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Developing UK strategy for nuclear SMRs

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Giorgio Locatelli, Tristano Sainati, Benito Mignacca

Nuclear Small Modular Reactors (SMRs) can play a role in UK decarbonisation, providing low-carbon electricity and heat. SMR investments are more affordable and less risky, therefore attracting a wider range of potential investors. The UK government needs to develop a consistent strategy to support UK SMRs.

Overview

- **Compared to large nuclear reactors, Small Modular Reactors (SMRs) could be cheaper, easier to finance and a less risky investment.**
- **However, our research suggests that novelty, construction cost risk, regulations, and long term economic uncertainty can be key barriers for SMR construction.**
- **We recommend the UK government develop short to medium term policy and regulation to support the development, licensing and construction of the first SMRs with substantial investment. A long-term policy should support market mechanisms to build and operate a fleet of standardised SMRs in the UK.**

In order to meet climate change commitments, the UK energy sector needs to decarbonise. Nuclear energy is a low-carbon energy source that can alter its output to match demand, as well as providing heat for non-electricity energy needs, potentially playing a valuable role in decarbonisation.

Multibillion megaprojects are financially risky investments, historically often delivered over-budget and late. Traditional large nuclear reactors megaprojects are not an exception, as recently seen in the EU and USA (Locatelli, 2018), leading to significantly higher cost of financing, and thus higher cost of electricity. Decreasing the size of investment (e.g. building SMRs) is a strategy to reduce the investment risk and cost of financing, so nuclear energy is more financially sustainable.

The Government has indicated their commitment to nuclear energy in their **ten point plan for a green industrial revolution**. This has been supported by an announcement in the **2020 spending review of investment of £525 million for**

nuclear energy projects, including small modular reactors and next generation advanced modular reactors.

It is important the UK Government clarifies its strategy for future deployment of SMRs. It must decide whether to support their development, which will largely determine if the UK will be an importer or exporter of SMRs. If the Government decides to support domestic reactor vendors, decisive and timely actions are required. This could include laying the foundations for the early deployment of SMRs in the UK to gain credibility in the international market. A UK position of 'first mover advantage' is possible and an essential aspect to gain shares of the SMR market globally.

The case for nuclear power

In June 2019, the UK Parliament approved legislation to reduce carbon emissions to net-zero by 2050. Progress since 1990 has been good with greenhouse emissions reduced by in excess of 43% (BEIS, 2020). However, since the UK started with a high carbon base (e.g. coal), decarbonising the next 40% might be harder than the previous 40%. As of 2018 the biggest source of greenhouse gas emissions is transport (28%) but decarbonising by electrifying transport, will further increase the demand for electricity.

Net-zero carbon electricity can be produced both by renewable resources (e.g. wind, solar, hydropower) and nuclear power plants. These technologies have unique qualities and therefore combinations of all of them may be needed on the power network. Wind and solar plants are becoming cheaper to construct and operate, but depend on primary sources that are intermittent, and uncorrelated to the need of electricity. For the proper operation of the electrical grid and the systems connected, the production of electricity needs to match the demand very closely. Today, the variability of renewables is mostly compensated by gas plants. However, the increasing share of electricity generated by renewables, and the phase out of coal and gas, will require more elaborate and expensive solutions, including energy storage and demand management.

Renewables are cost-competitive in terms of pure "generation cost" (usually measured as Levelised Cost of Electricity) but they need also backup costs (e.g. the cost to provide electricity when power plants are not working), balancing costs (e.g. reserves to ensure system stability) and possibly storage cost (e.g. hydrogen or batteries). In the UK, with scarce hydroelectric resources, nuclear power plants are the only available technology that can produce net-zero carbon electricity "on demand", with lower backup and balancing cost with respect to renewable plants. As today, nuclear power produces about one quarter of UK electricity, however all but one of these power stations will close by 2030.

What are SMRs

The International Atomic Energy Agency (IAEA) defines SMRs as "*newer generation reactors designed to generate electric power typically up to 300 MW whose components and systems can be shop fabricated and then transported as modules to the sites for installation as demand arises*" (IAEA, 2020). SMRs are a family of technologies and design philosophies. SMRs include water cooled reactors, which account for the vast majority of reactors in operation and under construction. This technology is well understood and the necessary elements (e.g. the nuclear fuel cycle) exist or require relatively little technological development. Still, there are no SMR designs certified for UK deployment and the designs require detailed engineering and development. It is unlikely that any of these designs will be in a position to produce electricity in the UK before 2030 unless substantial investments and political commitments are made. Other technologies (e.g. molten salt) have technical advantages, but far less construction and operating experience. They might require substantial R&D and may not be deployable until after 2030 (Locatelli et al., 2013; Mignacca and Locatelli, 2020a).

The case for SMRs

Large reactors, like Hinkley Point C in the UK, incorporate the technological lessons learned from over the last 60 years. Due to their size, they require massive multibillion investments and long construction times (a decade is common), leaving them prone to large budget over-runs and delays in construction (Locatelli, 2018). Consequently stakeholders are extremely cautious about investing. In the UK, in the last 15-20 years, several nuclear plants have been proposed, but only Hinkley Point C has started construction.

The challenge of delivering megaprojects is not limited to nuclear power plants. The majority of megaprojects are affected by cost overruns and delays in planning and construction, as the vast literature on this shows (Locatelli, 2018). In this regards, cost escalation is common for long-planned, multi-billion pounds, one-of-a-kind infrastructure projects. The literature, supported by several empirical studies, shows that the larger the project, the greater is the likelihood and magnitude of cost overrun and experience of a delay. The uniqueness in design and investment size are the critical drivers and predictors for likelihood and magnitude of cost overrun and delay of construction projects.

SMRs are designed to be small and standardised so that they can be largely manufactured in series in factories, which is less exposed to external factors such as the weather resulting in poor productivity as characterised by megaproject construction sites (Mignacca and Locatelli, 2020b). The smaller size means the financial cost and risk are significantly reduced compared to traditional nuclear plants because the investment required for an SMR is a correspondingly small. SMR construction time is shorter, allowing for earlier revenues which increase investor confidence, which further lower the financial cost and risk. Lower financial cost and risk make investments in nuclear more sustainable and more able to attract private investors. Private investors need a degree of certainty, therefore are unlikely to finance the first SMR units, but could support the financing of a subsequent SMR fleet. SMRs are ideal for co-generation of electricity and heat particularly if built close to cities or industrial parks (Locatelli et al., 2018).

Barriers to SMR deployment

For the past 20 years there has been an interest in SMRs for electricity and heat. The latest IAEA report (IAEA, 2020) identifies 72 reactor designs, developed in 18 countries, at various stages of development; however, only 2 units are in operation, and the vast majority still at the design stage. We identified the main elements hindering SMR construction by collecting opinions from around 100 nuclear experts (Mignacca et al., 2020).

Financing of the first unit(s): Although SMRs are a less risky investment in terms of value, compared to larger reactors, the lack of a "first unit" and the lack of a supply chain create a higher perceived investment risk.

Economics: Availability of cheaper alternative technologies to generate electricity and low wholesale price of electricity are a threat to SMR economics and competitiveness in the electricity market. Today the electricity market considers only generation costs, disregarding backup, balancing and storage costs, penalising plant that can "produce electricity on demands" like nuclear power plants.

Technological readiness: The lack of a first unit, technology readiness and supply chain availability are barriers related to SMR technological readiness (and in a certain extent to SMR financing).

Licensing and regulatory constraints, lack of political support: These are barriers related to SMR policy and regulation readiness. Political support in developing specific SMR licensing processes could be a solution to overcome these barriers and lower perceived investment risk by investors.

Public acceptance: Public acceptability of nuclear power may be improved with SMRs because of better security, less environmental impact, proliferation resistance, passive safety system and massive deployment. However SMRs can also be perceived as "novel and therefore more risky".

Licensing and regulations

The licensing process can be a key hurdle for SMRs (Sainati et al., 2015). Nuclear installations, including SMRs, are subjected to a strict regulatory control concerning nuclear safety, security, safeguards and environmental protection.

In the UK, the Office for Nuclear Regulation (ONR) grants, amends, suspends and revokes nuclear site licenses. The nuclear site license allows the licensee to undertake activities such as the construction, testing, and operation of nuclear power plants. The licensing system in the UK is relatively unique with a high degree of flexibility for ONR and the licensing applicant. The applicant is comparatively free to propose new reactor designs but needs to provide convincing "safety case" to the ONR to obtain the nuclear site license. This process is uncertain and can postpone the construction and operation of nuclear power plants by months or years.
The ONR is committed to reducing the time and perception of investment risk for stakeholders with non-binding guidelines, early meetings, and issuing Generic Design Assessments (GDAs). The GDA is a regulatory assessment providing preliminary and general safety assessment on new reactor designs. This approach reduces the perceived investment risk and promote licensing applications from alternative reactor designs, including SMRs. GDA does not substitute the nuclear site license and is not formally binding, even if the expectation is that it anticipates part of the regulatory assessment. The ONR has resource constraints, therefore an SMR design needs political support to secure the possibility of being scrutinise for a GDA. The engineering and experimental work related to a GDA is expensive, financial support is therefore important.

Financial arrangements

The deployment of SMRs is considered as the business under which the nuclear sector will evolve and renovate, including the financing approach, even if challenges remain (Sainati et al., 2019). For these reasons, the UK Department for Business, Energy and Industrial Strategy (BEIS), in 2018, convened an independent Expert Finance Working Group to produce an assessment of the market framework for financing SMRs (EFWG, 2018). This initiative identified alternative financing structures and models, including alternative forms of project financing, bespoke models inspired by existing projects in the UK and overseas, in nuclear and other sectors. The study highlights that the role of Government can be pivotal for promoting SMRs, particularly for the first units deployed.

The international dimension

Many countries are interested in building SMRs, however most of them are not keen to buy an SMR that has not been already successfully built elsewhere because it is perceived as a risky investment. Most SMR vendors aspire to gain significant market share because it is essential to manufacture at scale and reduce costs. Economic feasibility, is often reliant on the ability to manufacture and install many SMRs in multiple sites. Under this view, SMRs could become cheaper thanks to a sort of "mini-mass production" similar to aircraft production.

Many reactor vendors are supported by their respective Governments. For instance, Russia has a long tradition in the nuclear sector and it is aiming to export SMRs along with providing extensive financial and technical support. China aims at producing cost competitive and reliable SMRs, offering a competitive financial package to prospective buyers/importers of SMRs. The USA is traditionally oriented toward the open electricity market and does not promote their domestic reactor vendors directly, but does so indirectly, e.g. with grants for companies developing SMR. Vendors such as NuScale are gaining significant interest and reputation due to their ability to obtain nuclear licenses in the USA.

The UK has some advantages including:

- A long tradition of developing nuclear power plants.
- A flexible regulatory process that it is open for alternative reactor technology.
- An excellent reputation for safe nuclear installation.
- Long established political and commercial relations with foreign countries, particularly in the Commonwealth.
- Reactor vendors such as Rolls Royce with extensive experience in small nuclear reactors (a technology comparable to SMRs) which are historically used for military applications such as the nuclear submarines.

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Recommendations

Our research indicates that to support SMR deployment the UK government needs to develop a long-term energy policy for nuclear energy aiming at the construction of a fleet of identical SMRs, with a standard supply chain involved in the construction, operation and decommissioning. We recommend the following actions:

Developing a SMR strategy

- **Pick a winner.** The UK government needs to select and support a specific design for the UK. This design will need financial backing during the design, licensing and construction of first units. There are several financial mechanisms available for the UK government to support this design. The design should be based on a proven technology (i.e. light water reactors) and developed by a company with established know-how, ideally in the UK.
- **Invest in the design.** It could take about £1 billion from the conceptual reactor design to pass through the GDA. It is extremely unlikely that such money can be entirely raised in the market. A share of this money needs to come from the UK government.
- **Invest in the "British" supply chain.** To design and build a nuclear reactor requires a network of organisations: manufacturers, regulators, service providers, universities, etc. These companies need to invest to build capacity, including training people. They need UK government support.
- **Support the construction of the first unit(s).** It is extremely difficult to raise capital for a first of a kind nuclear reactor. First unit(s) are perceived as risky investments and are needed to "prove the design". The UK government should support, financially, the first unit(s). In particular, the Government should considered an effective mix of Government debt guarantee, contract for difference and direct investments (e.g. equity contributions).
- **Take a programme perspective, not a project one.** The advantages of SMRs won't be realised at a single unit scale. SMRs need to be conceived as a programme, both for the UK needs and exports. The UK government should develop partnerships at international level for building SMRs.
- **Take a life cycle perspective.** SMRs are designed to operate 60 years. This means that between construction, operation and decommissioning the life cycle can easily be a century. The UK government needs to understand how it is possible to both create value and distribute value for SMRs across the entire life-cycle.

About the authors

Giorgio Locatelli is a Professor of Project Management and expert on energy megaprojects in the School of Civil Engineering, University of Leeds. He was a member of the BEIS 2018 Expert Finance Working Group.
Email: g.locatelli@leeds.ac.uk

Tristano Sainati is an expert of financing and contracting in infrastructures, also based in Civil Engineering at Leeds.
Email: t.sainati@leeds.ac.uk

Benito Mignacca is a PhD candidate working with Professor Locatelli on energy megaprojects.
Email: cnbm@leeds.ac.uk

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Tel. +44 (0)113 2431751
policyleeds@leeds.ac.uk
leeds.ac.uk/policy-leeds
@policyleeds

Policy Leeds
University of Leeds
Leeds, United Kingdom LS2 9JT