Nuclear Energy in the UK and the Role of Advanced Nuclear Technology

Dr Fiona Rayment
Executive Director, NIRO

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The UK Climate Change Act sets an 80% decarbonisation target for the UK by 2050 - the path to this target is based on 5 year carbon budgets. We are in the 3rd carbon budget, and at 42% decarbonisation (against 1990 baseline level).

Over same period UK GDP has grown by 67%, so growth and emissions can be decoupled.

Energy use, including transport, accounted for more than 80% of UK greenhouse gas emissions in 2015 – so it’s a primary area to target for emission reductions.

Achieving our targets with current technologies at current costs will be difficult and perhaps impossible so innovation is critical.

Transport becomes the largest emitting sector of UK 2016 greenhouse gas emissions

Source: BEIS 2018
Clean Growth Strategy Innovation

…has a very strong focus on innovation to drive clean growth:

**INVESTMENT IN INNOVATION FOR CLEAN GROWTH**

To achieve the clean growth we want, the UK will need to nurture low carbon technologies, processes and systems that are as cheap as possible. It is only through innovation that we will see new technologies developed and the cost of clean technologies come down.

Government has significantly increased its investment in low carbon innovation

This strategy sets out, for the first time, where Government funding is targeted

<table>
<thead>
<tr>
<th>Sector</th>
<th>Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport</td>
<td>33%</td>
</tr>
<tr>
<td>Power</td>
<td>25%</td>
</tr>
<tr>
<td>Cross-sector</td>
<td>15%</td>
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<tr>
<td>Smart Systems</td>
<td>10%</td>
</tr>
<tr>
<td>Business &amp; Industry</td>
<td>8%</td>
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<tr>
<td>Land Use &amp; Waste</td>
<td>4%</td>
</tr>
</tbody>
</table>

£2.5 billion allocated 2016-2021

£2.5 billion
UK Nuclear: Current Status

The first of some 19GWe of new-generation plants is expected to be on line by 2025 of which there is an expectation that 16GWe of new nuclear capacity will be operating by 2030.

UK currently has 15 reactors (AGRs and PWR) generating ~ 21% of energy mix but almost half of this capacity is to be retired by 2025.

Shares of Electricity Generation by Fuel

Source: Digest of UK Energy Statistics (DUKES) 2018; Chapter 5

The first of some 19GWe of new-generation plants is expected to be on line by 2025 of which there is a expectation that 16GWe of new nuclear capacity will be operating by 2030.
UK Nuclear: Current Capability

~200 companies : 88,000 people : 30 universities
Beyond 2050: Scenarios for deployment

Deliver long term secure energy on the way to a low carbon energy future

Technology
- LWRs
- SMRs
- ANT - Gen IV systems

“In 2018 Nuclear Energy makes up 21% of the UK Energy Mix” Source WNA
Nuclear Energy Innovation Programme
Advanced Nuclear Technologies

- Small reactors offer the potential to boost skills and create jobs in the UK, as well as reducing the cost of energy through modularisation.
- Government has been working closely with industry to explore this potential.
- The advanced nuclear market is diverse and includes a range of technologies, at different levels of maturity and market readiness.
- Focus – Cost, Flexible Supply, Waste and Alternative Applications
Capitalised Cost Breakdown of the US PWR Benchmark

Reference: The ETI nuclear cost drivers project: summary report
Advanced reactor strategies to reduce construction costs

- Economy of scale replaced by economy of volume & factory production
- Intrinsic passive safety simplifies safety systems
- Higher energy density reduces footprint & materials
- Deep burn fuel reduces ops costs
Flexible Supply

Pumped Storage

Excess electricity is used to create gravitational potential energy

Thermal storage
SMR for Non-Electric Applications

- Very high temperature reactors
  - Gas-cooled fast reactors
  - Molten Salt reactors
- Supercritical water-cooled reactors
- Sodium-cooled fast reactors
- Liquid metal cooled reactors
- Water cooled reactors

- District heating
- Seawater desalination
- Pulp & paper manufacture
- Methanol production
- Heavy oil desulfurization
- Petroleum refining
- Thermochemical hydrogen production
- Methane reforming hydrogen production
- Coal gasification
- Blast furnace steel making
Announced Policies:

• **The Advanced Modular Reactor (AMR) Programme.** Up to £44m to assess the feasibility of innovative reactors projects and to accelerate the development of promising designs.

• **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.** Tasked with exploring the financial models of small and advanced reactor developers and advising Government on how small reactor projects could raise private investment. Due to report in May.

Looking to the future, in addition to conventional nuclear power plants, the **UK Government recognises the potential of small and advanced reactors.**

"The advanced nuclear sector has the potential to play an important part in the UK’s Industrial Strategy building on our existing economic strengths and competitive advantages in nuclear while shaping new advanced nuclear markets and contributing to tackling the Clean Growth Grand Challenge.”
### Advanced Modular Reactors: Demonstrating the feasibility of design

<table>
<thead>
<tr>
<th>Low cost electricity</th>
<th>Increased functionality e.g. heat</th>
</tr>
</thead>
</table>
| **Westinghouse UK Ltd**  
Lead Cooled Fast Reactor (LFR)  
UO₂ enriched or MOX fuel | **Ultra Safe Nuclear Corporation**  
High Temperature ‘Micro Modular Reactor’ (HTR)  
UO₂ kernel, TRISO in an SiC matrix (FCM pellet)  
Coolant, Helium  
Moderator, Graphite |
| **Leadcold, SEALERUK (Small, Economic and Agile Lead-cooled Reactors for the UK)**  
Lead Cooled Fast Reactor (SFR)  
Uranium Nitride fuel | **DBD Ltd**  
High Temperature Reactor (HTR)  
UO₂ kernel, TRISO in graphite pebble  
Coolant, Helium  
Moderator, Graphite |
| **Advanced Reactor Concepts LLC, ARC-100**  
Sodium Cooled Fast Reactor (SFR)  
U enriched metal alloy fuel | **U-Battery Developments Ltd**  
High Temperature Reactor (HTR)  
UO₂ kernel, TRISO, prismatic  
Coolant, Primary – Helium, Secondary – Nitrogen  
Moderator, graphite |
| **Moltex Energy Limited**  
UK Stable Salt Reactor  
Molten Salt Reactor (MSR)  
Fuel, NaCl / UCl₃  
Coolant, ZrF₄/KF/NaF | **Tokamak Energy Ltd**, the spherical tokamak  
Fusion Reactor (FR)  
Deuterium and Lithium fuel  
Coolant, Lithium |
The UK wishes to create a ‘Market Enabling Framework’ to foster the conditions needed for developers to bring new technologies to market. Other initiatives still in development are:

- **Enabling regulation** to recognise that small and advanced reactors may have differently regulatory requirements and undertaking work to understand these;

- Identifying **international collaboration** opportunities to de-risk technology development and develop relationships with our key international partners;

- Demonstrating the deliverability of cost savings through a **supply chain development** initiative that may feature in the nuclear sector deal;

- Considering the **siting** parameters for small reactors with the recognition that there is market interest in using NDA sites; and

- Understanding the **public acceptability** of advanced nuclear technologies.
Enabling Regulation:
Development and implementation of plans to:

– engage with SMR industry

– ensure that the regulators’ processes and guidance are fit for the purpose of assessing and licensing SMRs

– extend ONR & EA’s engagement with international regulators
Market Framework for Financing Small Nuclear
Recommendations from Expert Finance Working Group

Key Recommendation: HMG should help de-risk (perceived and real risks) the small nuclear market in order to enable the private sector to develop and finance projects.

Additional Recommendations:
1. HMG should enable small nuclear through a clear policy and market framework – rather than down selecting technologies
2. HMG should work with stakeholders from energy, nuclear and finance sectors to develop a common understanding of risks
3. For technologies capable of deployment by 2030, HMG should focus resources on bringing FOAK projects to market (only providing grants to enhance UK capability of in exchange for IP
4. HMG should establish an advanced manufacturing supply chain initiative (as with off shore wind) to drive new manufacturing capability with respect to balance of plant
5. HMG should work with regulator to review regulatory processes to develop an optimised and flexible GDA process
6. HMG should make sites available to FOAK small nuclear projects and should consider maintaining the UK’s existing Site Licencee capability to de-risk the licence role for small nuclear projects
7. For technologies capable of deployment by 2030 HMG should focus resources by enabling reduction in cost of capital (e.g. direct equity, Contracts for Difference, Power Purchase Agreements etc.)
