Will SMRs come true?
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Outline

- What are SMRs?
- What are the main designs?
- Which countries are pursuing SMRs most aggressively?
- Do the claims made for SMRs stack up?

Small Modular Reactors (SMRs)

For the past decade, there has been increasing levels of propaganda about SMRs. The claims are:

- They are cheaper & easier to build, less prone to cost & time overruns, easier to finance
- They are safer, melt-down proof, walk-away safe & produce less waste (per kW of capacity) than large reactors
- Being smaller, there will be less opposition to their siting
- They will create large numbers of new jobs

- As a result of this, the impression is that large numbers of SMRs are being ordered around the world

- ***These claims are unproven or misleading or simply wrong***

- No modern design SMR is operating, only 3 prototype SMRs are under construction (China, Russia, India) & no design of SMR is commercially available to order yet

- No available design has completed a full safety review by an experienced & credible regulator. Until this is done, it will not be known if the design is licensable or what the costs would be.

- Preliminary safety reviews have been carried out, but they do not prove the designs are licensable. They merely say that, in principle, the design could be licensable – but at what cost?

What are SMRs? (1)

- SMR covers a range of sizes & technologies & the term is too wide to be meaningful

- IAEA defines SMRs as reactors of 30-300MWe (reactors <30MWe are micro-reactors)

They can be divided 3 categories:

1. Smaller versions of the dominant existing reactor types: Pressurised Water Reactors, PWRs & Boiling Water Reactors, BWRs;
2. Technologies pursued for more than 50 years, but which have only been built as prototype or demonstration plants (e.g., Fast Reactors), all unsuccessful;
3. Reactor designs long talked about but never built (e.g., Molten Salt Reactors)

- The most realistic prospects are for PWRs & BWRs. These are technically, if not economically proven & could be commercially available well before the other types

What are SMRs? (2)

- PWR & BWR SMR designs are mainly 300MW or larger

- Rolls Royce SMR reactor design, 470MW, is about the same size as most reactors in E Europe

The claims on cost & buildability are based on:

1. Production-line manufacture of components;
2. Modular construction with site work mainly 'bolting together modules' & perhaps several interdependent reactors on the same site;
3. Smaller, therefore easier to build

- Some designs claim improved safety by use of: passive safety systems – in an accident, natural processes rather than engineered systems control the reactor; integral designs – all the major systems are contained in the reactor vessel, not just the reactor; reactors built underground & housed under water

- There are 6 SMR PWR & BWR designs (excluding Russia & China) that have seen significant development

GE-Hitachi BWRX-300

- Announced 2018. Scaled down version 300MW of 1520MW ESBWR, passive safety
- ESBWR design announced 20+ years ago was approved by US Nuclear Regulatory Commission in 2014 but never marketed because uneconomic. Why would scaling it down make it cheaper?
- Reports imply firm orders for 4 reactors in Canada, but these are only options that might be firm if/when the design receives safety approval from the Canadian regulator
- Limited support for BWRX-300 from 2 US utilities. Interest in Poland, UK, & Czech Rep
- Full safety review started in UK in January 2024 (4+ year process). Preliminary safety reviews underway in Canada & USA

Westinghouse AP300

- Announced 2023. Scaled down version (300MW) of the AP1000 (1170MW). AP1000 (advanced passive) is a modular design relying on passive safety

- 8 AP1000s sold (USA & China) but all suffered major construction delays (6+ years), were up to 4 times overbudget & 2 had to be abandoned after 4 years construction. Why would scaling down an expensive design make it economic?

- Full safety review in UK began in August 2024

NuScale SMR (VOYGR)

- Dates back to early 2000s & US government funded research. NuScale set up 2007, Fluor (large US engineering company) became major shareholder in 2011. Funding from US Dept of Energy

- Originally 35MW, then 40MW, 50MW, 60MW, now 77MW. Designed to be built in clusters of 12, now also clusters of 4 or 6 reactors. Integral design relying on passive safety. Reactor below ground level, immersed in a water pool

- 50MW design submitted to US safety authorities in 2016 but when the process was complete in 2021, 50MW design had been abandoned & it had been scaled up by 50%. Regulatory review for 77MW design restarted from scratch in 2023, no completion date forecast yet

- Only firm project was the Utah Associated Municipal Power System (UAMPS), announced 2016 as 12x50MW reactors, then 6x77MW reactors. About 50 utilities involved (2-3MW each) but despite large government subsidies only about a third of the capacity committed & the project collapsed in December 2023

- Expected cost nearly doubled in 2021 from $55/MWh to $91/MWh

- Interested countries include Romania, Jordan, Canada

- Share price of NuScale lost 2/3 of its value in 2023. Will NuScale survive the loss of its only major order prospect?

Holtec SMR-300

- Announced 2010 as SMR-160, 160MW PWR with integral design & passive safety
- At some point in 2023, unannounced, its size doubled & it became SMR-300
- Comprehensive safety review began in UK in October 2023. 1st stage of 3 completed August 2024, largely information exchange
- Some support from Mitsubishi. Interest in Ukraine, Canada

Rolls Royce SMR

- Announced 2017, originally 220-440MW, then 440MW, now 470MW. Old-fashioned design - not integral, not reliant on passive safety, built at surface level. No interest from UK utilities
- Partnership with CEZ (Czechia) announced September 2024
- Began UK safety review process in 2022, stage 2 completed July 2024
- Seen as a front-runner for UK but public funding required to develop the design to commercial status, to equip & set up factory production lines & guarantees for orders for 12+ reactors.
- Tens of billions of € required

Framatome Nuward

- Announced 2019. Twin reactors of 170MW each including passive safety, integral design with reactors buried & immersed in water

- Design still at conceptual stage when it was abandoned in July 2024 in favour of more conventional approach

UK Programme

- UK has been pursuing SMRs for a decade but with little progress until 2023 when it announced a competition to identify 2 SMR designs to receive large contracts

- Job of running the competition given to Great British Nuclear, announced March 2022 but by Oct 2024, no permanent executive, no permanent staff

- Contract specification gives a budget of £20bn to be spent by 2038. 2 companies to be given contracts for development including purchase of 2 each of winning designs

- Shortlist of 6 announced in Oct 2023 – Rolls Royce, GE-Hitachi, Westinghouse, Holtec, NuScale & Framatome. Framatome withdrew July 2024, & NuScale eliminated Sept 2024. This decision was 6 months late

- Winning 2 designs to be announced perhaps in early 2025. Rolls Royce appears a certainty because it is the only UK design. First reactor orders not planned till 2029

Canada Programme

- Canada announced in 2018 it wanted to be the world hub for SMR expertise.
- Several separate programmes in different provinces with different priorities but all led by public (federal & provincial) funds
- Ontario: Ontario Power Generators want to build grid size reactors & plan 4 GE-H BWRX-300s for Darlington site
- Saskatchewan: Also grid power for SaskPower but proposals at early stage
- New Brunswick: Plans for 100MW fast reactor (ARC-100) at existing site, Point Lepreau
- Alberta: Proposal for High Temp Gas Reactors (Xe-100) for use in processing tar sands

Czech Programme

- Czech Rep has been pursuing SMRs as well as large reactors for several years. 7 designs considered (Rolls Royce, GE-H, Westinghouse, Holtec, Framatome, NuScale & KAERI SMART (Korea)

- Reduced to 4 in 2024 eliminating Framatome, KAERI & NuScale

- Sept 2024, decision to collaborate with Rolls Royce & CEZ might take a stake in the Rolls Royce SMR company

Is Small or Large beautiful? Experience with AP1000

- Around 1990, Westinghouse announced AP600 claiming they had looked for scale economies in large reactors but there were none. It was assessed & approved by US NRC in 1998 after 5 years but by then clear it was uneconomic, so was never marketed

- Westinghouse scaled it up to 1170MW (AP1000) to improve the economics. It was submitted to US NRC in 2002 but only given final approval in 2011. All 8 orders including 4 for China were very expensive.

- China scaled the design up to 1550MW (CAP1400) to reduce costs. No CAP1400s completed yet

- Now Westinghouse has scaled the AP design down to 300MW

- Does scaling-up or scaling-down reduce costs?

Scale economies/diseconomies

- The size of reactors has consistently increased since the 1960s. Industry has tried to counter poor economics by seeking scale economies – a 1000MW reactor vessel weighs less & costs less than 5 x 200MW reactor vessels

- The challenge for SMRs is not to be cheaper than large reactors, it is to be cheaper than the cheapest low-carbon options

- Claimed savings from factory manufacture, modularisation etc will have to more than counter lost scale economies

- Are reactors difficult to build to time & cost because they are large or complex?

- Why would small reactors be less complex than large ones unless safety features were significantly cut back?

Production lines/modularisation/factory manufacture

- The image of equipment being made on a rolling production line like car manufacture is misleading. The Rolls Royce production lines would produce 2-4 reactors per year

- Production lines are expensive to set up & inflexible. If not fully loaded, they must be closed/mothballed. If the design needs to be changed, expensive retooling costs

- Rolls Royce wants to make its first reactor on a production line to prove the economics but if this is done, before the first kWh of electricity is generated, at least another 10-12 reactors will be in various stages of manufacture before the design is tested. This is a huge gamble on the design being economically & technically viable.

- All reactors require a mix of factory work & on-site assembly. The claim for SMRs is simply that the balance is more towards off-site work. The Westinghouse AP1000 is claimed to be modular & factory produced but this did not prevent construction of all 8 reactors ordered going badly wrong

Waste & safety

Waste

- All things equal, a small PWR/BWR will create more waste than the same capacity in large reactors
- Alison Macfarlane (ex Nuclear Regulatory Commission Commissioner) calculates that SMRs will increase the volume & complexity of waste by a factor of 2-30 (e.g., greater neutron leakage)

Safety

- Passive, integral & sub-surface designs are not necessarily safer, they just raise different safety issues
- Will small reactors be licensed without safety features needed for large reactors?

Jobs

- Nuclear reactors require large numbers of workers during the construction phase, typically having very specific skills unlikely to be found in the local region & these workers may come from abroad.

- Jobs typically last only a year & this is very disruptive to the local area requiring large amount of short-term accommodation & facilities

- An operating reactor requires few permanent staff. Operators require highly specific skills unlikely to be found among the local population

- If factories with production lines are efficient, they will require fewer workers than other manufacture methods. Factories are unlikely to be in the country of order for exports

Conclusions

- Reactor vendors have always overstated how close to commercially availability their designs are. No SMR design has completed a comprehensive safety review & it will be 2 years before the first review is complete & preliminary costs established. It would be reckless to order an SMR without this safety certification

- Memoranda of cooperation, letters of intent etc are worthless as indicators of ordering

- Producing new reactor designs is risky, expensive & lengthy. NuScale is not available after 20 years' work & $1bn spent including large amounts of US public money. All vendors looking for large amounts of public money to bring their designs to commerciality & guarantees of orders

- Traditional vendors don't have the funds to develop a new design without strong assurance of orders. Westinghouse & Framatome are emerging from bankruptcy. Scaling down existing designs (AP300 & BWRX-300) is a cheap way to produce SMR designs but given the large designs are uneconomic, why would smaller ones be better, why would they be less complex?

- New companies (e.g., NuScale) will need public funding & partners with credibility in power plant construction to sell reactors