Federal Ministry
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Climate Action, Environment,
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Small Modular Reactors – The Power of Promise

They are creating a major media stir. The wind power giant Ørsted dubbed them "dwarf reactors".[1] They – that is commercial reactors with less than 300 MWe capacity – do not exist in the western world, but there is much talk about them. If ever they did exist beyond a few prototypes, in 15 or 20 years, their electricity would be excessively expensive. Too late, too costly for our climate.

The promise is decades old but remains alive and kicking: The international nuclear energy industry is making a pitch for small modular reactors of the future – cheap, failsafe, and therefore ubiquitously deployable, even in areas of high population density. However, they do not really exist. But just like the illusion that concept drawings used to project onto walls back in the 1990s, the virtual spaces on computer screens and in Zoom rooms are being used to conjure up dreams across the continents.

Small Modular Reactors, SMRs for short, are en vogue again. From old hat to cutting edge.[2] In the 1950s and 1960s, a few of them were actually built, namely in the U.S.[3] That did not always end well. The small Elk River reactor started operating after a five-year construction period but found itself closed for good in 1968, just three-and-a-half years later. Fermi-1, an experimental fast breeder reactor located on the banks of Lake Erie, needed 10 years before it was able to supply its first kilowatt-hour of electricity in 1966.

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[1] Volker Kühn, "Verstrahlte Träume" (Irradiated Dreams), *EnergieWinde*, 27 November 2020, see energiewinde.orsted.de/energiepolitik/atomenergie-niedergang-keine-renaissance, accessed on 20 May 2024.

[2] See a summary of the history of SMRs penned by M.V. Ramana, "The Forgotten History of Small Nuclear Reactors", IEEE Spectrum, 27 April 2015, see spectrum.ieee.org/tech-history/heroic-failures/theforgotten-history-of-small-nuclear-reactors, accessed on 20 May 2024.

[3] 14 reactors with a capacity of less than 100 MWe were connected to the grid. Only six reactors with a capacity of between 100 MWe and 500 MWe began to operate. 115 out of a total of 135 nuclear reactors ever started up in the U.S. have a capacity of over 500 MWe.

Two months later, the reactor's core suffered a partial meltdown. The book "We Almost Lost Detroit" became a bestseller.[4]

Small Reactor Designs are Losing the Effect of Economies of Scale

Since the 1970s, newly built reactors have been increasing in size, mainly in an attempt to curb costs per unit of capacity. However, over the past ten years, it has become crystal clear that large reactors, regardless of their design, are too expensive, too large and too slow to keep pace with their nimble competitors from the renewables sector. Once again, SMRs are being billed as the panacea. Cheap, easy and quick to build, they are also supposed to be easy to operate.

However, any wine connoisseur will know that a glass of wine served in the restaurant may cost less than a whole bottle, but every single glass of wine added together will be more expensive than the same quantity taken from a purchased bottle. A compelling argument in favour of the entire bottle. This is called "economies of scale" in economics.

Conversely, if I decrease the size of anything I want to build by a factor of 10 or 20, I lose the cost-savings due to economies of scale. The Pebble-Bed Modular Reactor (PBMR), which was originally designed in the Federal Republic of Germany, was considered the SMR champion for decades. In Germany, the concept ultimately failed in 1988 after billions of public funds had been invested in two prototype reactors.[5] Initially, the Republic of South Africa started out with the idea of a 110-MWe facility, but the plant's capacity was gradually increased to 165 MWe in an attempt to make it economically viable. By 2010, this adventure at the Cape had cost the country's taxpayers €800 million. A prototype was never built and the government in Pretoria finally pulled the plug.[6]

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[4] John G. Fuller, "We Almost Lost Detroit", *Ballantine Books*, 1976.

[5] Experimental reactors AVR Jülich (15 megawatts) and THTR-300, a Thorium High-Temperature Reactor (THTR) in Hamm-Uentrop (300 megawatts).

[6] David Fig, "Nuclear energy rethink? – The rise and demise of South Africa's Pebble Bed Modular Reactor", Institute for Security Studies, ISS Paper 210, April 2010.

NuScale in the U.S., From Poster Child to Failure – Argentina, China, Russia Struggling

Since 2000, the U.S. Department of Energy has resumed generous funding for SMR research. The SMR concept by the name of NuScale in summer 2020 was the first of its kind in the world to obtain a conditional generic design approval in the U.S. Soon after, the company's financial department re-did the maths. The standard design provided for plants comprising no fewer than 12 modules to achieve something close to – theoretical – profitability based on economies of scale. However, despite the "volume discount", estimated costs for the NuScale project skyrocketed to levels exceeding the disastrous price tags for the latest generation of European large-scale reactors, the European Pressurized water Reactor or EPR with projects in Finland, France, and the United Kingdom. So project managers decided to increase the capacity of every NuScale module by over one half from 50 MWe to 77 MWe. In a second step, the envisaged number of modules per site was reduced from twelve to six. It did not help and in early 2023, NuScale announced its new cost estimates for the six-module 462-MWe project at US$9.3 billion (€8.7 billion), per MWe capacity vastly exceeding any EPR cost estimates. Also, the Nuclear Regulatory Commission (NRC) requested to re-open the licensing procedure following the design changes.[7] The new licensing procedure is expected to take an additional two years compared to the schedule, at least to 31 July 2025. Consequently, in November 2023, NuScale's partners in the only commercial arrangement on SMRs in the western world, the Carbon Free Power Project (CFPP), pulled the plug. NuScale laid off about one third of its staff.

In Argentina, a 25-MWe reactor has been in the making since 2014, startup is currently scheduled for 2027 at the earliest. In China, two 100-MWe modules have been finally connected to the grid in December 2021, after construction took ten years instead of scheduled five. In Russia, two "floating reactors" with a capacity of 30 MWe each began operating in 2019. Construction took nearly 13 years, almost four times longer than planned.

[7] NuScale's repeated claims to have the first and only SMR design certified by the NRC received a scathing rebuttal by analyst Iceberg, "NuScale ($SMR) Has Deceived Investors about the Certification of its Reactor", 16 May 2024, see iceberg-research.com/2024/05/16/nuscale-smr-has-deceived-investors-about-the-certification-of-its-reactor/.

In France, national champion EDF's subsidiary Nuward has been working for some years on a two-module concept with together 340 MWe. The design had been submitted for a pre-licensing assessment by the national safety authorities. Construction was to start in 2030. But in late June 2024, EDF pulled the plug and restart all over using only "proven technological bricks" rather than innovative designs. The economic daily Les Echos commented:

> "Winner of the "France 2030" subsidy program, Nuward has received a much larger grant from the French government than its competitors, who are also aiming to bring mini-reactors to market. EDF's project is set to receive 300 million euros in aid, compared with 25 million euros for Naarea and Newcleo."

Besides the inveterate SMR proponents, there are people who dream of Generation IV reactor technologies (See Factsheet "Generation IV Reactors"). TerraPower, for example, promises innovation in nuclear technology "to improve the lives of people everywhere and to build the clean energy of tomorrow – today".[8] The company was founded by Microsoft's Bill Gates in 2006. Eighteen years later, the reactor only exists on paper, with a design that has yet to be approved. Nevertheless, the company filed an application for a construction license in the U.S. in March 2024 for its Natrium 345-MWe sodium-cooled fast reactor with a scheduled grid connection in 2030. In the meantime, the design has not been licensed yet and the company does not know yet where the fuel is supposed to come from.

If not likely, it is not entirely impossible that a handful of prototype SMRs will start construction or even operate by 2030. That is a very long way to the demonstration of industrial and economic feasibility. Too long to deal with the climate emergency.

Last update: 2024

[8] TerraPower, "About us", see terrapower.com/about/, accessed on 25 November 2020.