# UK Innovation in Advanced Nuclear Technologies

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# Nuclear development in the UK

- Reasons for new nuclear development in the UK
- UK Nuclear R&D and innovation programme
- UK interest in modular reactors

# UK nuclear history – a quick recap

The UK has had a substantial history of developing (mainly) $CO_2$ cooled, graphite moderated reactors with increasing core design temperatures.

1950s-60s - Magnox (Gen I):

- Commercial operation 1956 – 2010s
- $CO_2$ coolant, unenriched U metal fuelled
- Core temperature 400°C

Source: Nuclear Decommissioning Authority

1970s-80s -

Advanced Gas-cooled Reactors (Gen II):

- Commercial operation 1976 - present
- $CO_2$ coolant, $UO_2$ fuelled
- Core temperature ~640°C

Source: Nuclear Decommissioning Authority



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# UK nuclear history – a quick recap

1990s

- The first of a new planned fleet of PWRs: Sizewell B opens.
- Nuclear programme then discontinued.
- No clear plans for new nuclear power plant



1980s - 2000s

- Decline in UK publicly funded nuclear R&D capacity
- 90% reduction in work force
- Even greater proportional reduction in funding.

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# Reasons for new nuclear development in the UK

## Climate Legislation

- For Greenhouse Gases, the UK has domestic targets that look ahead to 2050
- UK Climate Change Act - 80% cuts in greenhouse gas on 1990 levels of emissions by 2050

## Energy supply objectives

- Secure and affordable energy system

Energy Act 2008

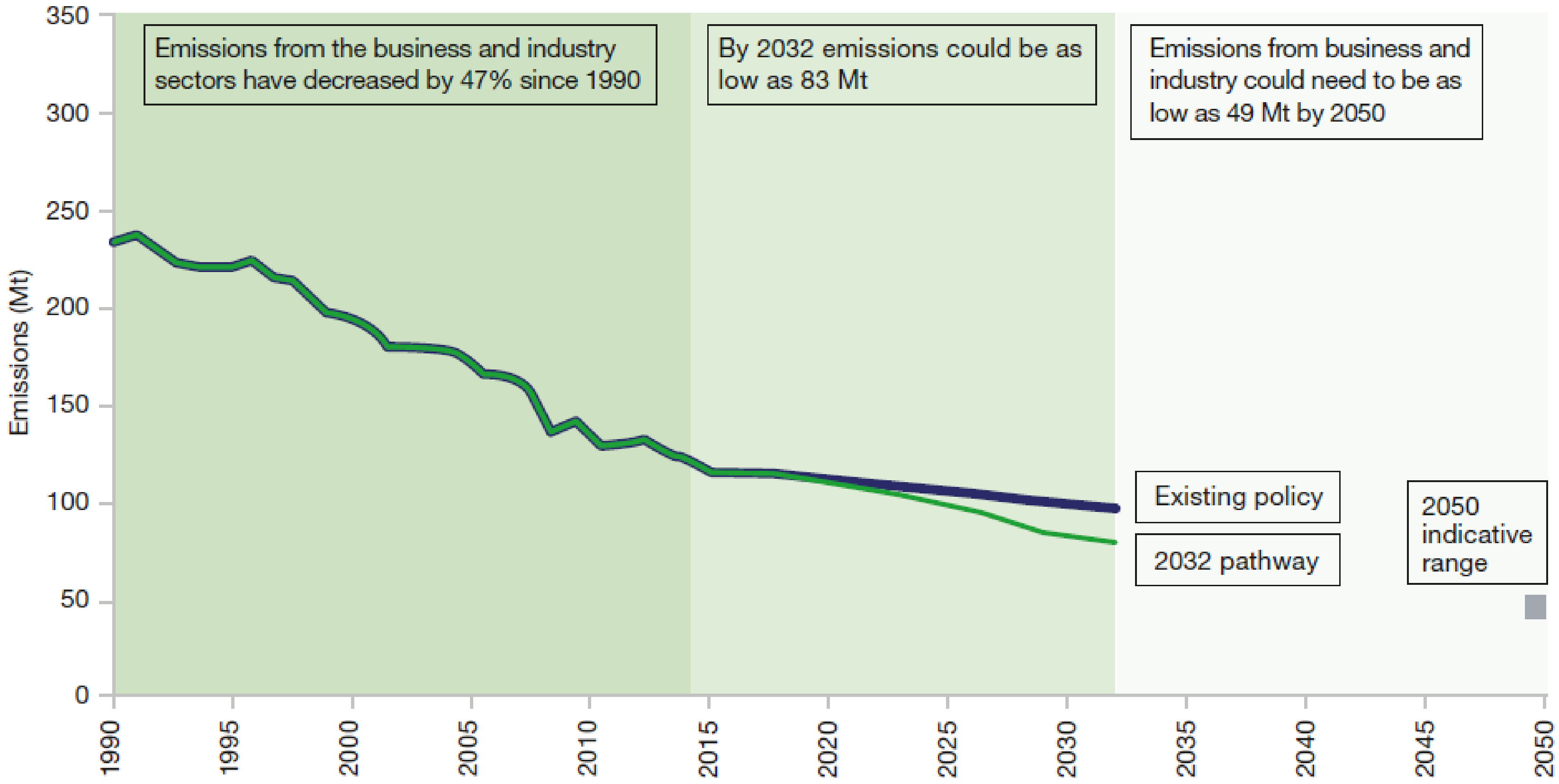
Climate Change Act 2008


http://www.opsi.gov.uk/acts/acts2008/pdf/ukpga_20080032_en.pdf
http://www.opsi.gov.uk/acts/acts2008/pdf/ukpga_20080027_en.pdf

# Reasons for nuclear development in the UK

## Considerable emissions reduction needed

**Actual and projected emissions in business and industry, taking into account the clean growth pathway, 1990-2050 (from UK Government's Clean Growth Strategy, 2017)**

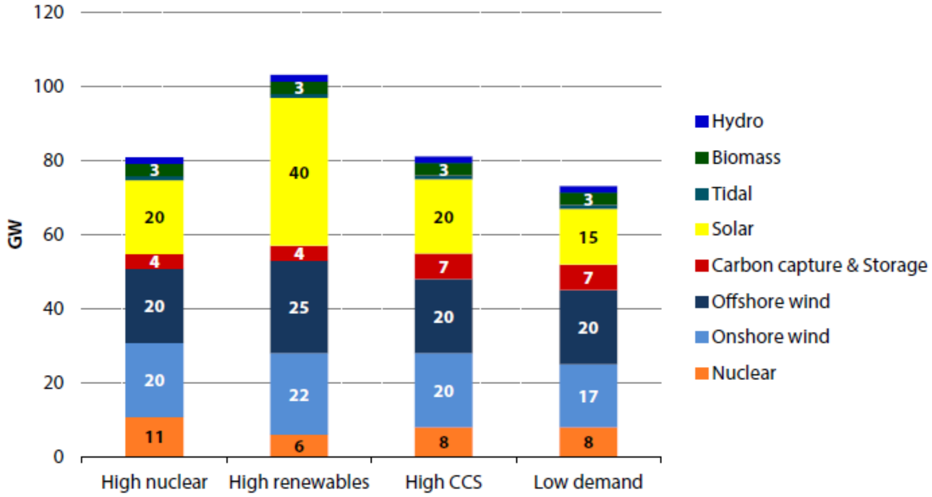



Source: BEIS

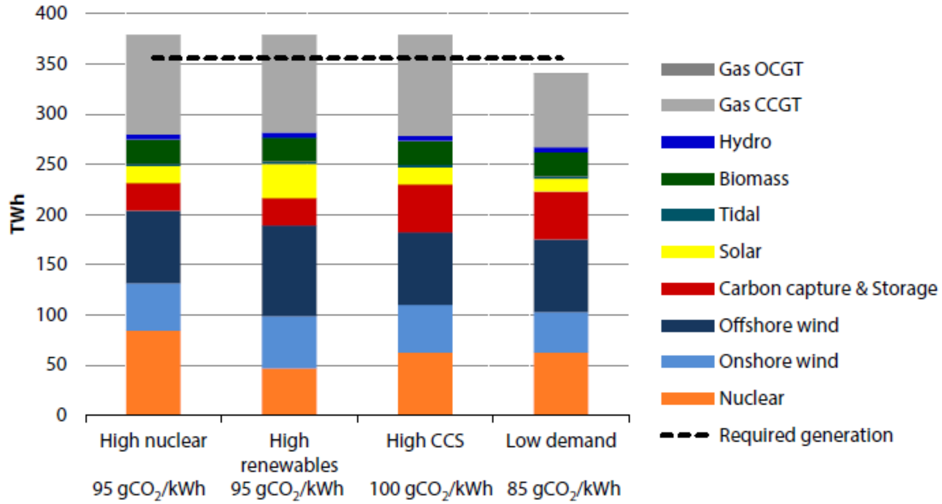
# Reasons for nuclear development in the UK

## UK Committee on Climate Change scenarios for the UK's 2030 electricity generation mix

### Generation capacity




### Annual generation



# Reasons for nuclear development in the UK

- Nuclear energy is seen as playing a role in the lower cost decarbonisation scenarios.
- Evidence that nuclear energy contributes to security and cost reduction for overall energy system.
- Built on resurgence of UK interest in nuclear on the basis of large scale, low carbon generation.

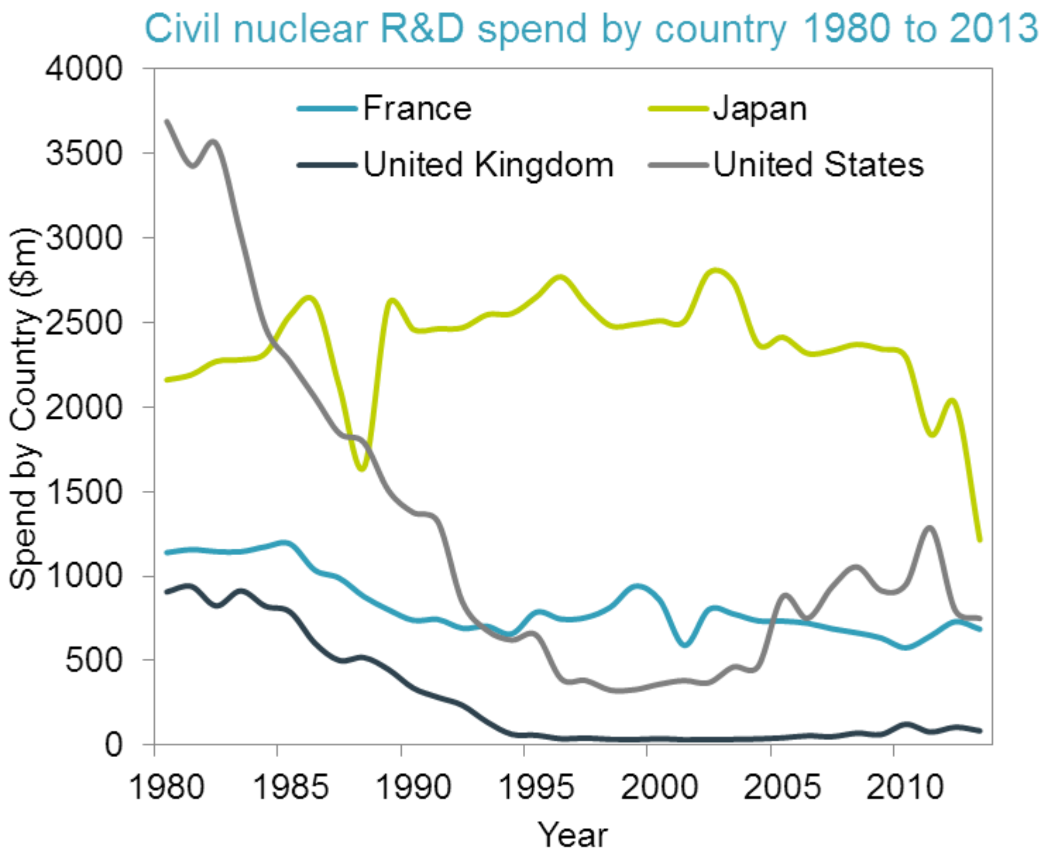
# BEIS Nuclear Innovation Programme

**History**

UK nuclear R&D declined following deployment of current fleet of power plant.

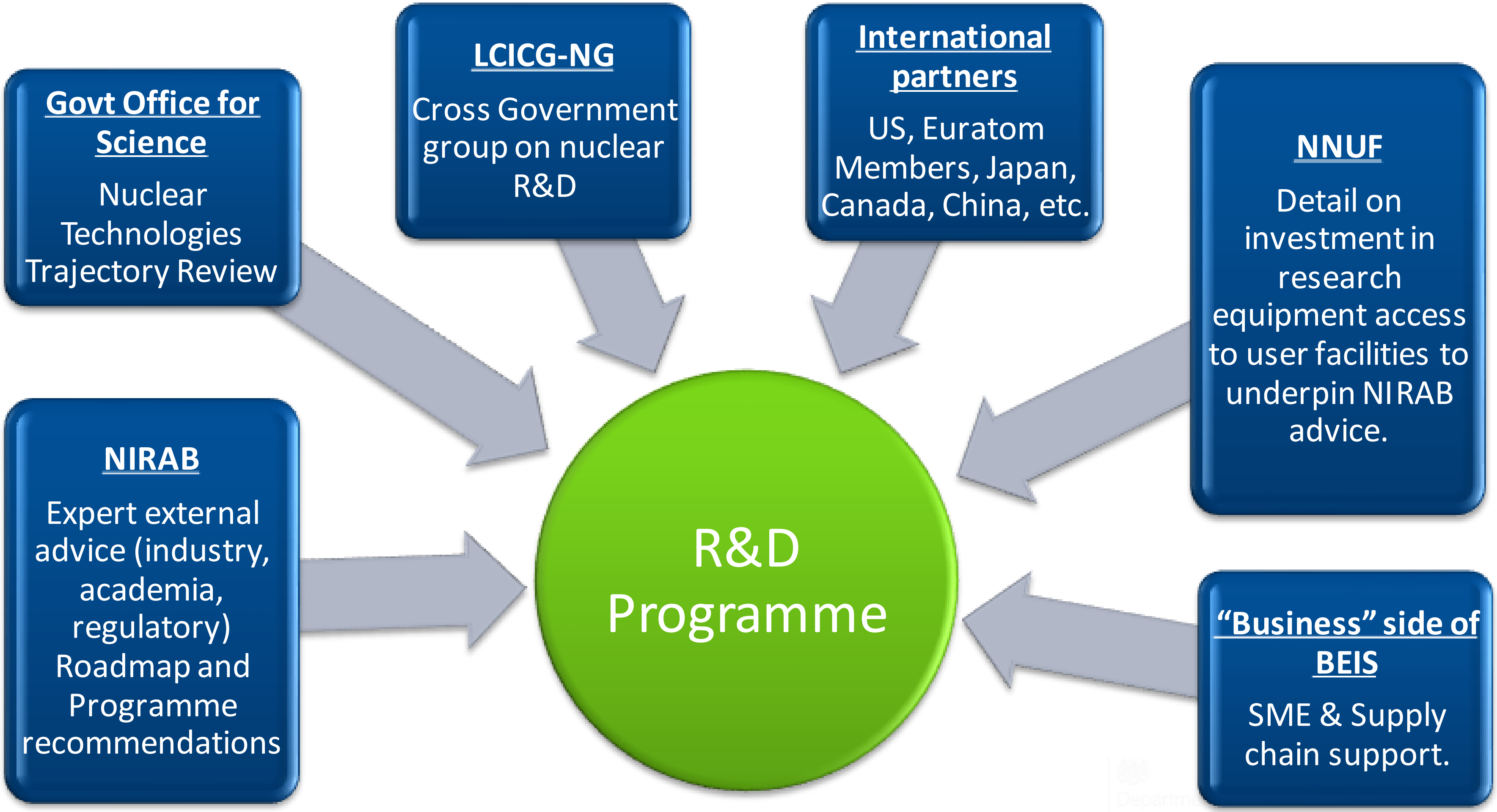
Review by UK Parliament in 2011 was highly critical of this in the light of increased enthusiasm over nuclear energy.

Prompted a review of nuclear R&D strategy and resulted in the current UK nuclear innovation programme.



# BEIS Nuclear Innovation Programme

## Input into developing the programme



# BEIS Nuclear Innovation Programme

## Programme aims

### Capability

- Secure, maintain and renew the indigenous skills and experience needed to ensure that nuclear can continue to play a part in delivering secure, low-carbon energy to the UK market.

### Supply Chain

- Develop the capability, capacity and credibility of the UK supply chain to support both civil and defence programmes and leverage greater commercial exploitation of domestic and global nuclear markets.

### Costs

- Seek to reduce the costs of the future nuclear life cycle.

# BEIS Nuclear Innovation Programme

| | |
|---|---|
| Nuclear Fuels | • Developing more robust and efficient fuels for current and future reactors. |
| Advanced Manufacturing & Materials | • Developing capability in advanced manufacturing and modular technology that will reduce the time and cost of future build projects. |
| Advanced Reactors | • Developing areas where UK strengths can contribute to reactors of the future. Including: Modernising regulatory safety methodologies; Developing robust modelling to support assessment of novel technologies; Virtual engineering; Safety and Security Engineering |
| Recycle and Waste Management | • Ensuring that UK maintains its global lead in technologies that could provide for a more secure and sustainable fuel supply. |
| Strategic Toolkit & Facilities | • Ensuring that we have the tools and capability to underpin future planning on nuclear R&D. Coordination and optimisation of our portfolio of existing and future facilities. |

# Potential attractions of SMRs

## Economic

- Easier than large nuclear to finance privately in the long-term (lower unit cost).
- Potentially quicker return on investment from shorter build time (lowering cost of borrowing money).
- Potentially lower cost in the long-term – reduced production cost through factory construction at scale (c.8GW).
- Potential to secure IP and create high value jobs.

## Technical

- Size / thermal load allows accommodation more easily on smaller sites (in UK's case - on more existing nuclear sites).
- Technical potential to load follow.
- Technical potential to provide district / industrial heat.
- Technical potential for easier maintenance due to factory based supply chain facilitating standardisation and QA.

# Understanding SMRs: 2015 TEA

March 2015 : UK Government launched a technoeconomic assessment (TEA) of Small Modular Reactors (SMRs) in order to contribute to the evidence base and help inform policy decisions.

Themed around 7 projects:

1. Comprehensive analysis and assessment of SMRs. Led by Atkins
2. Systems optimisation modelling for SMRs. Led by the Energy Technologies Institute
3. Assessment of emerging SMR technologies. Led by the National Nuclear Laboratory
4. Assessment of UK regulatory regime for SMRs. Led by Checkendon Hill
5. Advanced manufacturing
6. Advanced assembly, modularisation and construction
7. Control, operation and electric systems

# Findings of the TEA

## Technology readiness

- (I)PWR technology has the potential to contribute to the UK generation around 2030.
- HTGR and SFR could be ready for commercial deployment in the period between 2035 and 2050.
- Other reactor technologies are less likely to be deployed in this timeframe, given the amount of outstanding technical challenges.
- More developed designs offer fewer IP opportunities then the lower TRL ones.
- Emerging systems using recycling can offer waste disposal advantages, but require development of novel treatment routes for challenging wastes.
- Low-capacity (<<1GWe) groups of SMRs may have siting benefits due to lower cooling water and grid connectivity requirements.
- Technical challenges rise as site capacity increases or elements of the back end of the fuel cycle are required to be co-located on the reactor site.

# Findings of the TEA

## Build cost

- Expected factory production technology suggests rates of cost reduction will be higher than historic nuclear , based on comparison with aerospace, shipbuilding, CCGT and wind turbine sectors. Learning can be faster for SMRs than big NPPs, with a higher number of reactor years for the same output as large reactors.

- It is unlikely that this level of deployment to fully exploit this can take place in a purely national market, which suggests that successful cost reduction for an SMR design may be achieved through global deployment.

- International deployment of SMRs may be enhanced through international harmonisation of the licensing process for SMR technology. Conformity of design between a vendor's domestic and exported models should help cost reduction.

# Findings of the TEA

## Deployment and operation

- Generation costs could be significantly lowered by additional services, particularly heat provision (e.g. industrial CHP or heat networks).
- SMRs can offer improved load following ability in comparison with large reactors, although it is not economical within the current market.
- Advanced manufacturing techniques, modularisation and co-siting of reactors can further reduce SMR capex.
- Learning, with its associated cost reductions, is only possible with consistency in the supply chain.
- Regulatory stability is needed to reduce design change and enable higher production rates.

# Understanding SMRs: 2016 SMR Competition

- At the Spending Review and Autumn Statement 2015, the UK government announced that it would invest in an ambitious nuclear research and development programme. This included a competition to gather evidence to inform policy development on SMRs.

- In March 2016, government launched the first phase of the SMR competition as an evidence-gathering phase with the goal of gauging market interest among technology developers, utilities, and potential investors.

- Expressions of interest were received from 33 eligible participants, covering a range of LWR and more advanced designs, including 4 of the technologies covered by the Gen IV International Forum.

- Officials worked with these participants to understand the technological and commercial viability of new reactors in development. Project finished in late 2017

# Refinement of approach to SMRs

Lessons learned from 2016 competition : a two pathway approach

## Smaller Conventional Reactors

- “SMRS”
- Water-cooled
- On-grid electricity

Need market access assistance in current framework

## Advanced Modular Reactors

- Higher temperatures
- Fast Spectrum
- Different coolants
- Novel applications

Need assistance in regulatory engagement and feasibility assessment.

# Advanced Modular Reactors

- A broad group of advanced nuclear reactors (including Gen IV) which differ from the technologies of conventional reactors that utilise pressurised or boiling water for primary cooling purposes.

- Maximise the use of off-site factory fabrication of modules and target applications that include:
  - delivering low cost electricity
  - increased flexibility (e.g. load following) in delivering electricity to the grid
  - increased functionality (e.g. heat output for domestic and/or industrial use, facilitate the production of hydrogen)
  - providing alternative applications that generate additional revenue or economic growth

# Advanced Modular Reactors

| Enablers | Policy Initiatives |
|---|---|
| Policy | Providing options to Ministers mid 2018 |
| Financing | Expert Finance Working Group to advise on small reactor financing – report end of May. |
| Regulatory Framework | Funding to increase regulator capacity and capability. Regulator 1-to-1 engagement programme throughout April/May 2018. |
| Land & Siting | Seeking legal counsel to provide options for Nuclear Decommissioning Authority land use |
| Supply Chain Development | Potential advanced manufacturing initiative in the Nuclear Sector Deal |
| Public Acceptability | Commissioned project to explore public perception of small reactor |
| International Collaboration | Exploring opportunities with key partners |

# Supporting framework

### Advanced Modular Reactor (AMR) Programme.

- Up to £44m to assess the feasibility of innovative reactors projects and to accelerate the development of promising designs.
- Launched Dec 2017.

### Funding for the UK Regulators.

- Up to £12m to ONR/EA to increase the capability and capacity to assess and license new designs.
- This includes funding for a 1-to-1 vendor/regulator engagement programme.

### The Expert Finance Working Group.

- Exploring financial models of small and advanced reactor developers and advising Government on how small reactor projects could raise private investment.
- Providing options to ministers throughout 2018.

# Aims

- Helping to ensure that the UK has secure, long-term energy supplies that are reliable, affordable and clean.
- Creating opportunities for UK companies, securing high value content in leading designs, developing UK manufacturing bases and delivering highly skilled jobs.
- Ensuring the UK remains at the leading edge of science, research and innovation in AMR technologies.
- Tackling climate change by helping to commercialise key reliable and economic low carbon technologies.

# AMR Programme

**Phase 1** – Funding (up to £4m) to undertake a series of feasibility studies for AMR designs.

**Phase 2** – Subject to further HMG approval, up to £40m may be available for successful selected designs from Phase 1 to undertake applied R&D.

Complements R&D on specific technologies (e.g. recycling) in the UK's national Nuclear Innovation Programme.

# Phase 1 Objectives

- Develop common criteria for assessing AMRs
- Understand technical feasibility, timelines, energy system benefits and key risks of developing and deploying AMR designs in the UK.
- Identify opportunities for the UK supply chain in AMR development in the UK or overseas and identify opportunities for working with international partners.
- Validate projections of the resource requirements for the commercialisation of designs.
- Develop a business case for further R&D to overcome priority technical challenges and barriers to the deployment of AMRs, which will form Phase 2 of the AMR Feasibility and Development research initiative.

# Feasibility Studies

**Deliverable 1:**

- Design specific evidence base
- Business Proposition and delivery model
- *Cost data and cost reduction strategy*
- *Research and Development plan to commercial deployment*

***Deliverable 2:***

- Key safety, security and environmental information

***Deliverable 3:***

- Proposal for priority applied research to be undertaken during Phase 2 of this AMR Feasibility &Development project
- Scalable options between £5m and £10m
- Clear link to the Research and Development plan provided in Deliverable 1
- Demonstrate how Phase 2 Proposal represents value for money for government.

## International outreach

Increased interest in SMRs / AMRs in some partner countries.

| | |
|---|---|
| Canada | Poland |
| France | USA |

Drivers include:

- Energy supply to remote communities.
- Industrial heat supply.
- Energy security and supply independence.
- Cost reduction.

# Conclusions… for now!

- Evidence that modularity and size reduction are potential enablers to cost reduction.
- Some degree of conformity in designs and in approach to licensing are likely to assist deployment.
- Additional services (heat, load flexibility, etc.) seem likely to add to the economic and strategic cases for deployment – and may be key for some designs.
- Advanced (non-PWR) reactors may offer benefits over PWR designs, but need a concerted effort for development.

## The investigation is ongoing!

# THANK YOU FOR YOUR TIME AND ATTENTION!

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