HM Government

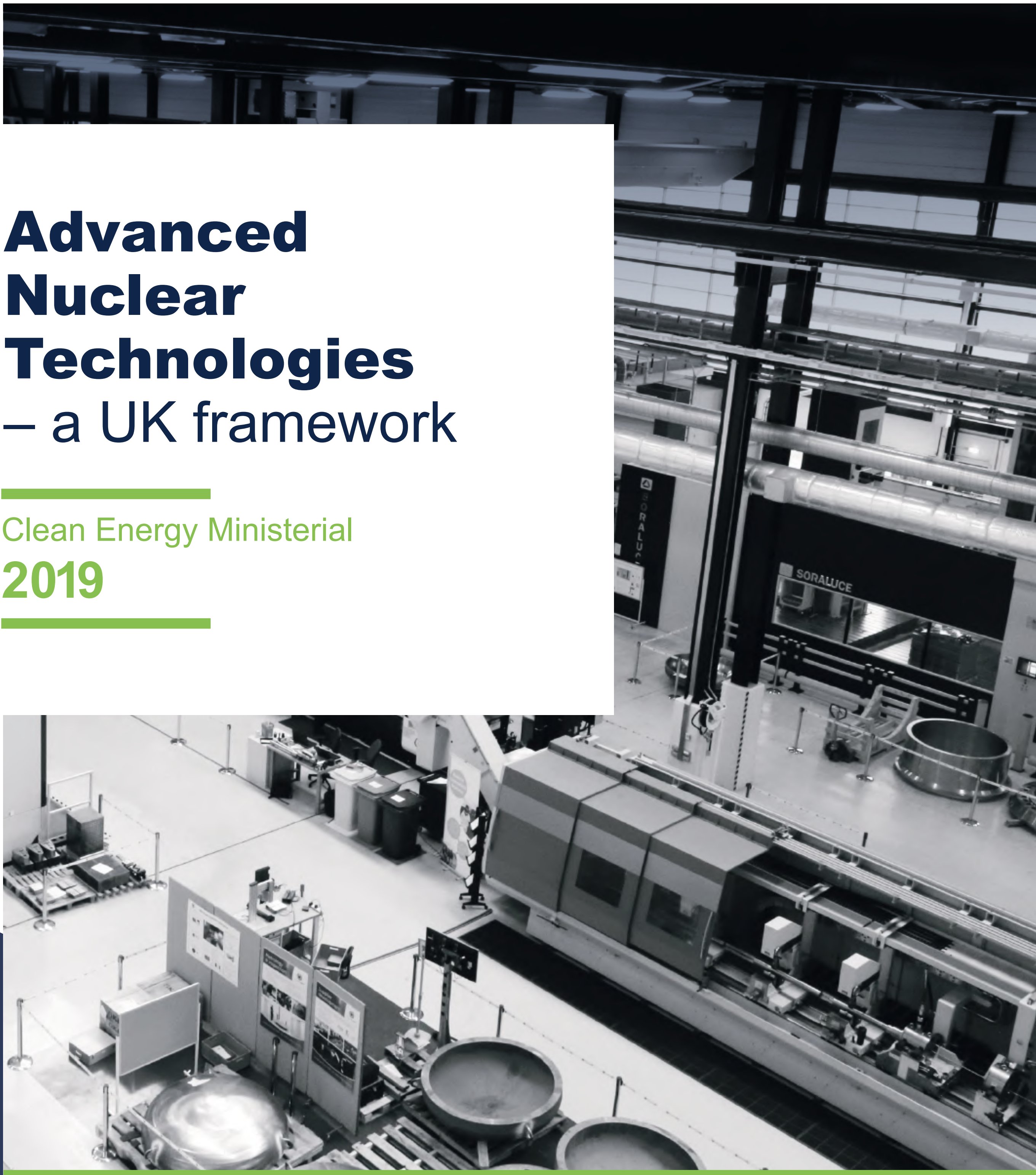
CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

NICE Future NUCLEAR INNOVATION: CLEAN ENERGY FUTURE
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

Advanced Nuclear Technologies
– a UK framework

Clean Energy Ministerial

2019



INDUSTRIAL STRATEGY

Ministerial foreword

Nadhim Zahawi MP

The UK government remains committed to combatting climate change through decarbonisation across all sectors. We have asked the Committee on Climate Change (CCC) to advise on how and when we could achieve net zero greenhouse gas emissions, and we are now the first major economy to legislate to end our contribution to global warming entirely. There is a global need for clean energy, and the choices that governments across the world make will impact our environment, on which we and future generations depend on. The UK's Industrial Strategy recognises the importance of a low-carbon future with its Clean Growth Grand Challenge, a commitment aiming to lead the world in the development, manufacture and use of low-carbon technologies, systems and services.

With this challenge in mind, the Clean Energy Ministerial (CEM) is a valuable forum for governments to discuss clean energy options and opportunities. Specifically, the CEM Nuclear Innovation: Clean Energy Future (NICE Future) initiative is an important vehicle for driving discussions among governments about the role advanced nuclear can play in future energy systems, and to better understand the cost-effective solutions they can provide. I would like to thank the US, Canada and Japan for their leadership of the initiative and for their efforts to steer the NICE Future initiative since its inception at CEM 9.

In the UK, we have been actively exploring innovative technologies and how we can encourage their commercial development and deployment. As our learning develops, we have a better understanding about the range of Advanced Nuclear Technologies and the opportunities they can provide. The potential wider benefits that these technologies can bring include increasing regional expertise, boosting capability and delivering a highly skilled workforce. Recognising these benefits, I was pleased that we were able to recently announce an initial award of up to £18m, subject to business case and other approvals to the UK SMR Consortium's proposal into the Industrial Strategy Challenge Fund. The consortium, led by Rolls-Royce, have proposed an exciting joint investment of more than £500m to design a first-of-a-kind SMR that could be operational by the early' 2030's.

This brochure aims to summarise the UK's journey so far, the learning we have identified and the policy framework we have put in place to encourage the development of Advanced Nuclear Technologies. We want readers to learn from our experiences, which we are sure will be of interest to policy makers across the CEM membership.

Introduction

Advanced Nuclear Technologies

The UK government is committed to tackling climate change through clean growth - cutting emissions while seizing the benefits of the low-carbon economy [1,2,3]. Nuclear energy currently provides around 20% of our total domestic electricity needs and 40% of our low-carbon electricity [4] and could be fundamental to any future decarbonised energy system, but not at any price. Advanced Nuclear Technologies (defined as **Small Modular Reactors** (SMRs) which are smaller versions of today's technology, and **Advanced Modular Reactors** (AMRs) which adopt next generation technologies) could work alongside other low-carbon sources in a hybrid energy system to offer cost-effective solutions to a range of energy needs.

Over the last few years we have been actively exploring the UK's future energy needs and how to encourage and facilitate the commercial development and deployment of advanced technologies. This has been a journey of discovery, learning about the range of Advanced Nuclear Technologies, the opportunities they could provide and their associated complexities and challenges. We are still on this journey, however the wealth of knowledge and evidence we have gained over the last few years has been invaluable.

This brochure highlights some of the work we have carried out, the learning we have identified and the policy framework we are putting in place to encourage the development and deployment of Advanced Nuclear Technologies. It has been produced by the Department for Business, Energy and Industrial Strategy and the Nuclear Innovation and Research Office to share our experience with Clean Energy Ministerial member countries as part of the **Nuclear Innovation: Clean Energy Future (NICE Future)** initiative. It aims to extract key policy learning points from the UK's journey so far, which, we hope, will be of interest to policy makers in other countries to allow them to benefit from our experience.

Our Policy Framework

Our interest in **Advanced Nuclear Technologies** includes **Small Modular Reactors and Advanced Modular Reactors**, and cuts across multiple policy goals [1,2,3]:

- **Playing a broad decarbonisation role -** advanced reactor designs target a wider range of applications beyond traditional baseload electricity supply, including flexible electricity generation; heat generation for domestic or industrial use, hydrogen production; remote off-grid deployment; and nuclear waste management solutions.
- **Delivering low cost energy -** Small and Advanced Modular Reactors have the potential to deliver cost reductions through, for example, enhanced passive safety features, step change technology and production innovations, a high level of off-site modular manufacture and innovative delivery and construction models
- **Clean growth -** we recognise the potential for the UK to become a world-leader in developing the next generation of nuclear technologies, creating high-skilled jobs and helping to meet decarbonisation targets both at home and abroad.

We have launched several initiatives over the last few years to test the potential application of Advanced Nuclear Technologies more widely, including exploring technical, economic, regulatory and social perspectives in a future low-carbon energy system. The wealth of evidence gained during this time has been invaluable in understanding the wide range of new reactor technologies under development, their benefits, key challenges, and where government support is needed.

However, it is important to have a clear understanding of what a government can and cannot do. We believe in the power of the competitive market; competition, open financial markets, and generating profits are some of the foundations of success of the UK.

We believe, where possible that the **market is best placed to identify and bring forward cost-effective Advanced Nuclear Technologies**. However, given uncertainty about the future, the UK government also recognises that we must be prepared to intervene to provide insurance and preserve optionality [5]. We have developed our policy **framework** [6] to enable the market to operate while keeping in mind the insurance principle.

Based on our learning over the past few years, the framework includes distinct but complementary strands which we feel are needed to commercialise technologies. Some elements of the framework are direct responses to evidence we have gathered, e.g. regulatory readiness, while others are still exploratory steps, such as public perception. Taken together, we believe the framework (see adjacent) can create a fertile environment for technically and commercially viable Advanced Nuclear Technologies to come to market.

- **Regulatory Readiness**
- **Finance**
- **Siting and Land Access**
- **Public Perception**
- **International Collaboration**
- **Supply Chain Development**
- **AMR Feasibility & Development project**

The UK's Advanced Nuclear Technology journey

The UK has been a pioneer of nuclear technology from the start of the atomic age. In 1954 the UK Atomic Energy Authority was formed with nearly 20,000 nuclear R&D employees, doubling by 1961 to 41,000. Built in 1956, Calder Hall in Cumbria was the first civil nuclear power station in the world.

Throughout the twentieth century the UK was involved in civil nuclear research with a wide range of activities across numerous reactor technologies. Amongst these were our Fast Reactor programme at Dounreay in Caithness, the Dragon experimental High Temperature Gas-cooled Reactor at Winfrith in Dorset, and our civil nuclear power stations using Magnox, Advanced Gas Cooled and Pressurised Water technology.

The 2013 Nuclear Industrial Strategy [7] signalled our current interest in the opportunities of modularisation, smaller scale and next generation reactors. This strategy was produced in partnership with industry. It set a vision of a vibrant nuclear industry in the UK and placed actions across the sector to realise that vision. For Advanced Nuclear Technologies, the strategy announced an SMR feasibility study to explore the potential for an SMR R&D programme. More widely it initiated a review of the level of public funding for civil nuclear R&D that paved the way for £460 million of government money being made available to nuclear between 2016 and 2021 [8].

Following the Nuclear Industrial Strategy our approach has been to **build an evidence base around the potential roles, benefits and importantly recognising the limitations of Advanced Nuclear Technologies**. This is to inform UK government policy and ensure that the decisions we make, to enable technologies through funding or other means or to impose restrictions on them, are underpinned by evidence. There have been **three major evidence-building milestones** between 2014 and 2016 on the journey leading up to the UK's present Advanced Nuclear Technologies policy framework.

START

2014

In 2014 we commissioned the National Nuclear Laboratory (NNL) to undertake a **Feasibility Study** [9] of the viability of SMRs, potential UK industry opportunities, and the potential role of government in this sector. The conclusions were favourable to the potential of SMRs. Importantly, it identified evidence gaps and recommended areas for further investigation. The most reported finding is that the scale of the global market opportunity for low-cost, low-carbon SMRs is estimated to be worth **£250 billion to £400 billion by 2035.**

2015

In 2015, we commissioned an independent Techno-Economic Assessment (TEA) [10] of SMRs to plug the evidence gaps identified by the NNL Feasibility Study. The TEA was made up of seven projects covering the technical maturity and economics of SMRs, the potential for cost reductions, and the capability of the UK's regulatory regime to assess emerging advanced technologies. Key conclusions from the TEA were:

- Smaller reactors could offer a step change in nuclear power costs, with the potential for costs to fall below £60/MWh;
- The UK supply chain could deliver as much as 70% of the value of any new smaller reactor;
- But a significant number of SMR units (>8GWe capacity) would be needed to realise economies of scale compared to deploying equivalent conventional nuclear using larger reactors.

2016

In 2016 we launched an **SMR competition** [11] to gauge market interest among technology developers, utilities, and potential investors as a first step to finding the best value SMR for the UK market.

We received 32 eligible expressions of interest and held two rounds of meetings with participants. Three recurring messages directly influenced the shape of the UK's current policy:

- A need for better and earlier access to regulators;
- Help to turn new ideas into detailed designs; and
- A need for the right conditions to bring new reactors to market.

Although the UK government discontinued the SMR Competition in 2017, the competition was invaluable in highlighting the variety of Advanced Nuclear Technologies being designed, their different potential roles within an energy system and therefore the different energy markets in which different types of reactors could compete in.

What did we learn?

The evidence base summarised in our journey was developed over four years, producing a significant quantity of written reports and analysis. While there are many detailed learning points in the various studies, there are three broad points that are pivotal to shaping UK policy.

The **first key point**, and one that is obvious looking back, is that there is a very diverse range of reactor types that are all commonly called Small Modular Reactors. But these 'SMRs' vary widely in their design maturity, their target markets, their size, and the fuels and coolants they use. While some may meet the IAEA definition of an SMR (having an output of 300MWe or less and being designed to be built with a high degree of factory fabrication) for policy making purposes they are often not directly comparable.

For example, a High-Temperature Gas-cooled Reactor for industrial use is not comparable with an integrated Pressurised Water Reactor for on-grid electricity generation. Treating these reactors as the same class or type of technology makes policy development more complicated. For example, it combines the advantages and disadvantages of different reactor types and of different advanced nuclear use-cases and therefore risks communicating at cross-purposes. Collectively, therefore, the UK government refers to these reactors as "Advanced Nuclear Technologies".

The **second key point** we learnt is that, despite the diversity in the sector, Advanced Nuclear Technologies currently fall into two groups:

1. **Generation III water-cooled "Small Modular Reactors.**" These are similar to existing nuclear power station reactors but on a smaller scale and aim to have enhanced passive safety systems. Typically designs are mature and close to demonstration or commercialisation.

2. **Next Generation "Advanced Modular Reactors."** These use novel cooling systems or fuels to offer new functionality (such as industrial process heat) and aim for further improved passive safety and, potentially, a step change reduction in costs. Typically, these reactors are at early design stages.

Both groups aim to use factory construction techniques rather than bespoke site-based engineering. They claim to be more easily financed because single unit capital costs are much lower, and build time is quicker and less prone to time and cost overruns.

The policy role for government varies with these technology groupings. For the nearer to market SMRs there is a need for policies which enable market access such as siting, licensing, and financing whereas for the advanced systems with lower maturity there is a need to support research, development and performance demonstration. This is both to help progress the technologies as well as to allow government to learn more about the advantages and disadvantages to inform future policy.

The **third key point** is that the Advanced Nuclear Technology sector is developing rapidly and the market context in which small or advanced reactors could deploy is also moving. In the four years since the TEA was commissioned the range of uncertainty on SMR costs has narrowed, the costs for offshore wind have fallen much more quickly than expected and the deliverability of large-scale nuclear projects has proved challenging - factors which all influence the relative economic case for SMRs in the UK context. As a result, we have been keeping our position under review, to keep building evidence and to be responsive to changing circumstances.

The Nuclear Sector Deal

The latest stop on the UK's Advanced Nuclear Technology journey is the **Nuclear Sector Deal** published in June 2018 [3]. The Nuclear Sector Deal announced a package of measures to support the sector as we develop low-carbon nuclear power and continue to clean up our nuclear legacy. The deal is about government and industry working in partnership to drive competitiveness across the nuclear sector.

Building on the evidence and learning over the past five years, the Sector Deal begins to set out the new framework for Advanced Nuclear Technologies in the UK. The framework comprises policy areas that are common enablers to deployment of any Advanced Nuclear Technology in the UK. The remainder of this brochure considers the seven parts of the framework in more detail.

The Advanced Nuclear Technologies Framework

Regulatory Readiness

Nuclear regulation and the licensing and permitting processes are crucial enablers in our new policy framework. The regulatory system for new reactors must be robust, provide public confidence and enable innovation. This strand of our framework aims to ensure that advanced reactor companies are ready to participate in the UK's formal regulatory processes and that the regulatory processes can accommodate them.

The Office for Nuclear Regulation (ONR) and the Environment Agency (EA) are reviewing guidance and processes to ensure they continue to be fit for purpose and accessible for small nuclear projects, together with undertaking a significant programme of work to build capability and capacity to assess Advanced Nuclear Technologies.

Modernising Generic Design Assessment

The ONR and EA have reviewed their Generic Design Assessment (GDA) process as part of their commitment to continuous improvement. In the UK, GDA is the main regulatory process carried out prior to site-licensing. The regulators have considered lessons from recent GDAs of large-scale nuclear projects to identify opportunities for improvements. They have considered the likely requirements of Small and Advanced Modular Reactors to introduce flexibilities suited to SMR and AMR business models. The regulators' review has also maintained consistency with the robustness of past GDAs.

In addition to modernising the GDA itself, we have committed to bring forward a clear process by which SMRs and AMRs can request to enter GDA.

Pre-Licensing/Pre-Assessment Engagement

In response to stakeholder concerns about the regulatory processes we have been piloting an early engagement process between a small number of mature SMR vendors and the ONR, EA and Natural Resources Wales (NRW).

This engagement process allows vendors to better understand the UK regulatory expectations and requirements before entering formal regulation. It also provides an opportunity for vendors to identify regulatory concerns and to address them early in the design process.

Upskilling the Nuclear Regulators

In parallel with our AMR Feasibility and Development (F&D) project (see page 16) we are investing up to **£12 million to build capability and capacity to regulate Small and Advanced Modular Reactors.**

This programme includes a significant increase in engagement with industry and international cooperation. It is also developing the regulators' capability and capacity for assessing AMRs and cultivating a regulatory environment in the UK which encourages the development of a domestic AMR supply chain.

Our regulators are presently assessing a wealth of evidence provided in Phase 1 of our AMR F&D project, and we anticipate significant learning from this, including identifying remaining knowledge gaps and associated regulatory challenges. The nuclear regulators have established a robust knowledge management approach and are working collaboratively with overseas regulators to share experiences, knowledge and good practice.

We anticipate Phase 2 of our AMR F&D project (subject to value for money decisions within government) to continue the close liaison with technology developers to further develop capability and capacity.

[1] *The UK has multiple environmental protection agencies with responsibility for nuclear environmental protection. These are the EA, NRW, and the Scottish Environment Protection Agency.*

Finance

Two key factors dominate the economics of nuclear power plant projects; the capital cost and the cost of capital, a key conclusion reached in the **Energy Technologies Institute (ETI) Nuclear Cost Drivers project** [12]. This applies to nuclear projects both large and small. However, the characteristics of small nuclear, with lower overnight capital costs, off-site modular manufacture and shorter construction duration, and reduced construction risk, may present an opportunity to introduce innovative financing models and be within reach of a wider pool of private investors.

The Expert Finance Working Group (EFWG)

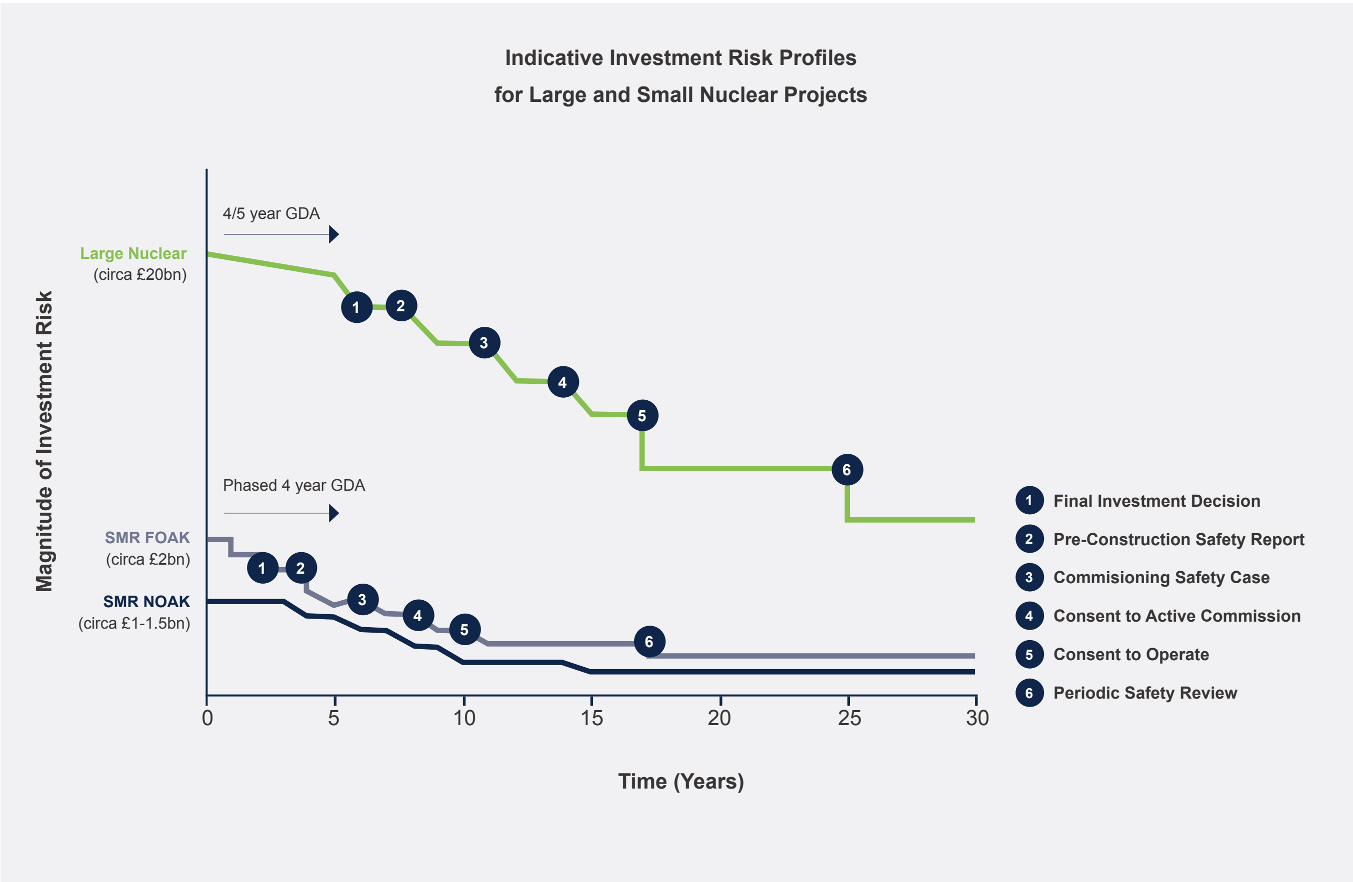
We wanted to test this hypothesis and so in December 2017 we set up an Expert Finance Working Group to advise on how Small and Advanced Modular Reactor projects could raise private sector investment in the UK. The EFWG brought together a wealth of expertise from across the financial sector, industry, academia and government. A critical part of the EFWG project was stakeholder engagement. Technology developers were invited to provide information and present to the group on their technologies, with a view to understanding key barriers to investment and the role of government in enabling small nuclear projects.

The EFWG explored in detail the risk profile of small nuclear projects and the allocation of risk. It assessed pros and cons of various financial models available in the infrastructure and energy development markets

The EFWG found that the **investment risk profile** (see diagram opposite) for a small nuclear project differs significantly from a Gigawatt scale project. Smaller reactors are characterised by a significantly increased proportion of factory build, which should **improve programme delivery cost and schedule certainty, and reduce construction times** to between 2.5 to 4 years compared with 6 to 8 years for large projects (For further detail on the risk profile shown see the EFWG report [13]).

The view of the EFWG is that this improved investment risk profile, combined with the scale of investment for smaller nuclear power stations (typically <£2.5 billion) being within the range of a significantly increased number of investors, should open the market to entities such as utilities, energy intensive industries and private investors.

The EFWG concluded the UK could be well placed to deliver a First of A Kind (FOAK) SMR by 2030 provided government has a conducive policy environment in place. Their report made several recommendations on ways the government can help to reduce the risk of small nuclear projects and to create a market enabling framework. The UK government has not yet formally responded to the recommendations. However, many closely align with our Advanced Nuclear Technologies



A simplified risk profile from the Expert Finance Working Group report [13]

framework and the initiatives we are already implementing, such as modernising the GDA process (see page 9) and investing in advanced manufacturing capabilities (see page 16). We are considering the report and its recommendations to help guide our policy development.

What did we learn?

The EFWG's work highlights a need for the nuclear sector to engage with the finance and investment community. This is to help develop a common understanding of risks associated with small nuclear projects, and to dispel misconceptions. Some stakeholders believe there are deep-rooted risks with nuclear projects based on historic performance.

Following on from the EFWG's report, we facilitated the **Commercialisation of Small Nuclear in the UK** conference in November 2018 [14] with the aim of engaging the investment community, alongside others to kick start this conversation. It brought together around 200 voices from the nuclear, finance, manufacturing and construction sectors to discuss investment opportunities of small reactor technologies, attend networking events, workshops and keynote speeches. The conference also demonstrated working examples from across multiple supply chains of some of the advanced manufacturing technologies and techniques that will be vital to the success of the modular reactor model.

We view this as the first event in an ongoing conversation and are looking to facilitate a follow-on event hosted in the City of London later this year.

Siting and land access

The need for clarity on siting has been a recurring theme with stakeholders throughout the UK's Advanced Nuclear Technology journey. The availability and suitability of places to build small nuclear power stations is vital for success.

This strand of the Advanced Nuclear Technologies framework aims to consider three linked but separate siting factors:

1. The suitability of sites to host the technical requirements of reactors;

2. The commercial arrangements for buying or leasing a site and the economic appeal for a developer to set up in any given place; and

3. The planning regimes where decisions to allow construction are taken.

The Energy Technologies Institute undertook a **Power Plant Siting study** [15] which ran a wide range of sensitivity studies to explore indicative site capacity for small nuclear plants in the UK. The study recognised that the specific characteristics of any given small or Advanced Modular Reactor may result in different siting needs. However, it concluded that, from a UK perspective, small nuclear projects were less limited than large ones in terms of technically suitable places. The study found the need for less cooling water was likely to open up the option for inland sites as well as coastal sites where large nuclear power stations in the UK tend to be located.

But another key learning point from the ETI **Nuclear Cost Drivers project** [12] is the potential for increasing cost efficiencies by co-locating multiple reactors on the same site, a benefit that small nuclear developers should look to exploit. This may make larger sites more commercially desirable, potentially introducing competition for the more limited options available for Gigawatt scale projects.

In the UK there is growing local, regional and stakeholder interest in redeveloping several sites with small nuclear projects. As a result, we are actively considering the question of siting for small and advanced reactors through the third lens of the UK planning permission regime.

We are exploring arguments that new, smaller power plants should (in the first instance) use or re-use existing, licensed nuclear sites to take advantage of past investment in infrastructure and grid connections, and the skilled workforces around them.

Public Perception

Energy and environmental policies are emotionally engaging subjects which capture peoples' imaginations and inspire public engagement outside elections – for instance through lobbying, participation in the planning process or through peaceful protests. Often this civil engagement is protesting against policies or types of infrastructure, leading to delays, increasing costs or sometimes preventing projects going ahead. What this demonstrates is that for nuclear, as with many other major infrastructure projects, governments, developers and proponents need to take people with them. As the NICE Future initiative identifies, we need to build "social license" if Advanced Nuclear Technologies are to happen.

As policy makers we want to engage with the public to understand their insights and expectations, their hopes and fears about Advanced Nuclear Technologies. We recognise that public perception and public support for new and Advanced Nuclear Technologies will be critical if they are to become part of the UK's secure, affordable and low-carbon energy system for decades to come.

Before starting more work in this area, we commissioned an independent literature review to assess how previous studies took perceptions of SMR and AMR technologies into account to establish a baseline understanding. In September 2018, we also began to ask questions about SMRs in the UK government's Public Attitudes Tracker (PAT) [16].

What did we learn?

The literature review of existing public perception studies about Advanced Nuclear Technologies primarily found that very little public engagement has been carried out on SMRs or AMRs in the UK or around the world. But within the projects that have been published it found consistent themes:

1. There is general acceptance that there may be advantages with Advanced Nuclear Technologies in decarbonising energy provision, but those advantages and the reasons for them are not fully understood;

2. The safety features of Advanced Nuclear Technologies are not understood and the perception of advanced nuclear being less safe is held by a small minority;

3. The opportunity to recycle nuclear waste is considered environmentally beneficial.

The literature review concluded that greater education on the technologies' advantages, safety features and role would be beneficial within a low-carbon energy system.

We are at the beginning of using the PAT to investigate public perceptions about Advanced Nuclear Technologies. However, we know that support and opposition for nuclear power in general have both been steady for several years.

The PAT found support to be at four in ten (38%) of those asked and opposition to be two in ten (22%). So far, the tracker has asked the UK public about their awareness of SMRs once - awareness was low, with 16% claiming to have heard something about them, and 2% saying they knew a great deal. Eight in ten had never heard of SMRs. This level of public awareness is consistent with the awareness of other nuclear issues such as geological disposal and radioactive waste management.

The findings of both the literature review and the PAT show that building greater public awareness and understanding of Advanced Nuclear Technologies is required if SMRs and AMRs are to be part of our solution to tackling climate change.

What are the next steps?

We are aiming to carry out a public dialogue project with UK communities later in 2019 to investigate public perceptions and build awareness of Advanced Nuclear Technologies.

International Collaboration

Deposit of the UK's Instrument of Ratification of the GIF Framework Agreement with the NEA

Collaboration with other nations will be a fundamental part of our policy to successfully realise the opportunities of Advanced Nuclear Technologies. This is a view we know we share with many countries, especially the sponsors and participants of the Clean Energy Ministerial NICE Future initiative.

Climate change is a global challenge. A challenge we can rise to by sharing international expertise and creating opportunities for scientists and engineers including in the advanced nuclear field.

International collaboration will be particularly important for Advanced Nuclear Technologies in unlocking the benefit of the economy of multiples. Nuclear nations and our regulators should work together to set standards that minimise additional regulatory costs when advanced reactors cross borders and enable wider markets to be opened.

We have long been an active participant in international programmes across the fuel cycle, and have recently added to this by:

- Re-joining the Generation IV International Forum in 2018 with participation in Sodium Fast Reactor (SFR) and High Temperature Gas Reactor (HTGR) technologies;
- Signing the UK-US Nuclear R&D Action plan in 2018 with six technical areas linked to UK and US priorities and programmes, sharing capabilities and facilities;.
- Pursuing a more active, engaged and coordinated role in the OECD NEA, with engagement in all eight of the standing technical committees, including jointly chairing the Nuclear Initiatives 2050 programme;
- Participating in the Euratom Fission/Fusion research and training programme; developing key action 10 in the European Strategic Energy Technology (SET) Plan and being a member of the Euratom Science and Technology Committee;
- Engaging with the IAEA and its nuclear research activities; playing a full role in the international community facilitated by the United Nations; and
- Engaging bilaterally with countries in pursuit of a clean safe nuclear generation programme;

Our work within the international research and innovation community leads to maintaining and improving safety, security, environmental and radiation protection issues. It seeks to ensure that nuclear energy generation is an affordable and deliverable low-carbon option.

What are the next steps?

- Continuing to identify international partners to engage with and secure research and innovation investment through bilateral and multilateral co-operations and shared key facilities;
- Delivering on the international bilateral arrangements and engage industrial and academic collaborators through our Nuclear Innovation Programme (NIP); and
- Progressing multi-lateral engagements through EU/Euratom, OECD NEA and IAEA for areas of interest and R&D priorities.

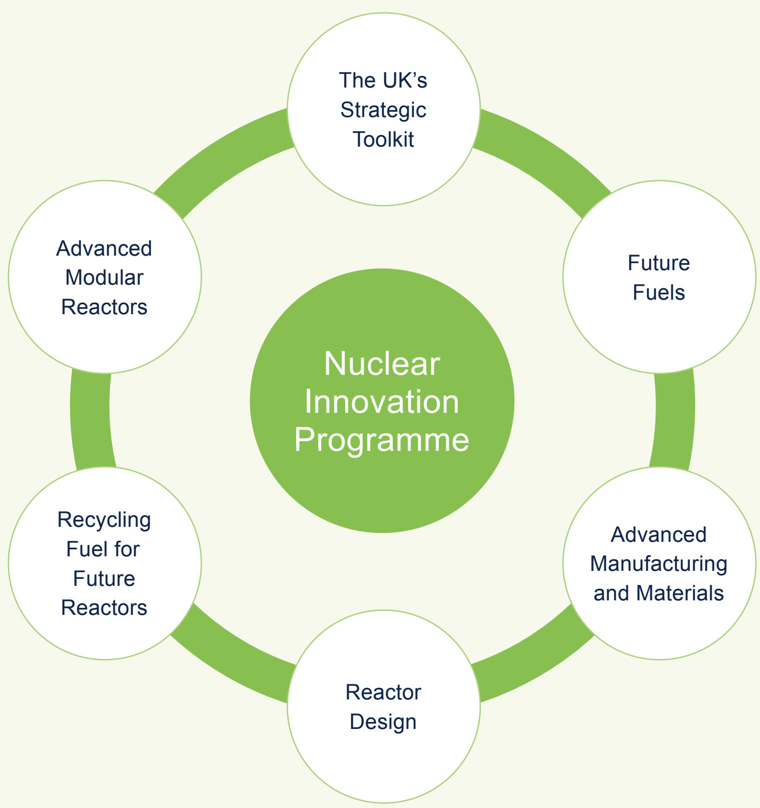
Supply Chain Development

An effective and efficient manufacturing and construction supply chain will be essential to commercialising any Advanced Nuclear Technology. The supply chain is critical for cost reduction through factory build.

The UK has a long pedigree in civil nuclear and we want UK supply chain companies to continue to play a leading role in the design, manufacture, construction and operation of Advanced Nuclear Technologies, both domestically and internationally. We know, for instance, from the SMR Techno-Economic Assessment that the UK supply chain can realistically support about 55% of the capital cost of an SMR at present, but this could increase to around 70% with the right initiatives in place [10]. As a result, we are investing in capability and capacity development in the supply chain.

Nuclear Innovation Programme

The Nuclear Innovation Programme (NIP) [8] is a priority research and innovation programme designed to equip the UK with the skills and ability to capitalise on both near and longer-term market opportunities. It is a £180 million scheme funded by government that aims to develop capabilities across the supply chain so that they can better support a new build fleet, SMR development and AMR R&D. The five year NIP programme was launched in 2016 and has engaged with 54 organisations across 16 countries in the areas shown below.



Future Fuels
Making more efficient and safer fuels for current and future reactors

Advanced Manufacturing and Materials
State of the art techniques embedded in the supply chain, reducing the cost of nuclear projects

Reactor Design
Digital tools to design and build future generations of reactors in an accelerated and cost effective way

Recycling Fuel for Future Reactors
Sustainability through fuel recycling and waste minimisation

Advanced Modular Reactors
Moving next generation technologies towards commercialisation

The UK's Strategic Toolkit
Tools to critically assess emerging technologies, providing a policy evidence base

Advanced Manufacturing and Materials

One of our key learning points from our SMR and AMR evidence is the common aim to use manufacturing facility construction techniques rather than bespoke site-based civil engineering. If this change in delivery approach is successful, it will shorten construction times, improve productivity and quality, and ultimately lower programme risk – critical to attracting investment.

The use of factory manufacturing and off-site assembly of smaller reactors will rely on a highly productive and capable supply chain that uses cutting edge technology and processes to manufacture nuclear components cost-effectively.

Within this strand of the NIP, and as part of the Nuclear Sector Deal, we have committed **up to £20 million for an Advanced Manufacturing and Construction initiative**. This is expected to be match-funded by £12 million from the sector. The aim of this initiative is to demonstrate that new techniques can deliver cost reductions within conventional nuclear new build, Advanced Nuclear Technologies or nuclear decommissioning. The initiative seeks to prove the potential of new advanced manufacturing and construction techniques and the value of digital engineering and assurance. Importantly, by funding real projects the initiative expects to build commercial capabilities within the supply chain, gearing it up to support the civil nuclear sector for the future and especially the advanced nuclear sector.

UK Supply Chain Readiness for AMRs

We have already noted that one of the key learning points in our Advanced Nuclear Technology journey is the diversity of technologies being developed. While we expect that many supply chain capabilities will be useful to many technologies, it is likely that some SMRs or AMRs may have unique requirements that will rely on specialist technology.

To investigate this, the UK's National Nuclear Laboratory (NNL) and Nuclear Advanced Manufacturing Research Centre (NAMRC) are undertaking a project to assess the technology and manufacturing gaps for different Advanced Nuclear Technologies and to map this against the UK's current R&D and supply chain capabilities. We expect that this work will identify where the UK already has state of the art facilities capable of manufacturing advanced reactor components, and, importantly, the capability gaps that may need to be plugged in future with additional development or by working with overseas partners.

Overall the study aims to identify:

- Potential AMR market opportunities for the UK supply chain;
- Opportunities to engage in UK and international R&D programmes;
- Key requirements for an effective AMR Supply Chain and R&D capability; and
- The current capabilities (supply chain and R&D) and how these may be developed to secure market share.

The analysis will help inform policy makers on the current readiness level of the UK supply chain and R&D capability and potential actions which may support these in securing an ambitious share of the AMR market.

The AMR Feasibility and Development project

Since the SMR evidence gathering exercise in 2014, we have learnt that the development of Advanced Modular Reactors would benefit significantly from government R&D funding support to accelerate technology commercialisation and attract private investment. While much was already known about the potential costs, benefits and technology of water-cooled SMRs, much less was known about the next generation reactors planning to use new fuels and coolants. Further evidence was needed around technology readiness, remaining development needs and timescales, and cost projections. It was also needed to inform debate around the proposed new roles for nuclear energy that AMRs could perform.

The UK does have experience of using nuclear energy for more than just electricity generation notably with Calder Hall both being the world's first power station to generate electricity on an industrial scale and the source of steam for process heat across the whole Sellafield nuclear site (in Northern England). However, we have not recently considered the balance of societal benefits and disbenefits of using nuclear energy like this again in the future, or in any other capacity except on-grid electricity generation.

In 2017 we launched a **£44 million AMR Feasibility and Development (F&D) project** [17] to develop further evidence for AMR technologies. The aim was to understand the technical feasibility and commercial viability of advanced reactors and to identify promising designs where UK government development funding could move them closer towards commercial deployment.

We focussed our interest on technologies that maximise the use of off-site fabrication of modules, and that provide:

- low cost, low carbon electricity;
- increased flexibility in providing electricity;
- increased functionality, such as providing heat and electricity; or
- an alternative application that will generate additional revenue or support economic growth.

Phase 1

The AMR programme is a two stage R&D programme. Phase 1 is a feasibility study phase designed to:

- Gather information against common criteria for assessing AMRs, identifying key technical challenges and barriers to deployment;
- Understand the technical feasibility, timelines, energy system benefits and key risks (including regulatory confidence) of developing and deploying AMR designs in the UK;
- Identify opportunities for the UK supply chain in AMR development both domestically or overseas and identify opportunities for working with international partners; and
- Confirm projections for resource requirements to commercialise the designs.

Based on learning from the SMR TEA [10], we required information be provided in a structured, consistent format that would ensure a common interpretation of requirements and enable comparison.

Over twenty organisations submitted proposals for Phase 1 of the AMR F&D project, from which we awarded eight contracts. We have received all eight feasibility studies from participants which is an important milestone that will inform policy for next generation reactors.

Phase 2

Phase 2 of the programme will include a sub-set of contractors from Phase 1. Subject to value for money decisions within government, it intends to provide up to ~£10 million development grants to successful organisations to undertake applied R&D on their technology. The aim is to help progress the development of key components or sub-components that confirms the technical feasibility and cost projections of the reactor designs.

References

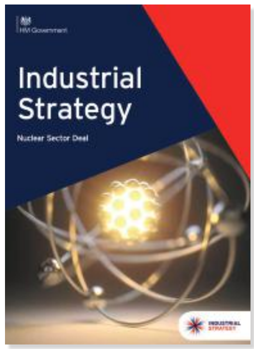
1.
The Clean Growth Strategy

www.gov.uk/government/publications/clean-growth-strategy

2.
Industrial Strategy

www.gov.uk/government/publications/industrial-strategy-building-a-britain-fit-for-the-future

3.
Nuclear Sector Deal



www.gov.uk/government/publications/nuclear-sector-deal

4.
Digest of United Kingdom Energy Statistics 2018

www.gov.uk/government/statistics/digest-of-uk-energy-statistics-dukes-2018-main-report

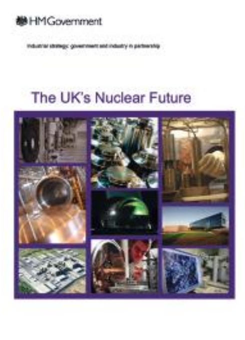
5.
Speech - After the trilemma - 4 principles for the power sector

www.gov.uk/government/speeches/after-the-trilemma-4-principles-for-the-power-sector

6.
Policy paper - Advanced Nuclear Technologies

www.gov.uk/government/publications/advanced-nuclear-technologies/advanced-nuclear-technologies

7.
Nuclear Industrial Strategy

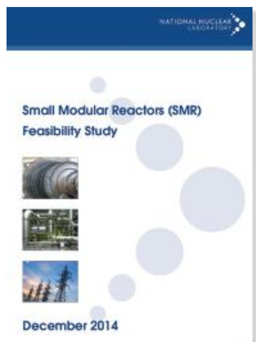


www.gov.uk/government/publications/nuclear-industrial-strategy-the-uks-nuclear-future

8.
Funding for Nuclear Innovation

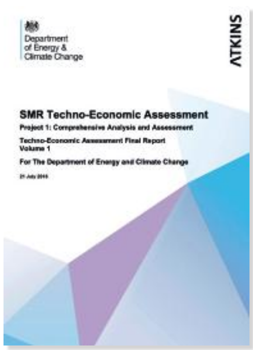
www.gov.uk/guidance/funding-for-nuclear-innovation

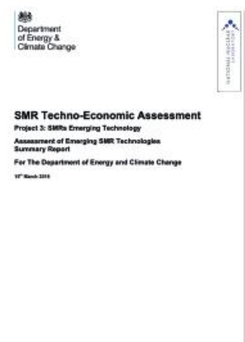
9.
SMR Feasibility Study

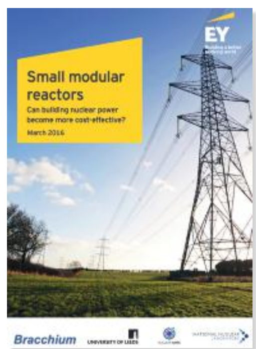


www.nnl.co.uk/wp-content/uploads/2019/02/smr-feasibility-study-december-2014.pdf

10.
SMR Techno-Economic Assessment

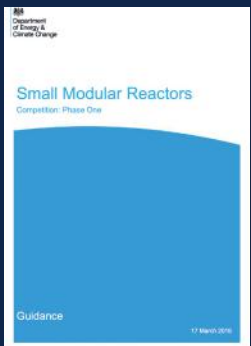






www.gov.uk/government/publications/small-modular-reactors-techno-economic-assessment

11.
SMR Competition



www.gov.uk/government/publications/small-modular-reactors-competition-phase-one

12.
ETI Nuclear Cost Drivers Project

www.eti.co.uk/library/the-eti-nuclear-cost-drivers-project-summary-report

13.
EFWG – Market Framework for financing Small Nuclear

www.gov.uk/government/publications/market-framework-for-financing-small-nuclear

14.
Commercialisation of Small Nuclear Event

www.marickpartners.co.uk/smallnuclearuk/

15.
ETI Power Plant Siting Study

www.eti.co.uk/library/power-plant-siting-study-summary-report-and-peer-review-letters

16.
Public Attitudes Tracker

https://www.gov.uk/government/collections/public-attitudes-tracking-survey

17.
AMR Feasibility and Development Project

www.gov.uk/government/publications/advanced-modular-reactor-amr-feasibility-and-development-project

For more information contact: smrteam@beis.gov.uk
or visit Advanced Nuclear Technologies on gov.uk