SMALL MODULAR REACTORS

The compact future for nuclear power

An artist's rendering of the SMR design visible from a nearby road.

Photo: Rolls-Royce

A new kind of nuclear power station could be producing low carbon power for the UK grid within the next 10 years. It is being designed and developed by a consortium of engineering companies and research institutions, writes *Tim Chapman*.

In avoiding the financing hurdles of large-scale infrastructure and power projects – and exploiting the advanced manufacturing technologies used in other sectors – the UK's small modular reactor (SMR) concept promises to play an affordable and flexible role in the drive towards net zero emissions.

The UK SMR is a compact power station design, based on established pressurised water reactor (PWR) technology, and generating 440 MW of electricity – enough to meet the current demands of a city the size of Leeds.

The entire plant is being designed as a number of modular sub-assemblies which will be manufactured in factories and transported to site for rapid assembly inside a weatherproof canopy. This will cut costs and project risks by avoiding weather disruption, and also secure efficiency savings by using streamlined and standardised manufacturing processes for all the reactor's components.

The consortium – which includes Assystem, Atkins, BAM Nuttall, Jacobs, Laing O'Rourke, the National Nuclear Laboratory (NNL), the Nuclear Advanced Manufacturing Research Centre (Nuclear AMRC), Rolls-Royce and TWI – aims to have its first power station in operation around 2030. That's a demanding timeline, considering the engineering and supply chain challenges of designing and producing a first-of-its-kind reactor. The UK SMR will also have to go through the UK's generic design assessment (GDA) and site approval process.

As well as helping meet the government's net zero commitment, development of the UK SMR could provide a major economic fillip. By 2050, a full UK programme of up to 16 of these power stations could create up to 40,000 jobs and £52bn of value to the country's economy. Developing an SMR in the UK could also create an estimated £250bn of exports – Rolls-Royce is already working with Turkish utility EUAS International on behalf of the consortium, to explore SMR deployment there.

With an initial £18mn match-funding awarded from the UK government's Industrial Strategy Challenge Fund in November 2019, the consortium members are now preparing the design to enter the GDA process and they're making final decisions on which innovations to pursue and realise.

Small is enough

The UK SMR is just one of around 50 competing designs of small modular reactor in development around the world. Some come from established reactor designers – Westinghouse, for example, is developing a 225 MWe modular PWR, largely based on proven technologies deployed in its AP1000 design. Others are from new entrants such as US-based NuScale Power, whose Power Module is a 50 MWe pressurised water reactor and generator, designed to be deployed in clusters of up to 12 per site.

As defined by the International Atomic Energy Agency, SMRs are advanced reactors producing up to 300 MW of electric power (the UK SMR qualifies with its two reactors of 220 MWe each) that can be largely built in factories as modules to minimise costly onsite construction.

Initial cost modelling suggests that SMRs may not be significantly cheaper, in terms of capital cost per megawatt output, than the current generation of gigawatt-scale reactors. They should however be much more affordable to build, by avoiding the huge upfront costs and decades-long development times of current reactors. An initial SMR power station would be a fraction of the cost of a gigawatt-scale new build, could be built in four or five years and, once operational, would generate revenue to help finance additional units.

Because SMRs are designed to be made in factories, manufacturers will be able to use lessons learned from other sectors such as aerospace and oil and gas to drive down costs and exploit advanced manufacturing techniques which aren't approved for current reactor designs.

The UK SMR consortium is targeting a cost of £1.8bn per 440 MW power station by the time five have been built, with further savings possible. That translates into a delivery price for baseload electricity of between £40 and £60 per MWh, a similar price to offshore wind but without the additional large costs of energy storage or backup generation required for intermittent renewables.

With the UK's net zero commitments likely to require a quadrupling of low carbon electricity generation by 2050, SMRs have a vital role to play in the energy mix. They are intended to complement the current generation of gigawatt-scale reactors, rather than be a substitute – and, as noted by engineering group Atkins in its recent *Engineering Net Zero* technical report, the UK's capability to deploy new designs of SMR and other advanced reactors will be seriously threatened if gigawatt-scale newbuild is curtailed.

To provide secure low carbon power, while maintaining essential skills and supply chain capabilities, we need both.

In the optimal net zero scenario outlined by the Energy Systems Catapult in its *Innovating to Net Zero* report, a combination of SMRs and large reactors will produce half of all electricity for the UK. The report notes that SMRs can also potentially play a role in directly decarbonising domestic and industrial heating through combined heat and power plants linked to district heating schemes.

This scenario would need SMRs located close to major population centres, which would require regulatory changes as well as a shift in social acceptance of nuclear power.

To start with, it's likely that any UK SMR will be built on a current nuclear licenced site, such as the former Magnox site at Trawsfynydd in North Wales or Moorside in Cumbria.

Modular thinking

The key to making SMRs economically viable lies in using advanced modular manufacturing techniques to drive down production costs while ensuring quality and on-time delivery.

SMRs offer the nuclear industry the opportunity to become more like other high value, low volume manufacturing sectors such as aerospace or oil and gas, where the UK has proven expertise. To achieve this, the SMR design must allow economies of volume when making 50 or 100 units, and manufacturers will need to demonstrate high learning rates as production ramps up.

> ***SMRs may not be significantly cheaper, in terms of capital cost per megawatt output, than the current generation of gigawatt-scale reactors – but should be much more affordable to build***

UK manufacturers in other high value sectors already use a range of processes which have not yet been approved by nuclear codes. By working with manufacturers, technology providers and research centres, SMR developers will be able to include new processes into the safety case for their new designs and use techniques such as design for manufacturing and modularisation to build in production efficiencies.

Manufacturing processes which could be exploited for SMRs include a range of machining techniques such as robotic machining, single-platform machining and cryogenic cooling, as well as supporting technologies including intelligent fixturing and on-machine inspection. Advanced joining and near-net shape manufacturing processes such as electron beam welding, diode laser cladding, automated arc welding, bulk additive manufacturing and hot isostatic pressing also offer significant savings in cost and lead time.

Many of these technologies are already being developed for civil nuclear applications by the AMRC. The centre's advanced machine tools and fabrication cells have been specified to work on representative-size parts for gigawatt-scale reactors, which means that they can also produce full-size prototypes for SMRs.

Over the past three years, the Nuclear AMRC has worked with the US-based Electric Power Research Institute (EPRI) to develop new manufacturing and fabrication methods for SMR pressure vessels. The project aims to reduce the total time needed to produce a vessel, based on NuScale's Power Module design, from three to four years to less than 12 months. The project is funded by the US Department of Energy and involves industrial partners on both sides of the Atlantic, including Sheffield Forgemasters.

In the first phase of the four-year collaboration, the Nuclear AMRC developed diode laser cladding and electron beam welding techniques on vessel sections made from hot isostatic pressing of metal powder. The electron beam project successfully demonstrated that girth welds of large vessel sections can be completed in less than 60 minutes.

Bringing innovation to market

Turning the UK SMR into commercial reality, with a first plant connected to the grid by 2030, is undoubtedly a major challenge. But with the breadth of expertise in the consortium and the backing of government, it is a truly national endeavour with the potential to deliver significant economic and environmental benefits.

For the next phase of development, the consortium is seeking match funding of £217mn, a similar amount to the recent government award to UKAEA for early development of its STEP fusion reactor. That would underpin full-scale development of the UK SMR programme, and trigger economic benefits across the UK through early investment in the supply chain.

The much-anticipated Energy White Paper is expected to set out the proposed role for SMRs in the UK's energy mix. Achieving their full potential will also require regulatory changes, including an amendment of the national policy statement on nuclear power generation to allow power stations below the current 1 GW output threshold; an allocation of appropriate regulated sites for SMR deployment; and additional enabling legislation.

The Office for Nuclear Regulation is developing its understanding of small and advanced reactor technologies to ensure that its team is ready to assess these innovative reactor designs. An early GDA review for the UK SMR would allow rigorous independent scrutiny of the design and provide an internationally respected benchmark to support export of the technology.

Responding to the continuing climate crisis and reaching net zero will require a national and international effort on a similar scale to the ongoing response to the coronavirus pandemic. The UK SMR is an achievable and affordable part of that effort. ●

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