higher susceptibility to flooding and difficulty in gaining access to underground reactors.[14]

While building these facilities underground might reduce the risk from a direct hit, what happens when explosions or fires follow? Some parts of the plant will still be vulnerable such as steam turbines, condensers, electrical switchyards, and cooling towers. Smaller facility footprints also provide would-be terrorists quicker access and reduce warning time for facility operators.

Regulatory concerns: Current regulations for SMRs don't require new reactors to have a decreased frequency of core damage. In addition, while proponents of SMRs suggest that smaller reactors are less of a public risk, "small reactors do not necessarily imply smaller risks if there are more of them."[15] To actually reduce the risks where multiple, smaller units are concerned, a greater number of support staff and the amount of safety equipment would need to increase for each unit on site (again, **increasing overall costs**).

SMR vendors, like NuScale, have suggested the use of a single control room for as many as a dozen units. Yet, what would happen if multiple failures occur, like at Fukushima, where the explosion at one unit disrupted emergency operations at neighboring units? The Nuclear Regulatory Commission will not even have a risk assessment for multiple unit reactors for years because of the complex analysis that is necessary, which is very concerning.

Most alarming, though, is that proponents of SMRs are seeking to reduce and weaken regulations for safety and security.[16]

<u>Nuclear Security concerns of SMRs</u>

Too many unanswered questions: A Department of Energy paper (Sandia National Laboratories) on SMRs lists thirteen (13) questions about security of SMRs, an abundance of unanswered questions to begin hasty deployment of SMRs. Here's one example: Could sabotage lead to Unacceptable Risks (URC) or High Radiological Consequences (HRC) based on the state regulations per NSS-13 (*Nuclear Security Recommendation on Physical Protection of Nuclear Material and Nuclear Facilities INFCIRC/225*; published by the International Atomic Energy Agency, Revision 5)?

Sabotage: The terrorist attack on September 11, 2001 (911) on the World Trade Center, followed by the 2013 Boston Marathon pressure-cooker assault that killed and maimed many people, reminds us

[14] Ibid.
[15] Ibid.
[16] Ibid.

that we remain vulnerable to terrorists outside and within our nation. Since 9/11, a typical nuclear reactor requires approximately 120 security officers per week, with a minimum of 10 armed responders/shift to stave off any design-based threat of radiological sabotage. Yet, proponents of SMRs are proposing a 70-80% reduction in armed security personnel—an ill-advised strategy to cut overall costs. Just imagine assembly line SMRs, manufactured and deployed in large quantities at numerous locations. And then think about the amount of security personnel and the number of well-trained emergency responders needed to thwart a well-planned terrorist attack. What will it take to defend one, let alone 100s or 1,000s of SMRs?

Nuclear proliferation: SMRs have been used to produce fissile material for weapons regardless of design. Alarmingly, SMRs "could become the technology of choice for proliferators: reactors that produce significant amounts of plutonium each year without the expense of a gigawatt-scale nuclear power program."[17] Small scale reactors have already been used to produce fissile material for weapons in the UK, North Korea, and India. Saudi Arabia has shown interest in acquiring a South Korean-designed SMART SMR to possibly unlock the technological potential of SMRs with a clear interest in developing nuclear weapons capability. The US's National Nuclear Security Administration has even been invited to consider using an SMR to produce tritium—to boost the explosive yield of the US nuclear arsenal.[18]

The CCO of NuScale Power, a company that's been green-lighted to construct the first SMR in the US, said in 2013 that the company isn't in the business to sell reactors to politically unstable countries; however in 2019, NuScale participated in a meeting at the White House where selling nuclear power technology to Saudi Arabia was discussed. [19]

Emergency! Now what? People living in the "inhalation emergency planning zone," (EPZ) i.e., the evacuation zone, are issued free potassium iodide from the NRC to prevent excessive radiation exposure to the thyroid gland within a10-mile radius of a traditional nuclear plant. Proponents of SMRs want to reduce this distance requirement with a claim that they are smaller and safer. Their plan increases flexibility for potential siting at other locations such as former coal plants or military bases—even at densely populated areas without having to develop evacuation plans for the public. Imagine an emergency at an SMR with no siren, no evacuation plan, and no emergency planning.[20] To date no models of SMRs have been validated for safety that have actual operating experience.

Maintain the "gold" standard for security performance tests: Post 9/11, security regulations require the NRC to conduct periodic performance tests (force on force) of the armed response strategy; however, some in the industry are proponents of "alternative performance assessment techniques," whatever that means. We need the highest security requirements for nuclear power plants regardless of size.

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[17] https://wiseinternational.org/nuclear-monitor/872-873/small-modular-reactors-and-nuclear-weapons-proliferation
[18] Ibid,
[19] Ibid.
[20] Ibid.

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Nuclear waste: How to transport and store radioactive nuclear waste from SMRs is a concern, one that to date hasn't been resolved for conventional nuclear reactors. A recent study from Stanford, published in the *Proceedings of the National Academy of Sciences,* indicates that nuclear waste generated from SMRs will not only be complex, but also could produce from 2 to 30 times greater amounts than conventional light-water nuclear reactors, especially in the case involving a sodium coolant.[21] Akin to disposal issues, "recriticality" is higher (higher amounts of fissile material) in the spent fuel of SMRs due to less efficient fuel burnup (fuel utilization).[22] Nuclear waste is an issue from cradle to grave (decommissioning); even the steel components will contain short- and long-lived nuclides. **Red flag:** The NRC's new reactor design certification application doesn't have a chapter on geologic disposal (geologic repository).

Dangers of Uranium Mining: Most US mines producing uranium as a primary commodity are, or were located, in Colorado, Utah, Wyoming, New Mexico and Arizona, and are typically on federal and Tribal lands. The current number of locations associated with uranium, as identified in the EPA database, is around 15,000. (*Uranium Location Database Compilation*, Office of Radiation & Indoor Air EPA 402-R-05-009, Radiation Protection Division [6608J] August 2006).

According to the US Center for Disease Control (CDC), the following diseases are associated with uranium mining[23]:

- Primary lung cancer (including any physiological condition of the lung, trachea or bronchus that is recognized as lung cancer.)
- Pulmonary fibrosis, fibrosis of the lung.
- Silicosis.
- Cor pulmonale related to fibrosis of the lung.
- Pneumoconiosis.
- Kidney damage
- Bone and liver cancer

Uranium-235 (U-235) Half-life*: 700 million years

Uranium-238 (U-238) Half-life: 4.47 billion years

*the time taken for the radioactivity of a specified isotope to fall to half its original value.
"iodine-131 has **a half-life of** 8.1 days"
(https://www.cdc.gov/nceh/radiation/emergencies/isotopes/uranium.htm

Conclusion: A New York *Times* columnist, Farhad Manjoo, attended the World Nuclear Symposium in September, 2022, where pro-nuclear folks were making their case, essentially saying nuclear is "relatively safe, reliable and clean; compared to the destruction caused by fossil fuels…" Considering the current imperative to limit global warming to 1.5 degrees Celsius above preindustrial levels, Manjoo points out that the average nuclear facility took 10 years to build and that in 2020-2021, the world added 464 gigawatts of solar and wind, more power than all the currently operating nuclear plants worldwide. Given the long timetable and expense along with all the unresolved issues, deploying SMRs or new traditional nuclear power plants doesn't make sense, when wind and solar can be deployed in a few months at a much cheaper cost. (*Times Digest*, Fahad Manjoo, September 17, 2022, p. 8.)

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[21] https://news.stanford.edu/2022/05/30/small-modular-reactors-produce-high-levels-nuclear-waste/
[22] Ibid.
[23] https://www.cdc.gov/nceh/radiation/emergencies/isotopes/uranium.htm