Small Modular Reactors: the last-chance saloon for the nuclear industry?

Steve Thomas, Greenwich University, critically assesses the current enthusiasm for Small Modular Reactors in the UK and elsewhere. Will they help in the struggle against climate change, or will they sound the death knell for nuclear fission in the power sector?

In January 2023, the UK government announced that six more Small Modular Reactor (SMR) vendors had applied for their designs to be formally assessed with a view to commercialisation in Britain. In this, they join a Rolls Royce-led consortium (see Table 1). The process is called Generic Design Assessment (GDA),[1] and is carried out by the UK's Office of Nuclear Regulation (ONR) by looking in exhaustive detail at reactor designs proposed for construction. Designs that successfully complete the process, expected to take 4-5 years, are then in principle ready to be built anywhere in the country subject to meeting site-specific requirements. This situation adds further weight to the claim by nuclear advocates that all that is holding back construction of these SMRs is government infighting preventing the necessary public funding being offered.[2] However, the counterview is that the obstacles to deployment – including technical, economic, safety, security and environmental problems – are so great that it is unlikely they will ever be built.

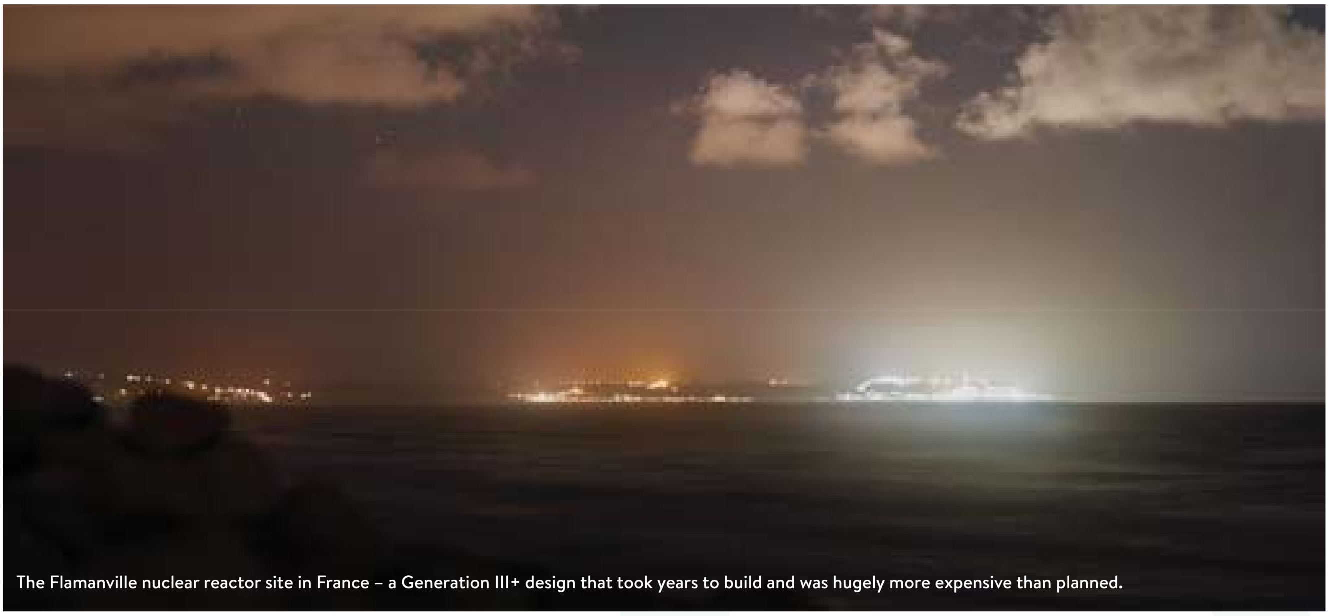
This article delves into the debate by asking six key questions:

- Why do we need new reactor designs?
- What are SMRs and what is the basis for the claim to be cheaper than large reactors?
- Are there SMR designs ready to be built?
- How can the economics of SMRs be tested?
- Which designs are being pursued in the UK?
- Will SMRs be a major contributor to meeting UK's climate change targets?

Table 1. UK reactor designs requesting Generic Design Assessment[1]

Design	Vendor	Reactor type	Size (MW)*
SMR	Rolls Royce	Pressurised Water	470
Xe-100	Cavendish/X-Energy	High-temperature gas-cooled	80
BWRX-300	GE-Hitachi	Boiling Water	300
Nucell	GMET Nuclear	Lead-cooled Fast	100
SMR-160	Holtec	Pressurised Water	160
MiniLFR/ Small LFR	Newcleo	Lead-cooled Fast	30/ 200
?	UK Atomics	Thorium Molten Salt	30

* Of electricity


The Flamanville nuclear reactor site in France – a Generation III+ design that took years to build and was hugely more expensive than planned.

Why do we need new reactor designs?

For the past 40 years or more, a key argument the nuclear industry has had for not giving up on nuclear power was that a new generation of reactor designs was just round the corner that would solve the problems that existing designs had suffered. Around the turn of the century, people began to talk about Generation III+ designs that would be based on the designs that dominated existing capacity, Pressurised and Boiling Water Reactors (PWRs and BWRs). But they would be simplified, use passive safety, and rely on factory work rather than site engineering. These features would make them safer, but cheaper and easier to build. There was also talk of Generation IV designs, such as Lead-cooled Fast Reactors (LFRs) and Very High Temperature Reactors (VHTRs) that would use reactor technologies not yet built on a commercial scale. It was claimed these designs would use fuel more efficiently, reduce waste production, be economically competitive, and meet stringent standards of safety and proliferation resistance.[3]

The results of the few Generation III+ orders placed were uniformly poor, with reactors invariably late and overbudget. In the worst cases, such as the notorious Olkiluoto (Finland) and Flamanville (France) projects, construction periods of 18 years and costs of three to four times the expected level are being seen. Generation IV designs seem no closer to deployment than when they were first mooted 20 years ago.

What are SMRs and what is the basis for the claim to be cheaper than large reactors?

The new 'saviours' for the nuclear industry are Small Modular Reactors (SMRs). This category embodies a range of technologies, uses and sizes but relies heavily on features that were the selling points for Gen III+ and Gen IV designs. They are smaller than typical Gen III+ designs which produce 1,200 to 1,700 megawatts (MW) of electricity, but the sizes range from 3MW to about 500MW. The Rolls Royce design is a 470MW PWR[4] – bigger than one of the reactors at Fukushima in Japan that suffered serious damage in the 2011 Tsunami. The smallest reactors are usually targeted at isolated communities and mineral extraction facilities or hydrogen production, while the larger ones would mainly just supply power to the grid. The technologies encompass scaled down versions of the dominant existing technologies, PWRs and BWRs, to Gen IV technologies that are not commercially available. The large number of PWRs and BWRs in service worldwide suggests SMR versions of these might be reliable electricity generators.

The advanced designs are not new. For example, sodium cooled fast reactors and high temperature reactors were built as prototypes in the 1950s and 1960s but successive attempts to build demonstration plants have been short-lived failures. It is hard to see why these technologies should now succeed given their poor record. Other designs have been talked about for decades but have not even been built as prototype power reactors – so again it is hard to see why the problems that prevented their deployment to date will be overcome. A particular usage envisaged for some of the technologies is production of hydrogen. However, to produce hydrogen efficiently, reactors would need to provide heat at 900°C, a temperature not yet achieved in any power reactor and not feasible for a PWR or BWR, and one that will require new exotic and expensive materials.

Are there SMR designs ready to be built?

Developers of SMRs give the impression that their designs are ready to build, the technology proven, the economic case established and all that is holding them back is government inactivity. However, taking a reactor design from conception to commercial availability is a lengthy and expensive process taking more than a decade and perhaps costing more than £1bn. Several Gen III+ designs underwent a large amount of development work but were found to be unsaleable and the cost written off.

The main steps required to bring a design to commercial availability include:

- Developing the design from broad concept to a level detailed enough to be assessed by a safety regulator.
- Establishing a supply chain including the production lines for the components. The small number of reactor orders globally in the past two decades means that the number of accredited suppliers capable of meeting the exacting quality standards required has fallen dramatically and few suppliers would be willing to invest in setting up a production line unless there was a guarantee of a full order book.
- A customer to build the first of a kind. The days when a utility could place an order for an untested design, secure in the

knowledge it could pass on the costs to consumers are gone. Utilities must risk their own cash now and will want to see a successfully operating demonstration plant in the vendor's home market before they commit to it.

- A large engineering company partner with experience of integrating a reactor design into an overall power plant design and building commercial power plants.

The only SMR design that comes close to meeting these requirements is the 77MW US-based NuScale PWR. This has been under development for 20 years, it has been reviewed successfully by the US Nuclear Regulatory Commission, its developer is backed by a large long-established engineering company, Fluor, and a demonstration project, the Utah Associated Municipal Power System (UAMPS) is planned. However, there are problems with all these elements. The design was originally conceived of as clusters of 12 reactors each of 35MW. Then this has been progressively uprated to try to improve the economics to 40MW, 50MW, 60MW and now 77MW offered in clusters of four or six reactors. Regulatory approval was given in 2021 for the 50MW design but by that time, it had been uprated twice and, as the 50MW design was not going to be offered, significant regulatory issues did not need to be resolved. An application was made in late 2022 for the 77MW design but given the 50% power increase and the unresolved issues, the review will effectively have to start from scratch. The UAMPS project was set up in 2016 and continues to be financially supported by the US Department of Energy which has agreed to pay for some of the project costs. However, rapidly increasing cost estimates mean it is struggling to find enough investors to buy the 476MW (six reactors) of capacity proposed.[5]

How can the economics of SMRs be tested?

The main claim for SMRs over their predecessors is that being smaller, they can be made in factories as modules using cheaper production line techniques rather than one-off component fabrication methods and delivered to the site on a truck essentially as a 'flat pack'. This would avoid much of the site-work that is said to be difficult to manage and is a major cause of the delays and cost over-runs that large reactor projects suffer from.

Photo by Frédéric Paulusson on Unsplash

However, any savings made from factory-built modules will have to compensate for the scale economies lost.[6] Reactor sizes have increased to gain scale economies. In simple terms, a 1,600MW reactor ought to be much cheaper than 10 reactors of 160MW. It will be expensive to test the claim that production line techniques will compensate for lost scale economies.

The first reactor built will need to be built using production lines if the economics are to be tested but once the production lines are switched on, they must be fed. Rolls Royce assumes its production lines will produce two reactors per year and that costs will not reach the target level until about the fifth order. So, if we assume the first reactor takes five years to build, there will be another nine reactors in various stages of construction before a single unit of electricity has been generated from the first, and the viability of the design tested, and perhaps about 15 under construction before the so-called 'nth of a kind' settled down cost is demonstrated. There will be pressure on the government to continue to place orders before the design is technically and economically proven, so the production lines do not sit idle.

But it will not be sufficient for SMRs just to be more economic than large reactors. Given how poorly large reactors compare in cost terms with other low-carbon technologies such as wind and solar technologies or many energy efficiency measures, it is these technologies SMRs will have to beat.

Which designs are being pursued in the UK?

The British government began to target development of SMRs in 2016[7] but these efforts came to little. In 2019, the government made another attempt to launch UK development of SMRs. Over the following year, it allocated £18m to the Rolls Royce SMR for early development of its design,[8] and £10m each to two advanced designs, a Westinghouse 450MW LFR,[9] and 3MW HTGR, U-Battery.[10,11] These latter two technologies were talked about in connection with hydrogen production although the proposed designs are only expected to operate at 750°C – not hot enough to produce hydrogen efficiently. These two designs are not well enough developed to be submitted for a GDA and they remain, at most, a long-term possibility. Given that none of the six new SMR designs put forward for the GDA process in January 2023 (see Table 1) has received support from the UK government, they must be regarded as long shots. The most realistic contender for orders in the next decade is the Rolls Royce design, which Rolls Royce claims is essentially ready to be built.

The Rolls Royce design was announced in 2017 with few design details revealed. In evidence to a UK parliamentary select committee, the cost and risk of getting from a conceptual design to a saleable design was made clear in the conditions they demanded the government met if they were to proceed with the design. These included:[12]

- Match funding (at a minimum) up to the end of the licensing phase.
- A GDA slot.
- A suitable site to develop a First of a Kind.
- A guaranteed UK electricity market of 7GW.

It also asked that only one SMR technology be pursued and that, if an overseas technology was chosen, Rolls Royce should be the UK partner. Agreeing to these conditions – especially the need for 7GW of orders which realistically could only be given by the

The Olkiluoto nuclear reactor site in Western Finland.

government for reactors owned by them – would represent an extraordinary gamble on a design that is still in its infancy. In November 2020, the government allocated its £18m, matched by the Rolls Royce consortium, to develop a concept design. This phase was concluded a year later when the project moved to a second phase, to further develop the concept reactor design enough to allow it to pass through the GDA process. This phase was backed by a £210m grant from the government matched by £250m from private sector investors. In April 2022, the government instructed the nuclear regulator, the ONR, to begin the GDA. While this funding has kept the project going so far, it represents only a small fraction of the cash needed to bring the design to commercial status. The government will be increasingly unwilling to commit more money to the technology while its economic and technical viability remains unproven, while the Rolls Royce-led investors will be reluctant to commit more of their own funds unless there is a guaranteed market.[13]

Rolls Royce appears to have recognised the implausibility of its demands and was reported to be requiring guarantees from the government for only four orders claiming it could supplement this with export orders. It is hard to believe that export customers would place orders before the technology had been well demonstrated in the UK. Giving Rolls Royce exclusive rights to the UK market was clearly not politically credible. Nevertheless, Rolls Royce is ramping up its promotional effort aimed at convincing the public its reactor design was ready to go. Committing to this would release a bonanza of jobs, the company claims, at the construction sites[14] and at the sites where the production lines would be installed, and would open up a large export market.[15] By the start of 2023, the UK government had not agreed to Rolls Royce's demand that it guarantee orders.

Will SMRs be a major contributor to meeting UK's climate change targets?

The selling point for nuclear is that it is a relatively low-carbon source of power that can replace fossil fuel electricity generation in the UK and elsewhere. However, by the time SMRs might be deployable in significant numbers, realistically after 2035, it will be too late for them to contribute to reducing greenhouse gas emissions. Electricity will be the easiest sector to decarbonise and, if the whole economy is to reach net zero emissions by 2050, then this sector will have to reach that point long before then. So SMRs appear to be too little, too late.[16]

However, despite the past failures of nuclear power, there remains an appetite in the British government to give the industry just one more chance despite increasing public scepticism. Pursuing SMRs will require massive underwriting by consumers and taxpayers, and it remains to be seen whether the government follows its instinct to continue supporting the sector or whether the amount of public money at risk makes such a decision politically impossible.

The claims being made for SMRs will be familiar to long-time observers of the nuclear industry: costs will be dramatically reduced; construction times will be shortened; safety will be improved; there are no significant technical issues to solve; nuclear is an essential element to our energy mix. In the past such claims have proved hopelessly over-optimistic and there is no reason to believe things would turn out differently this time. Indeed, the nuclear industry may well see itself in the 'last-chance saloon'. The risk is not so much that large numbers of SMRs will be built, they won't be. The risk is that, as in all the previous failed nuclear revivals, the fruitless pursuit of SMRs will divert resources away from options that are cheaper, at least as effective, much less risky, and better able to contribute to energy security and environmental goals. Given the climate emergency we now face, surely it is time to finally turn our backs on this failing technology?

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16 The Conservative government has a target to decarbonise the electricity sector by 2035, the Labour Party has a target to reach this by 2030 while the UK's National Grid Company scenarios foresee decarbonisation by 2032–34.