

SMRs promoters must face up to some very inconvenient truths

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1 June 2018

At the end of October 2015, some 130 nuclear company representatives, R&D specialists and innovators, along with some and key policy players, met in the shadow of The Tower of London for *Nuclear Energy Insider*'s two-day First Small Modular Reactor (SMR) UK summit. (<http://www.nuclearenergyinsider.com/smr-uk/>)

Nearly a year earlier, the UK's National nuclear Laboratory had released a 64-page technical appraisal of SMRs – titled a *Small Modular Reactors (SMR) Feasibility Study* for deliberation among the nuclear technology community. (<http://www.nnl.co.uk/media/1627/smr-feasibility-study-december-2014.pdf>)

Westinghouse's roving global chief, Jeff Benjamin, vice president for new plants and major projects, chose the Summit to unveil his company's plans to offer the UK government a partnership in the deployment of small modular reactor (SMR) technology, "a move that would advance the UK from being a buyer to a global provider of the latest nuclear energy technology, According to a Westinghouse statement. The proposal is intended to complement the current [Phase 2 SMR study](#) that the UK government had recently commenced.

Westinghouse had already done considerable research into SMRs, according to a presentation by the company to an IAEA forum – "10TH INTERNATIONAL CONFERENCE: NUCLEAR OPTION IN COUNTRIES WITH SMALL AND MEDIUM ELECTRICITY GRIDS" in Zadar, Croatia on the 'Westinghouse Small Modular Reactor (SMR) Program' (http://www.iaea.org/inis/collection/NCLCollectionStore/_Public/46/136/46136338.pdf)

As proposed, the partnership was planned to be structured as a UK-based enterprise jointly owned by Westinghouse, the UK government and UK industry, in which Benjamin revealed to the Summit it would be expected the British government would take an equity stake, which could be reduced as the risk profile reduces.

(<http://www.westinghousenuclear.com/About/News/View/Westinghouse-Proposes-Joint-SMR-Development-with-UK>)

In an outspoken presentation, Benjamin, who asserted he was not a big corporate profit –driver, said for Westinghouse “nuclear was not a be all-end all technology,” and conceded that despite Westinghouse planning to base its SMR operations at its UK base in Springfields nuclear fuel plant near Manchester, some of the Westinghouse SMR equipment may be covered by restrictive US export controls.

A few months later, Westinghouse announced that it was working with the UK’s *Nuclear Advanced Manufacturing Research Centre (Nuclear AMRC)* to “explore the most effective way to manufacture” Westinghouse SMR Pressure Vessels (RPVs) in the UK. The US company stated “The manufacturing study will focus on RPVs – one of the largest and most demanding parts of any reactor. The Nuclear AMRC will provide a professional, independent assessment of the current Westinghouse Small Modular Reactor RPV design, and determine an optimal manufacturing solution. Nuclear AMRC has extensive experience in design for the manufacture of large complex parts for safety-critical applications, drawing on broad academic and industry knowledge.” (“Westinghouse to Promote Advanced U.K. SMR Manufacturing Efficiencies, 3 March 2016; <http://www.westinghousenuclear.com/About/News/View/Westinghouse-to-Promote-Advanced-U-K-SMR-Manufacturing-Efficiencies>)

Mick Gornall, UK managing director for Westinghouse, subsequently said 18 months later: “The UK is an extremely important market for Westinghouse. We believe that we can deliver even greater economic benefit to the UK through our nuclear new build projects, in addition to the £100m spent annually by the company in the local economy. More than 85 per cent of our SMR’s design, licence and procurement scope can be delivered by the UK.

Another Westinghouse spokesperson added: “The deployment of Westinghouse’s SMR in the UK would help safeguard these skills for the future, and ensure the UK supply chain continues to benefit from the £100m spent annually by the company in the local economy.”

(“Moorside reactor company Westinghouse makes development call,” Whitehaven News, 29 September 2017; www.whitehavennews.co.uk/news/business/Moorside-reactor-company-Westinghouse-makes-development-call-4fe2546f-68ba-4ea2-8b55-fcdd88e1bf4e-ds)

But despite this optimistic promotion, (*Next Start Alliance*, www.nexstartalliance.com/Default.aspx) Westinghouse gradually lost interest in SMRs for reasons of escalating costs and announced that it was pulling back from UK SMR development, having already dropped out of US SMR development.

(“Westinghouse backs off small nuclear plants,” Pittsburgh Post-Gazette, 14 February 2014; <http://www.post-gazette.com/business/2014/02/02/Westinghouse-backs-off-small-nuclear-plants/stories/201402020074>)

Yet on 8 January 2014, the popular US science monthly, *Scientific American*, carried an article on SMRs entitled 'Is There a New Nuclear Kid on the Block?'

(<http://www.scientificamerican.com/article/is-there-a-new-nuclear-kid-on-the-block/>)

where it quoted the World Nuclear Association's most optimistic estimate that there could be as many as nearly 100 SMRs up and running by 2030, suggesting some 20 designs at various stages of development were already underway. It is clear the SMR world is regularly in flux.

British opportunities

On 26 February 2015 the British Government's published its response to the House of Commons Energy Committee report on Small Nuclear Reactors, which was released on 17 December 2014. The response stated the UK Government recognised the long-term potential of SMRs as an additional source of generation, which is why it commissioned the SMR feasibility study ...published by the [UK] National Nuclear Laboratory (NNL) in December 2014, [which] provided an initial evidence base for SMRs and whether there is a role for SMRs in the UK."

(http://www.nnl.co.uk/media/1048/nnl_1341842723_small_modular_reactors_-_posit.pdf)

It recommended a more in-depth analysis to establish the robust evidence base needed to enable a policy decision on SMRs and help Government decide whether it wants to pursue a UK SMR programme. This second phase of work has been underway for several years. (www.publications.parliament.uk/pa/cm201415/cmselect/cmenergy/1105/110504.htm)

The SMR Summit heard from three key British contributors to this work. Mike Middleton, strategy manager for nuclear at the public-private *Energy Technologies Institute*, which published its own interesting scoping study on *The role for nuclear within a low carbon energy system* (<http://www.eti.co.uk/wp-content/uploads/2015/09/3511-ETI-Nuclear-Insights-Lores-AW.pdf>) in early October 2015.

And also from Dame Professor Sue Ian, former executive director of technology for British Nuclear Fuels (BNFL) and now a chair of the UK Nuclear Innovation and Research Advisory Board (NIRAB) (<http://www.nirab.org.uk/about-us/about-nirab/>) and several times from Dr Gordon Waddington, a 35-year veteran of Rolls Royce, ending up as President for civil nuclear research, who is also a past Chairman of the Industrial Advisory Board Imperial College (London), and who drafted the 64-page UK feasibility study on SMRs, published by UK National Nuclear Laboratory (<http://www.nnl.co.uk/media/1627/smr-feasibility-study-december-2014.pdf>).

Waddington claimed as "it was always going to be difficult for the UK" to be directly involved in the large (GW) reactors development – as there are several major global (ie non –British) players- SMRs are "an option for the UK to enter the reactor market." But, he stressed, the economic climate has to be right.

Dame Sue, who chaired a closed UK-only workshop convened by the UK Department of Energy and Climate Change (DECC) - which led to the 2014 UK NNL SMR feasibility study- made a strong appeal for Government investment in new nuclear research

including for SMR R,D&D, especially when the DECC internal techno-economic assessment (TEA) study is complete.

Warning that the UK regulator needs serious technology to assess – “stuff not fluff “ as she dubbed it- she said NIRAB has made a bid for substantial resource support from the Treasury (finance ministry) in the UK Government in the UK *Comprehensive Spending Review*.

The ETI is arguing the UK could accommodate up to 75 GW of new nuclear in the UK to help decarbonize the UK power generation sector. Using a model developed by ETI (Energy System Modelling Environment, ESME), Middleton said SMRs could provide some 63 GW of this new capacity, especially if they were developed in conjunction with a planned national heat grid program for domestic district heating and industrial process heat, to enhance the SMRs' economic competitiveness.

It became clear from Summit discussions that many considered there would be considerable siting problems for so much capacity especially if greenfield sites beyond Government-owned locations, such as surplus defense department land, and existing nuclear installation locations, were sought.

Professor Andrew Sherry, chief science and technology officer for UK NNL, in a presentation on public perceptions of new nuclear, flagged up several key new siting and public perception issues with which promoters of SMRs will have to engage. These include:

- SMRs will have new designs and concepts;
- prototypes will provide essential learning tools;
- the costs are at present unknown, but they will come down with modular production; they could have a dual power and heat production purpose;
- their siting will demand different engagement with communities than GW size plants, as many SMRs will inevitably be built much closer to centres of concentrated population.

He pointed out that DECC's *Public Attitudes Tracker* survey of energy technologies, that “support for the use of nuclear energy has dropped to its lowest level so far during the tracker. At ‘wave 14’ one third (33%) supported this, whilst around a quarter (24%) were opposed. However, although support was higher at this point in previous years - 36% in June 2014, 37% in June 2013.”

NNL delivers a vision for innovation

<http://www.world-nuclear-news.org/V-NNL-delivers-a-vision-for-innovation-17051801.html>

17 May 2018

Paul Howarth, CEO of the UK's National Nuclear Laboratory (NNL), gives his account of the SciTec 2018 conference held this week in Liverpool, England.

We're under no illusion that the world faces a huge energy challenge as demand continues to grow. The ability to meet future energy needs will become increasingly important as countries also seek to meet environmental targets. In the UK alone, the government has set targets for all new cars to be electric powered by 2040 and for carbon emissions to be reduced by 80% before 2050. This will put enormous pressure on our electricity requirements - demands that renewable energy sources alone are unlikely to be able to fulfil.

Nuclear has a significant role to play in helping to meet these energy requirements but it has its own challenges that it must address first if it is to protect its future. To build confidence in nuclear, there's a strong belief that project timescales and costs need to be controlled and significantly reduced. There's also a dawning realisation that we will not be able to achieve that by working in isolation.

Taking responsibility for innovation

That's why collaboration and a willingness to disrupt traditional approaches and thinking were the resounding messages at *NNL SciTec 2018*. There was a sense that the nuclear industry can no longer afford to operate in siloes and keep the challenges we face to ourselves - hidden away from potentially industry changing opportunities to innovate. If we're willing to embrace the spirit of open-mindedness, innovation can come from unlikely sources. This was a sentiment expressed by Professor Andrew Sherry, NNL's chief science and technology officer, and backed up by guest speaker Jonathan Brown, director of Cammell Laird, who shared his vision for industries planning together and factoring innovation into those plans.

One of the key objectives of *NNL SciTec 2018* was to demonstrate the results of collaboration in practice, giving tangible examples of projects that are already under way and the benefits they have delivered - as well as highlighting the opportunities for working with a wider range of industries, beyond the traditional scope of the nuclear industry supply chain.

A global vision

NNL is itself well positioned to facilitate collaborative partnerships and act as a conduit for change in the industry. As a government-owned business, the organisation reinvests its profits back into innovations that have seen it develop world leading facilities for analysing materials and managing highly active waste and used fuels. Its

responsibilities include providing vital technical support and innovation to legacy clean-up at Sellafield and naval propulsion and it has delivered billions of pounds worth of savings to the UK economy.

NNL SciTec 2018 is our platform for promoting the worldwide opportunities for nuclear collaboration and for examining how the UK can take a leading position in the global industry. *The innovation happening around advanced small modular reactors (SMRs), for example, offers great potential for increased capacity and savings by significantly reducing build times.* While not a replacement for large units, they can complement projects that are currently under way such as Hinkley Point C, Moorside and Wylfa Newydd.

There is growing traction behind SMRs in this country and, as such, the UK has an opportunity to take the lead globally by developing a collaborative domestic supply chain industry that could provide almost all the components, including the reactors. When combined with the innovations being developed around decommissioning, we're looking at a bright future for nuclear and its prospects for resolving our future energy crisis.

Disrupt your thinking

To make all this possible we need to collaborate, however, and make the case for that nuclear future. That's why NNL welcomed more than 300 attendees, both from the international nuclear sector and from a broad range of other industries to review how the industry can be secured over the coming decades. The only way to do this is by disrupting our current thinking. With that in focus, delegates were challenged to share their existing problems and consider new ways of overcoming them.

Meanwhile, the UK Nuclear Industry Council (<https://www.gov.uk/government/groups/nuclear-industry-council>) - on which Professor Sherry sits - has published a relevant report "Nuclear Energy and Society". Professor Sherry gave preview of "this concordat on public engagement" to the Summit, which he emphasized recognizes the need to take the public concerns about the nuclear industry seriously. To this end, the NIC report aims to ensure that its engagement with the public will be characterised by best practice including:

- Dialogue:** We value two-way communication and will listen to the public voice.;

- Trust:** We seek to build public trust by showing respect and being open and transparent about the challenges we face and the actions we are taking to address them.

•**Clarity:** We ensure that public engagement is characterised by clear, consistent and concise information written or spoken in plain language.

•**Consultation:** We listen to communities and actively consult with them, particularly when our activities impact on daily life.



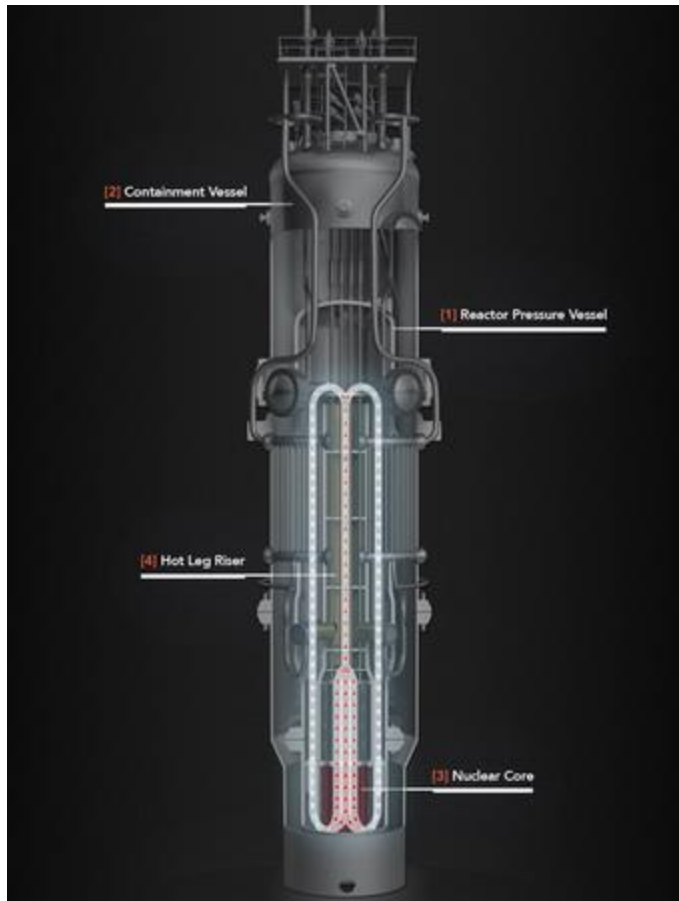
Two Summit speakers on prospective investment in SMRs - Dominic Holt of PWC and Anurag Gupta of KPMG - indicated they considered investors would be more likely to provide support if SMRs made sense in their own power generation terms, and were not complicated by attachment to DH systems, Additionally contributors wondered whether projected SMR costs would be believed in light of huge cost escalations in the currently under construction GW reactors at Olkiluoto in Finland and Flamanville in France

Ron Cameron of UK Trade and Investment observed some of the cost history of [GW nuclear stations] has been “disappointing to put it mildly. First of a kind (foak) reactors have many difficulties:- SMRs will too.” He stressed the big challenge was getting factory modularization to greater than 50% of the total.

Technology showcase

Several would-be suppliers of SMRs have unveiled status reports on designs and development of their own SMR prototypes.

Westinghouse’s



Reactor Diagram (PDF)

NuScale's executive vice president for program development, Tom Mundy, argued that SMRs are part of the energy mix, and should not be regarded as alternatives to big GW reactors. NuScale had he said secured backing of \$217 million from the US Department of Energy for reactor development, based on an early conceptual design by one of NuScale's founders when he worked at Oregon State University a decade ago

Each NuScale Power Module™ is a self-contained module that operates independently of the other modules in a multi-module configuration. All modules are managed from a single control room. The reactor measures 65 feet tall x 9 feet in diameter, and sits within a containment vessel. Design certification is expected by end of 2016. He pointed out the NNL SMR feasibility study last December described the NuScale Module concept as "credible" and deployable within 10 years.

<http://www.nuscalepower.com/our-technology/technology-overview>

He claimed, without supportive evidence, that the levelized cost of power from the NuScale Module would be \$100 MWh, considerably cheaper than the projected cost of the Hinkley C GW reactor. He also erroneously claimed nuclear power produces carbon-free electricity, a common claim by nuclear energy supporters, which is only true if the front- and back –end industrial emissions are ignored. A full carbon footprint of nuclear reactors, including SMRs, shows nuclear to emit significant carbon along its entire fuel cycle. One study, published in the journal Energy Policy ten years ago,

authored by Professor Benjamin Sovacool (then at the University of Singapore, now Professor of Energy Policy at the Science Policy Research Unit (SPRU) at the School of Business, Management, and Economics, part of the University of Sussex), explained the analysis thus:

“It calculates that while the range of emissions for nuclear energy over the lifetime of a plant, reported from qualified studies examined, is from 1.4 g of carbon dioxide equivalent per kWh (g CO₂e/kWh) to 288 g CO₂e/kWh, the mean value is 66 g CO₂e/kWh. The article then explains some of the factors responsible for the disparity in lifecycle estimates, in particular identifying errors in both the lowest estimates (not comprehensive) and the highest estimates (failure to consider co-products). It should be noted that nuclear power is not directly emitting greenhouse gas emissions, but rather that lifecycle emissions occur through plant construction, operation, uranium mining and milling, and plant decommissioning.”

(‘Valuing the greenhouse gas emissions from nuclear power: A critical survey,’ *Energy Policy*, published 2 June 2008; http://www.nirs.org/climate/background/sovacool_nuclear_ghg.pdf)

Perhaps the most novel reactor type is the micro-SMR from British company U-Batteries (www.u-bat.com), with an output of only 4MWe. The concept design suggests a single generation hall for the U-Battery. The company hopes to have the demonstration U-Battery operating by 2023 at the URENCO site at Capenhurst, close to Manchester. A market scoping study by CollinsonGrant -released in April 2014 - suggested that there could be a world market for this micro-SMR of 280 by 2035, including 41 in the UK,

Insecurity proliferated

U-Battery presenter, Dr Paul Harding, a former URENCO MD, was the only SMR promoter to mention security and proliferation concerns with the prospective deployment of thousands of new reactors worldwide, which is an extremely significant omission from the other presentations.

The picture below was created by Westinghouse, and shows a illustration of one of its proposed SMR designs. Note the relatively low security fence is very close to the reactor complex and associated external building, making all vulnerable to determined malevolent actors, such as terrorists, using portable hand held rocket systems



Source: Westinghouse

<http://www.westinghousenuclear.com/New-Plants/Small-Modular-Reactor>

SMRs would inevitably increase **nuclear insecurity**, as their proliferation in numbers would be accompanied by a massive proliferation in nuclear sites and nuclear materials transports, both in the form of fresh unirradiated nuclear fuel and irradiated (spent) nuclear fuel (SNF). Both of these give greater new opportunities for malevolent actors (eg terrorists) to intervene with potentially catastrophic consequences.

Visual demonstration of vulnerability of very robust containment to shape charge attack is more powerful than any number of words. In January 2008, there was a real demonstration test of a Raytheon Shaped Charge, Intended as the Penetration (Precursor) Stage of a *Tandem Warhead System*.

The before and after pictures below demonstrate super strengthened store to simulate an SNF transport cask in transit before and after being targeted directly by a widely available precision-guided penetrator missile, to demonstrate their vulnerability to terrorist intervention





It is both interesting and disturbing that the Commission background paper for the ENEF 2018 in Bratislava does not address this key aspect of SMR roll-out.

Current issues

The UK still seems very keen to support SMRs, led by defence and aerospace industry manufacturer, Rolls Royce, now separate from the luxury car maker of the same name

In September 2017, the company launched its promotional 28-page report

<https://www.rolls-royce.com/~media/Files/R/Rolls-Royce/documents/customers/nuclear/a-national-endeavour.pdf>

Here are some of the projected benefits of SMR development promoted by Rolls Royce:

- Creation of **40,000** jobs through peak construction period and sustained level of >15,000 jobs. Requirement for additional skilled individuals to design, construct and operate expanded nuclear fleet
- Investment of >£100m in research & technology to develop the UK SMR power station design. Sustained investment of ~£40m per annum through life of fleet
- Overall benefit to the UK economy of more than £100Bn in Gross Value Added (GVA). Majority of benefit spread across UK regional areas.
- Construction of 16 new nuclear power stations nationwide to support safe, secure and cost-effective provision of low-carbon electricity.

RR perpetuates the myth that nuclear, including SMRs, is a low carbon power generator.

Here is how it was covered in one conservative British newspaper:

'Mini' nuclear reactors could help solve Britain's energy crunch and cut a third off bills, ministers hope

Daily Telegraph, 9 September 2017

www.telegraph.co.uk/business/2017/09/09/go-ahead-mini-reactors-energy-crunch-looms/

Ministers are ready to approve the swift development of a fleet of “mini” reactors to help guard against electricity shortages, as older nuclear power stations are decommissioned.

The new technology is expected to offer energy a third cheaper than giant conventional reactors such as the ongoing Hinkley Point in Somerset.

Industry players including Rolls-Royce, NuScale, Hitachi and Westinghouse have held meetings in past weeks with civil servants about Britain’s nuclear strategy and development of “small modular reactors” (SMRs).

A report to be published by Rolls-Royce in Westminster this week claims its consortium can generate electricity at a “strike price” – the guaranteed price producers can charge – of £60 per megawatt hour, two thirds that of recent large-scale nuclear plants.

SMRs are a fraction of the size and cost of conventional plants and were earmarked for funding from the £250m pledged by the Government in 2015 to develop “innovative nuclear technologies”. It is hoped a fleet of these small reactors could be cheaply produced to guarantee Britain’s energy supply, with further ambitions for the technology to be exported worldwide.

Whitehall sources confirmed that officials from the Department for Business were whittling down proposals from consortia keen to work with government to develop SMRs, with an announcement on the final contenders for funding expected soon.

The report to be published by Rolls-Royce, entitled “*UK SMR: A National Endeavour*”, which has been seen by *The Telegraph*, claims SMRs will be able to generate electricity significantly cheaper than conventional nuclear plants.

The mini reactors are each expected to be able to generate between 200 megawatts and 450 megawatts of power, compared with the 3.2 gigawatts due from Hinkley, meaning more of them will be required to meet the UK’s energy needs.

This report was followed by another SMR report -from London-based think tank, *Policy Exchange* - earlier this year, which was sponsored by Rolls Royce, although this is not clear from the report itself. It merely makes the general acknowledgment that ‘Policy Exchange is thankful to Rolls-Royce for their support of the Energy and Environment Unit’ [at PE]

Policy Exchange describes itself as “the UK’s leading think tank. We are an independent, non-partisan educational charity whose mission is to develop and promote new policy ideas that will deliver better public services, a stronger society and a more dynamic economy.”

This report, titled ‘*Small Modular Reactors: The next big thing in energy?*,’ spends as much time arguing that renewables are insufficient to meet electricity demands in a growing market, as it does promoting SMRs

<https://policyexchange.org.uk/wp-content/uploads/2018/01/Small-Modular-Reactors-1.pdf>

Worldwide scene

Other SMR concepts have been presented by Bruce Power and Hatch from Canada and China National Nuclear Corporation (CNNC)’s New Energy Company (www.cnncc.com.cn) .

The latter would be competing with its big brother GW Plants, as CNNC looks for global market expansion. Its ACP-100 design, which has been under development since the Fukushima accident in Japan in March 2011, would be multifunctional for co-generation,

In China, it would require a much shrunk emergency planning zone as ACP-100s would be built close to urban areas.

Senior CNNC engineer, Dr Song Danrong, told the UK SMR summit that CNNC wanted to co-operate with the UK nuclear sector to promote innovation and overcome technical challenges. And to build a FOAK, to overcome economic challenges

Dr Danrong has stressed that the benefits of SMRs is that “with lower power, lower residual heating, suitable for passive safety facilities application.” Included in its applications is a floating reactor ship, that could provide off shore power, and desalination support.

CNNC says the technical characteristics of ACP100 comprise:

Innovative SMR ACP100 is a self-reliance NPP design of CNNC □ Integrated layout of reactor □ Forced coolant circulation □ Steam pressurizer □ internal OTSG □ Canned primary pumps □ Integrated head package □ Passive safety systems □ Digital I&C



Canada leapfrogs US in SMR push

Here are two recent nuclear industry articles on Canadian SMR development

Canada begins SMR strategy roadmap

World Nuclear News, 27 February 2018

<http://www.world-nuclear-news.org/NN-Canada-begins-SMR-strategy-roadmap-2702187.html>

Canada has launched a process to prepare a roadmap to explore the potential of on- and off-grid applications for small modular reactor (SMR) technology. The roadmap will help position Canada to become a global leader in the emerging SMR market, according to Natural Resources Canada (NRCan).

The roadmapping process, which is part of NRCan's Energy Innovation Program, was announced on 22 February by Parliamentary Secretary Kim Rudd on behalf of Minister of Natural Resources Jim Carr. Driven by interested provincial and territorial governments and energy utilities, the exercise will be delivered by the Canadian Nuclear Association. It will engage stakeholders to better understand their views on priorities and challenges related to the possible development and deployment of SMRs in Canada.

Participation in the roadmap will eventually expand to include all "essential enabling partners" including manufacturers, researchers, waste management organisations and the national nuclear regulator, the Canadian Nuclear Safety Commission (CNSC).

According to NRCan, the roadmap aims to foster innovation and establish a long-term vision for the industry, as well as to assess the characteristics of different SMR technologies and their alignment with Canadian requirements and priorities.

"Through the Generation Energy dialogue, we heard that a pan-Canadian approach is needed on nuclear energy to help guide important decisions by private and public leaders," Rudd said, referring to 2017's national dialogue on Canada's energy future, to which over 380,000 Canadians contributed. "We are bringing this approach to the SMR roadmap, working with key stakeholders to better understand their views on how we can develop and deploy this emerging technology," she said.

National nuclear science and technology organisation Canadian Nuclear Laboratories (CNL) last year set a goal of siting a new SMR on its Chalk River site by 2026, receiving 19 expressions of interest in siting a prototype or demonstration SMR at a CNL site. Canadian company Terrestrial Energy in June last year began a feasibility study for the siting of the first commercial Integrated Molten Salt Reactor at Chalk River.

The CNSC is currently involved in pre-licensing vendor design reviews - an optional service to assess of a nuclear power plant design based on a vendor's reactor technology - for ten small reactors with capacities in the range of 3-300 MWe. It received its most recent VDR applications - for NuScale Power's self-contained 50 MWe integral pressurised water reactor and Westinghouse's eVinci micro reactor - earlier this month.

The roadmap is expected to be completed in the autumn.

Dominion Energy invests in GE Hitachi SMR

21 May 2018

Dominion Energy is to provide funding that could lead to commercialising the BWRX-300 small modular reactor (SMR), GE Hitachi Nuclear Energy (GEH) announced today. The 300 MWe reactor is derived from GEH's 1520 MWe Economic Simplified Boiling Water Reactor (ESBWR) design.

Jon Ball, Executive Vice President of Nuclear Plant Projects for GEH, said the company was "thrilled" at Dominion's investment, the size of which has not been announced. "The BWRX-300 represents a significant improvement in the economics of new nuclear, an imperative for the long-term viability of the industry. It is more efficient, simpler, safer and needs a fraction of the footprint compared to the current fleet of light water reactors," he said.

According to GEH, the BWRX-300 leverages the design and licensing basis of the ESBWR, which received design certification from the US Nuclear Regulatory Commission (NRC) in 2014. The company projects the BWRX-300 will require up to 60% less capital cost per MW when compared to other water-cooled SMRs or existing large nuclear designs, which would make it cost-competitive with combined cycle gas and renewables.

"We believe that nuclear power has a vital role in ensuring a clean, reliable, and cost-effective supply of electricity to meet the needs of a growing economy," Dan Stoddard, Dominion Energy's Chief Nuclear Officer, said. "We also believe the innovations GE Hitachi is pursuing with the BWRX-300 Small Modular Reactor have the potential to make it a strong competitor in the marketplace. Our view is that a modest investment now to support further development of this technology is in the interest of both companies."

GEH said Dominion Energy's funding of the BWRX-300 provides "seed money" to further work that could lead to commercialisation of the technology, but noted that Dominion "has no plan at this time" to build the reactor at any of its commercial nuclear plants.

The NRC in 2015 approved a combined construction and operating licence (COL) for an ESBWR, Fermi 3, to be built by DTE Energy in Michigan. The ESBWR was also selected by Dominion Virginia Power as the technology of choice for a potential third reactor at North Anna in Virginia; for which a COL was issued in 2017. DTE has not to date taken a decision to proceed with Fermi 3, while Dominion placed the North Anna project on hold in September 2017.

(Dominion Energy invests in GE Hitachi SMR, World Nuclear News, 21 May 2018;
<http://www.world-nuclear-news.org/NN-Dominion-Energy-invests-in-GE-Hitachi-SMR-2105187.html>)

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SMR Design Concept Families

Water-cooled SMRs

•CAREM-25(Argentina) ACP100(China) Flexblue(France)
AHWR300(India) IRIS(International) DMS(Japan) IMR(Japan)
SMART(S Korea) KLT-40S(Russia) VBER-300(Russia) ABV-
6M(Russia) RITM-200(Russia) VVER300(Russia) VK-300(Russia)
UNITHERM(Russia) RUTA-70(Russia) mPower(US) NuScale(US)
Westinghouse SMR(US) SMR-160(US) Elena(Russia)
SHELF(Russia)

High Temperature Gas-cooled SMRs

•HTR-PM(China) GTHTR300(Japan) GT-MHR(Russia) MHR-
T(Russia) MHR-100(Russia) PBMR-400(SA) HTMR-100(SA)
EM2(US) SC-HTGR(US) Xe-100(US) **U-Battery (UK)**

Liquid-metal cooled Fast SMRs

•CEFR(China) PFBR-500(India) 4S(Japan) SVBR-100(Russia)
BREST-300(Russia) PRISM(US) Gen4 Module(US) **Astrid (France)**

Molten-salt cooled SMRs

•Terrestrial En (Canada) Seaborg Tech (Den) Fuji (Japan) LFTR
(China) **Moltex (UK)** EVOL (EU) Flibe Energy (US) WAMSR
Transatom (US)

Source: Presentation by Professor Tony Roulstone, University of Cambridge

Negative Economics

Dr Paul Dorfman of the Energy Institute at University College, London University, stressed to the British House of Lords (unelected upper chamber) at a Seminar on 17 November 2017 that SMRs will be more expensive than large reactors per kW - the key parameter. He noted that “It’s cheaper to build one 1.2GW unit than six 200MW units. .. exactly the same is seen in wind power - one of the main reasons why offshore wind costs has come down so much is the move to larger wind turbines.” Babcock & Wilcox have joined Westinghouse and already pulled out of SMR development due to cost problems associated with economies of scale.

SMRs: some further uncomfortable truths

One really surprising omission from every single presentation at the London SMR summit was consideration of the long term management of radioactive waste arising from such a huge projected increase in nuclear capacity, especially as it is recognized the greatest public concern over nuclear surrounds radioactive waste.

But this is now changing. The UK *Committee on Radioactive Waste Management* (CoRWM) published its programme of work, 2018 to 2021 on 30 May 2018

(<https://www.gov.uk/government/publications/committee-on-radioactive-waste-management-corwm-programme-of-work-2018-to-2021>)

This report contains the following paragraph in its priority tasks:

9C Consideration and advice (Note) regarding the impact of additional inventory from new nuclear build, the development of Advanced Nuclear / SMR technologies [...]to the availability of current and future storage capacity [...].

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/712149/corwm-work-programme-2018-21.pdf

ANNEX1

SMR 2018 – Addressing Technical Lifecycle Challenges

20 February 2018



09:00 - 16:30

AMRC Knowledge Transfer Centre, Advanced Manufacturing Park, Rotherham

Organiser: Nuclear Institute

Website: <http://www.nuclearinst.com/Events/SMR2018/52565>

Supported by the Nuclear Advanced Manufacturing Research Centre the Nuclear Institute's SMR 2018 conference will bring a first opportunity of the year to meet, discuss and refresh your knowledge on the latest developments relating to future UK deployment of Small Modular Reactors, refresh yourself on the technical lifecycle challenges, stay engaged and informed of the Government view on the next steps for a Small Modular Reactor (SMR) programme in the UK.

Listen to speakers and take part in the conversation, with interactive panel and roundtable sessions a key part of this year's programme.

Benefits of attending

- Receive an update from UK Government on the latest developments regarding SMRs and enabling activities being undertaken by the government ensuring that your business gains the latest thinking on the potential for SMRs in the UK
- Understand the regulatory perspectives and challenges in licensing/permitting SMRs in the UK
- Hear from potential SMR technology vendors on the current status of their technology and the safety, operational and economics benefits they each bring, including the potential for UK supply chain involvement
- Inputs from a range of organisations that can bring technical innovation to increase the potential for UK deployment of SMR technology including manufacturing and construction techniques to accelerate construction on-site and reduce project risk
- Understand the research & development and skills required to support a future UK SMR programme
- Hear from a potential SMR host location in the UK and what an anticipated end-user roadmap could look like
- Discuss the capabilities and capacity of the UK supply chain to manufacture and construct SMRs and understand the potential commercial opportunities that could result for your organisation
- Discounts are available for individual and corporate NI members. To enquire about your personal or organisational membership please contact membership@nuclearinst.com

Sponsored by NuScale Power.

Supported by Department for Business, Energy & Industrial Strategy.

Hosted by Nuclear AMRC.

ANNEX 2

Nuclear research and technology: Breaking the cycle of indecision

Published 2 May 2017

https://publications.parliament.uk/pa/ld201617/ldselect/ldsctech/160/16007.htm#_idTextAnchor048

Chapter 4: Small Modular Reactors

Small Modular Reactors

70. SMRs represent a new approach for civil nuclear power generation. They are smaller than conventional nuclear reactors, with power outputs of around 300MW or less.⁶⁹ The modularity of SMRs means that much of the plant can be fabricated in a factory environment and transported to site, unlike existing nuclear power plants where there is more on-site fabrication. It is believed that prefabrication of components can reduce costs, improve quality control and speed construction. Globally there are some 45 designs at various stages of development, though none as yet are ready for deployment.⁷⁰ A number of SMRs can be linked to give a particular output for a power station. The UK has experience, through Rolls-Royce, in building reactors within the SMR size range for submarine propulsion. There are, however, important structural and operational differences between these and those reactors used for generating electricity.

71. At the request of the Government the NNL, with industry partners, carried out a feasibility study of SMRs, published in December 2014.⁷¹ The study concluded that the size of the potential global SMR market is approximately 65–85GW of base load electricity by 2035, valued at £250–£400bn. It also concluded that there could be a UK market for 7GW of power from SMRs by 2035 and that it would be desirable for the UK to partner with another country to help access the international market. Rolls-Royce told us that 7GW of power would “be of sufficient scale to provide a commercial return on investment from a UK-developed SMR, but it would not be sufficient to create a long-term, sustainable business for UK plc.” Therefore, any SMR manufacturer would have to look to export markets to make a return on their investment. This point was also made to us by the NNL.⁷² Furthermore, David Orr, Senior Vice-President, Future Programmes and Technology at Rolls-Royce Nuclear, commented that there is not a large enough market in the UK for more than one design to be commercially viable.⁷³

72. Prof Tynan outlined some of the criteria that any SMR design would have to meet to be suitable for deployment in the UK:

“First, the SMR has to be economically viable and bring indigenous value to the UK. To put that into context, it would have to mean value derived from significantly cheaper energy prices ... It would have to create long-term, sustainable, high-value jobs. It would have to stimulate the UK supply chain, particularly for advanced manufacturing. It would have to provide intellectual property ownership for the UK. That would have to translate into value by export sales.”⁷⁴

73. A study by the Energy Technology Institute suggested that it would take around 10 years to complete the design, safety analysis, manufacturing development and construction of the first UK demonstrator SMR. Once a demonstrator SMR has been built and operated successfully, series production of SMRs could then proceed.⁷⁵ Similarly Tom Mundy, Executive Vice-President Program Development, Managing Director UK & Europe at NuScale Power, told us that if NuScale's SMR design entered the Generic Design Assessment (GDA)⁷⁶ process in 2017 then it could be deployed by 2027 in the UK.⁷⁷ Mr Orr told us that Rolls-Royce would be looking at 2028–30 to deploy an SMR in the UK.⁷⁸

74. The Cambridge Nuclear Energy Centre explained that SMR reactor technologies can be divided into two groups:

- Light-water technology that is used in existing reactors (albeit R&D is needed on the issues of modularisation and cost); and
- Generation IV technologies (see Box 2) that are experimental and have yet to be proven and would need significant further R&D before deployment.

They went on to say that only the first group is capable of being deployed in volume from about 2030.⁷⁹

Potential benefits

75. The NIA told us that there is major potential in the UK for SMRs as a complementary technology to the current new nuclear build programme.⁸⁰ However, Westinghouse UK told us that "the potential benefits ... will be heavily dependent on the specific reactor design in question."⁸¹ That is to say whether the reactor design chosen is a Generation IV or light water based SMR as outlined in paragraph 74. According to the NIA, SMRs could contribute to the UK's energy security and climate change objectives while having the potential to mitigate some of the challenges associated with new large-scale nuclear power plants, such as financing, infrastructure and siting.⁸²

76. Penultimate Power UK, a business developing an SMR design, outlined some of the further potential benefits of SMRs:

"[L]ower capital costs, quick to build so faster return on investment, offsite modular construction mitigating onsite risks, new passive safety features and, depending on design, new applications for a low carbon economy such [as] electric heat and transport."⁸³

77. Rolls-Royce explained that, given the absence of any established global SMR supplier, there could be substantial benefits of being the first to market. They went on to say:

"A UK SMR programme will create many highly skilled jobs in both the near and longer term and also re-establish the UK as a leading global nuclear nation. Rolls-Royce estimates that a regular production schedule of one SMR per annum would generate >10,000 jobs within the supply chain, which could increase to c.40,000 jobs on the basis of two UK plants per annum and secured export opportunities of c.9GW."⁸⁴

78. In addition to generating low carbon electricity for distribution across a national grid, SMRs are proposed for a range of alternative or additional uses depending on the reactor design, including the generation of process heat for industrial or district heating applications, water desalination in arid regions and the production of valuable additives such as hydrogen, isotopes and certain chemicals.⁸⁵

79. SMRs could be placed on existing nuclear sites, which are already licensed and have the necessary grid infrastructure. In particular the sites of Magnox power stations, which are in the process of being decommissioned, may be suitable for SMRs.⁸⁶ Furthermore, the local workforces at these sites have the necessary nuclear skills. North Wales Economic Ambition Board told us that the Trawsfynydd Magnox site in North Wales is ideally suited for an SMR because "it is [in] public ownership, it has the right infrastructure (cooling capacity; grid connectivity; road connections; routes to transport large loads to site), local support, support at a North Wales and Wales level [and] proximity to centres of excellence for manufacturing."⁸⁷

Potential challenges

80. There are a number of potential challenges to be overcome before the deployment of SMRs. The NIA told us that development of an SMR would require significant Government support in terms of "an appropriate regulatory framework, including a GDA slot for licensing the design, and other ... issues [such] as siting (including public acceptance) ... and funded decommissioning arrangements."⁸⁸

81. The NNL told us that novel fuel designs or fuel cycles will increase the time and cost of licensing and commissioning an SMR. NNL also said that, while SMRs offer a range of potential benefits, "the economic case for [SMRs] is yet to be fully demonstrated."⁸⁹

82. Dame Sue Ion explained that "SMRs by definition will require multiple units across multiple [sites]" and therefore additional nuclear licensed sites may be needed, depending on the extent of deployment. She went on to say that:

"[S]mall nuclear should be considered as complementary to large nuclear reactors and not simply as an alternative, given the ability of larger stations to provide the bulk of baseload requirements."⁹⁰

83. Nuclear proliferation is defined as the spread of nuclear weapons, special fissionable material and weapons applicable nuclear technology to non-nuclear weapons states (as defined by the Treaty on the Non-Proliferation of Nuclear Weapons (NPT))⁹¹ or non-state actors (as covered by United Nations Security Council Resolution 1540)⁹². Under the NPT nation states have a legal responsibility to safeguard nuclear weapons, material and technology. The International Atomic Energy Agency (IAEA) has responsibility for providing a safeguards verification system for monitoring and verifying the non-proliferation obligations of member states.⁹³ Within Europe Euratom (see Chapter 6) also provides additional safeguards verification.

84. SMRs have the potential to increase or decrease the proliferation risk depending upon the type of SMR produced. Dame Sue Ion told us that proliferation risks "are likely to arise due to an increased number of reactor units."⁹⁴ SMR designs that intend to use relatively high enrichment

fuels, will also present more of a proliferation risk. It is also possible that more countries of concern could obtain SMRs because of the lower cost of procuring them and the lower technical skills entry point required. However, there are potential opportunities to reduce the proliferation risk with SMRs such as alternative fuel designs to reduce material attractiveness or the fuel cycle being operated outside of the country of operation, including the storage of spent fuel.

Box 3: Summary of potential benefits and disadvantages of SMRs

Potential Benefits

Smaller reactor size meaning both a lower absolute capital cost and a shorter construction period than a large reactor.

The reactor system can be manufactured in a factory setting, rather than in-situ at the construction site.

The smaller size means that SMRs could be constructed on a much wider range of sites than large reactors, giving more flexibility and the option to increase the generating capacity beyond that which could be met by large reactors.

There is potentially a large international export market for SMRs, for early movers.

SMRs could be placed on existing nuclear licensed sites.

Certain SMR designs offer more value than just the production of electricity. Products such as heat, hydrogen, isotopes and high value chemicals are all additional possible outputs.

Potential Challenges

The 'first of a kind' build cost for any commercial SMR would be comparable to that of a conventional large reactor and would therefore need Government support.

Cost savings for manufacture will typically only be realised after 10 or more reactors have been built, which is likely to be bigger than the UK market for SMRs.

SMRs have the potential to both increase and decrease the proliferation risk depending upon the type of SMR produced.

Government inaction

85. As part of the £250m announced for nuclear R&D (see paragraph 34) in the spending review and autumn statement 2015, the then Chancellor of the Exchequer announced that part of the funding would be for a competition to "identify the best value Small Modular Reactor design for the UK".⁹⁵ The Government launched Phase One of an SMR Competition in March 2016.⁹⁶ The Government told us that Phase One provided "interested parties an opportunity to present their

views on the benefits and risks of SMR deployment". Furthermore they told us that the criteria set out in Phase One were designed "to encourage a wide variety of entrants to participate, enabling the gathering of evidence from a cross-section of interested parties, including reactor vendors, specialist manufacturers and service providers".⁹⁷

86.The Government has also stated that it intends to develop an SMR Roadmap, which will "summarise the evidence so far, set out the policy framework and assess the potential, for one or more possible pathways for SMRs to help the UK achieve its energy objectives, while delivering economic benefits".⁹⁸ The Government has stated that the roadmap will also include details of how it will identify suitable sites or types of sites for SMRs, and work it will undertake with the Office for Nuclear Regulation to ensure that appropriate provision is made within the process for regulatory approval.⁹⁹ Alongside Phase One and the SMR roadmap the Government commissioned a Techno-Economic Assessment of SMRs in May 2015. The assessment was carried out by a group of contractors led by Atkins Limited and was completed by August 2016. BEIS is yet to publish the analysis. Phase One of the Competition was expected to be completed in Autumn 2016 with the publication of the roadmap happening at the same time.¹⁰⁰

87.Mr Orr told us that this has not happened yet and that Rolls-Royce were "seeking clarity" from BEIS as to when it will take place.¹⁰¹ In its written evidence the Government said it "will provide further information on next steps for the programme in due course."¹⁰² When we asked the Minister, Jesse Norman MP, for more information on the Government's timetable he was unable to provide any further information.¹⁰³ In a reply to a written question on 29 March 2017 Lord Prior of Brampton, Parliamentary Under Secretary of State at BEIS, re-stated that the Government would provide information of the next steps of the SMR competition "in due course". Furthermore he said that Phase one "does not involve the down-selection of a reactor design".¹⁰⁴

88.The Cambridge Nuclear Energy Centre made it clear in its evidence why SMR development requires Government support:

"It is clear that no SMRs will be developed in the UK without government involvement and support. No vendors could bear the development cost by themselves. There is no effective market in nuclear power plants—small or large. Government, as in the US, needs to be involved at least in the development of a SMR."¹⁰⁵

89.NuScale Power echoed this, telling us:

"[T]here is a key role for Government to be a part of the "first-mover solution" specifically by taking action that will reduce risk associated with SMR development and deployment."¹⁰⁶

90.Professor Neil Hyatt told us that there is a lack of clarity over the national strategy on SMRs¹⁰⁷ and Dame Sue Ion suggested that companies that have invested significantly in preparing responses to Phase One are likely to lose interest if the Government delays any decisions on SMRs. ¹⁰⁸

91.Penultimate Power UK went further, telling us that ongoing delays by Government and a lack of clarity on how the competition will proceed have paralysed the market and that "without

urgent action the window of opportunity for meaningful participation will soon close.”¹⁰⁹ Plaid Cymru told us that “the failure of the Government to publish its SMR roadmap ... and techno-economic assessment of SMRs is causing concern about its capacity and focus to the development of the industry at this pivotal time.”¹¹⁰

92. Lord Hutton explained to us that the NIA “are, and remain, disappointed that, having kicked this off and raised expectations so much, we have not had anything back [from the Government] at the points when we were promised”.¹¹¹ While he accepted that the decision to commit to SMRs is a big call, he said: “that is what Governments are there to do. They are not there to avoid the big decisions, they are there to take the big decisions ... if [the Government] are going to maintain the interest of the commercial sector here, they really have to be clear about which direction they want to go in.”¹¹²

93. When we asked the Government about the risk of paralysing work in the SMR industry by further delaying the SMR competition, Craig Lucas, Director of Science and Innovation for Climate and Energy at BEIS, told us that:

“We are very sensitised to that risk, if you like. I would also say that this is a very complicated area and the range of things that has come forward to us has meant we have had to do a lot of thinking about the evidence presented and what is a viable proposition and what is not. The long-term nature of this decision, to some degree, justifies the level of effort we have been putting into it, I think.”¹¹³

94. Mr Norman told us that he did not think the SMR competition should have been named as a competition and that “it was more a ... call for ideas across a much wider spectrum”.¹¹⁴

95. Mr Lucas said that BEIS “have done an extensive piece of evidence work to look at the state of maturity of the different technologies and the likely level of costs they might achieve” and that this showed “that the possible technology outcomes are of a very wide range” and therefore the Government needs to look at “the question of investability ... and the question of the amount of value that UK plc could capture”.¹¹⁵ This piece of work is the techno-economic assessment of SMRs commissioned by the Government (see paragraph 86). In response to an oral question in the House of Lords on 24 April 2017 Lord Prior said:

“[W]e simply do not yet know whether small modular reactors will represent a cheap source of low-carbon energy for the future. We just do not know what the economics are, which is why in due course we will be publishing a technical and economic evaluation, based on assessing the 32 proposals that have been put to us for SMRs. The only truthful answer at the moment is that the jury is still out.”¹¹⁶

96. In order to make a decision about SMRs the Government needs access to the best possible independent expert advice. We were concerned when Prof Howarth told us that the NNL “stand ready to support government in being able to determine the market assessment and how effectively we move into [the SMR] market”,¹¹⁷ implying that the Government was not already seeking the NNL’s advice. **The Government should seek technical advice from NNL as a**

matter of routine, as well as other industry experts, when considering technical decisions such as the development of SMRs.

97. It is important to recognise that there are several distinct questions that arise from the consideration of SMRs. Perhaps the most important, given that deployment before the late 2020s is unlikely, is what role they could be expected to play alongside the other elements in the UK energy mix at that time. In principle a number of SMRs on a single site could replace a single large reactor. Alternatively SMRs could be more widely distributed with attendant advantages and disadvantages. Both public acceptability and availability of finance, public and private, will be very important. Although a UK role for SMRs would be important, alone it would be unlikely to justify major investment. A joint venture between manufacturers with different and substantial home markets would be welcome.

98. We are disappointed that the Government launched a competition for SMRs and has not kept to its stated timetable. This has had a negative effect on the nuclear sector in the UK and if the Government does not act soon the necessary high level of industrial interest will not be maintained. It is particularly alarming that the results of Phase One of the competition, which does not involve the selection of an SMR design, have yet to be announced by the Government.

99. *We did not detect any urgency from the Government to make a decision on the SMR competition. Whilst acknowledging the need for due care, the Government must publish its strategy for SMRs without delay if industrial interest is to be maintained and if commercial opportunities are not to be missed. We have reached a critical moment for the future of the United Kingdom as a serious nuclear power strategically positioned to capture coming opportunities.*

100. *The Government should also publish its techno-economic assessment of SMRs immediately and make clear whether it believes there is a sound economic case for the UK to make a substantial strategic investment.*

69 In oral evidence Rolls-Royce suggested that SMRs could be as large as 500MW; Q 12 (David Orr)

70 House of Commons Library, New nuclear power, Briefing Paper, CBP-7705, 15 September 2016

71 NNL, *Small Modular Reactors (SMR) Feasibility Study* (December 2014): <http://www.nnl.co.uk/media/1627/smr-feasibility-study-december-2014.pdf> [accessed 16 March 2017]

72 Written evidence from the NNL (PNT0046)

73 Q 12 (David Orr)

74 Q 5 (Prof Mike Tynan)

75 ETI, *Preparing for deployment of a UK small modular reactor by 2030* (September 2016): <https://d2umxnkyjne36n.cloudfront.net/insightReports/Preparing-for-deployment-of-a-UK-SMR-by-2030-UPDATED.pdf?mtime=20161011145322> [accessed 20 March 2017]

76 Generic design assessment (GDA) is the process used by the nuclear regulators (ONR and the Environment Agency) to assess the new nuclear power station designs. It allows the regulators to assess the safety, security and environmental implications of new reactor designs, separately from applications to build them at specific sites.

77 Q 13 (Tom Mundy)

78 Q 13 (David Orr)

79 Written evidence from the Cambridge Nuclear Energy Centre, University of Cambridge (PNT0056)

80 Written evidence from the NIA (PNT0041)

81 Written evidence from Westinghouse UK (PNT0027)

82 Written evidence from the NIA (PNT0041)

83 Written evidence from Penultimate Power UK (PNT0013)

84 Written evidence from Rolls-Royce (PNT0006)

85 Written evidence from University of Leicester (PNT0022), Terrestrial Energy Inc. (PNT0057) and Rory Trappe (PNT0008)

86 Q 16 (David Orr)

87 Written evidence from North Wales Economic Ambition Board (PNT0059)

88 Written evidence from NIA (PNT0041)

89 Written evidence from the NNL (PNT0046)

90 Written evidence from Dame Sue Ion (PNT0031)

91 Treaty on the Non-Proliferation of Nuclear Weapons (NPT), 1 July 1968:
<https://www.un.org/disarmament/wmd/nuclear/npt/text> [accessed 24 April 2017]

92 United Nations Security Council Resolution 1540 (2004), 28 April 2004:
[http://www.un.org/ga/search/view_doc.asp?symbol=S/RES/1540%20\(2004\)](http://www.un.org/ga/search/view_doc.asp?symbol=S/RES/1540%20(2004)) [accessed 24 April 2017]

93 IAEA Statute (updated version of 28 December 1989): <https://www.iaea.org/sites/default/files/statute.pdf> [accessed 30 March 2017]

94 Written evidence from Dame Sue Ion (PNT0031)

95 HM Treasury, *Spending review and autumn statement 2015* (27 November 2015), section 7.7:
<https://www.gov.uk/government/publications/spending-review-and-autumn-statement-2015-documents/spending-review-and-autumn-statement-2015> [accessed 20 March 2017]

96 BEIS, *Small Modular Reactors Competition Phase One* (17 March 2016): <https://www.gov.uk/government/publications/small-modular-reactors-competition-phase-one> [accessed 20 March 2017]

97 Written evidence from HM Government (PNT0029)

98 DECC, *Small Modular Reactors Competition: Phase One Guidance* (17 March 2016), p 5:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/508616/SMR_Competition_Phase_1_Guidance.pdf
[accessed 20 March 2017]

99 BEIS, *Small Modular Reactors Competition Phase One* (17 March 2016): <https://www.gov.uk/government/publications/small-modular-reactors-competition-phase-one> [accessed 20 March 2017]

100 DECC, *Small Modular Reactors Competition: Phase One Guidance* (17 March 2016), p 8: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/508616/SMR_Competition_Phase_1_Guidance.pdf [accessed 20 March 2017]

101 Q 14 (David Orr)

102 Written evidence from HM Government (PNT0029)

103 Q 33 (Jesse Norman MP)

104 HL Deb, 29 March 2017, HL6114

105 Written evidence from the Cambridge Nuclear Energy Centre, University of Cambridge (PNT0056)

106 Written evidence from NuScale Power (PNT0049)

107 Written evidence from Prof Neil Hyatt, University of Sheffield (PNT0028)

108 Written evidence from Dame Sue Ion (PNT0031)

109 Written evidence from Penultimate Power UK (PNT0013)

110 Written evidence from Plaid Cymru (PNT0042)

111 Q 57 (Lord Hutton of Furness)

112 *Ibid.*

113 Q 33 (Craig Lucas)

114 Q 33 (Jesse Norman MP)

115 Q 33 (Craig Lucas)

116 HL Deb, 24 April 2017, col 1212

117 Q 46 (Prof Paul Howarth)

ANNEX 3:

UK GOVERNMENT RESPONSE TO THE HOUSE OF LORDS SCIENCE AND TECHNOLOGY SELECT COMMITTEE REPORT:

“Nuclear research and technology: Breaking the cycle of indecision”

<https://www.parliament.uk/documents/lords-committees/science-technology/Nuclear-research-technologies/HMG-response-nuclear-research-development-report.pdf>

SMR extract:

Small Modular Reactors

The Government should seek technical advice from NNL as a matter of routine, as well as other industry experts, when considering technical decisions such as the development of SMRs.

22. We regularly consult NNL on research funding priorities and have commissioned advice from them specifically on SMRs on a number of occasions.

23. A consortium led by NNL produced the SMR 2014 Feasibility Study that set out to determine the specific benefits available to the UK by investing in SMRs. This report provided the initial evidence base for SMRs. The recommendations made by NNL were implemented by Government including the need to undertake further evidence gathering to increase our understanding of SMR technologies and the challenges they present. NNL has continued to support Government as it develops its approach on SMRs.

24. Government is reviewing how it can make better use of NNL so that it can ensure the technical advice provided by NNL is an integral part of the SMR policy development process.

It is important to recognise that there are several distinct questions that arise from the consideration of SMRs. Perhaps the most important, given that deployment before the late 2020s is unlikely, is what role they could be expected to play alongside the other elements in the UK energy mix at that time. In principle a number of SMRs on a single site could replace a single large reactor. Alternatively SMRs could be more widely distributed with attendant advantages and disadvantages. Both public acceptability and availability of finance, public and private, will be very important. Although a UK role for SMRs would be important, alone it would be unlikely to justify major investment. A joint venture between manufacturers with different and substantial home markets would be welcome.

25. Government agrees that SMRs offer a number of potential benefits to the UK, both in terms of securing a low carbon energy future and broader industrial benefits. However, the development, and potential deployment of SMRs,

raises a number of technical, commercial, regulatory and public acceptability questions that need to be addressed.

26. It is also important to recognise that there is a great deal of diversity in the SMR market. The wide range of technologies, at different levels of development and market readiness, means that it is unlikely that a single policy approach from government on SMRs would be suitable for the sector.

27. As we move to de-carbonise our economy, there will continue to be a demand for the secure, low carbon energy that nuclear provides. This could include energy from SMRs. For example, third generation modular reactors have the potential to play an important role within the near-term electricity generation market, but only if they can reduce costs to a competitive level. While more novel modular reactor technologies offer the potential to deliver major breakthroughs in cost, safety or functionality but are less technologically mature and require further basic research and development support.

28. If the market is going to commercialise and deploy an SMR design, we understand that the right market conditions and regulatory framework must be in place. We recognise that elements of the existing framework may not be best suited to facilitate SMR deployment. One of the aims of the SMR competition was to give industry an opportunity to discuss their views including identifying potential barriers and this engagement has provided valuable insights into the conditions industry considers necessary to deliver an SMR in the UK. This has been complimented with evidence gathering to help Government is best placed to make strategic decisions and consider models for Government interaction with SMRs.

29. We also recognise that Government could have a role in reducing barriers, including on siting and regulatory approvals, which could help de-risk projects and ensuring they are acceptable to the public. We anticipate that as SMR development proceeds across the world there may be benefits to international collaboration, for example, in design assessment and licensing and we welcome the UK's regulators current engagement with international counterparts on SMRs. Government is also open to exploring global partnership opportunities, including sharing IP.

We are disappointed that the Government launched a competition for SMRs and has not kept to its stated timetable. This has had a negative effect on the nuclear sector in the UK and if the Government does not act soon the necessary high level of industrial interest will not be maintained. It is particularly alarming that the results of Phase One of the competition, which does not involve the selection of an SMR design, have yet to be announced by the Government.

30. The SMR competition has attracted significant interest from industry and has provided participants with an opportunity to discuss their proposals directly with Government. We are grateful to vendors who have given their time to the Government's evidence gathering process.

31. We are in continued engagement with industry about the policy framework for SMRs and have been holding further meetings with competition participants over the summer to discuss the enablers we are considering to help facilitate SMR development and deployment.

We did not detect any urgency from the Government to make a decision on the SMR competition. Whilst acknowledging the need for due care, the Government must publish its strategy for SMRs without delay if industrial interest is to be maintained and if commercial opportunities are not to be missed. We have reached a critical moment for the future of the United Kingdom as a serious nuclear power strategically positioned to capture coming opportunities.

32. Government acknowledges that industry is eager for greater clarity on the approach we will adopt on SMRs. The commercial case for SMRs is still uncertain. Given this uncertainty, it is essential that the Government's approach is informed by thorough evaluation of best available evidence. We must invest time now to make a strategic decision for the UK – a decision that could have implications stretching many decades into the future.

33. The time taken has also allowed those in the SMR industry to join together where they see mutual benefits, and to further develop their designs and proposals. The greater the certainty vendors can provide on technical and commercial aspects of their designs, the more attractive an investment proposition it becomes and the more likely they will be to attract the necessary private sector investment. Government is undertaking a further round of engagement with industry to discuss options and our on-going policy development for SMRs. We expect to be in a position to close the existing SMR competition shortly and to announce our policy approach to SMRs in the coming months.

34. It can be challenging to attract private sector investment and so operators must have confidence not only in the technical feasibility of SMRs, but also that the commercial proposition as a whole is sufficiently attractive. We recognise that the Government could have a role in reducing barriers, including on siting and regulatory approval, which could help in de-risking projects.

35. Government has also been supporting the industry in other ways, for example, in advanced manufacturing and the first round of funding for the nuclear R&D programme, which will benefit the whole sector including SMR developers.

The Government should also publish its techno-economic assessment of SMRs immediately and make clear whether it believes there is a sound economic case for the UK to make a substantial strategic investment.

36. Government is committed to publishing the techno-economic assessment of SMRs and we expect this to happen shortly. We will provide more information on the Government objectives for SMRs once the policy development process is complete. We intend to make an announcement on SMRs in the coming months.