AFCP
Advanced Fuel Cycle Programme

Energy System Modelling and Fuel Cycle Roadmaps

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Briefing to JAEA Tues 17th August 2021

Department for Business, Energy & Industrial Strategy

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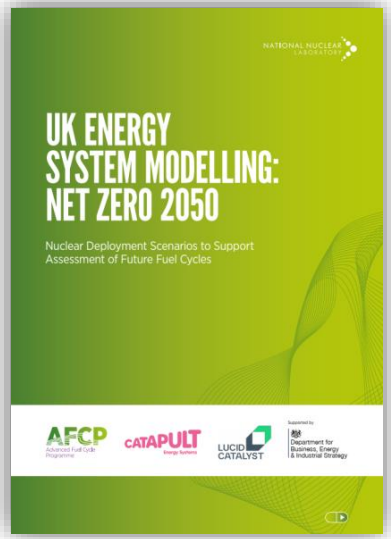
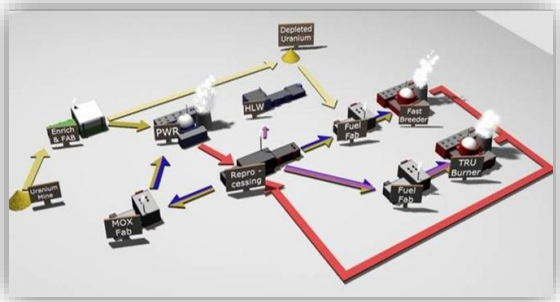
Three key questions…

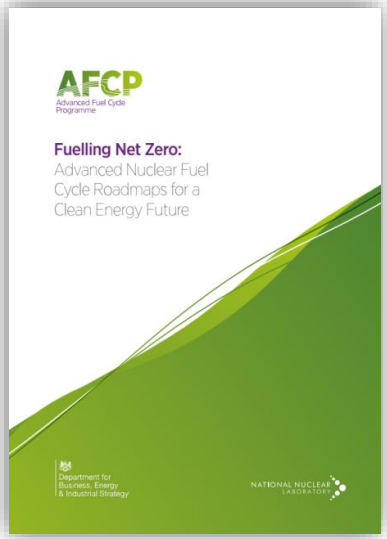
What could the future energy system look like and what role for nuclear technology?

What could this mean for resource demand and used fuel management?

How do we ensure the technology and capability is ready to meet the demand?



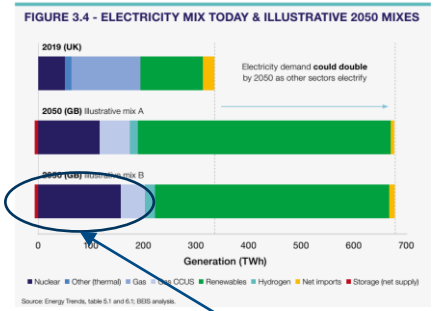




Energy White Paper

Published 14 December **Supportive of all forms of new nuclear energy**

https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future



Approx 18GWe from nuclear by 2050. In supporting modelling states between 5 and 40 GWe of nuclear

Large Nuclear

- **We will aim to bring at least one large-scale nuclear project to the point of Final Investment Decision (FID) by the end of this Parliament, subject to clear value for money and all relevant approvals.**

RAB review published

Government "will examine the potential role of government finance during construction"

Advanced Nuclear

- **We will provide up to £385 million in an Advanced Nuclear Fund for the next generation of nuclear technology aiming, by the early 2030s, to develop a Small Modular Reactor (SMR) design and to build an Advanced Modular Reactor (AMR) demonstrator.**

"As the first major commitment of the programme, in 2021 we will open the **Generic Design Assessment** to SMR technologies"

ADVANCED MODULAR REACTOR

Advanced Nuclear Reactors (AMRs) are reactors which use novel cooling systems or fuels and may offer new functionalities (such as industrial process heat). These reactors could operate at over 800°C and the high-grade heat could unlock efficient production of hydrogen and synthetic fuels.

Fusion

- **We aim to build a commercially viable fusion power plant by 2040.**

"The government has already committed over £400 million towards new UK fusion programmes"

Hydrogen

- **We will publish a dedicated Hydrogen Strategy in early 2021 which positions the UK as a world leader in the production and use of clean hydrogen.**

A variety of production technologies will be required to satisfy the level of anticipated demand for clean hydrogen in 2050. This is likely to include methane reformation with CCUS, biomass gasification with CCUS and electrolytic hydrogen using renewable or nuclear generated electricity.

Net Zero Innovation Programme

£1 billion NZIP

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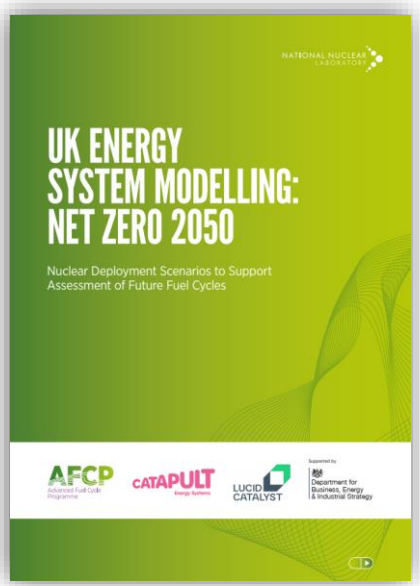

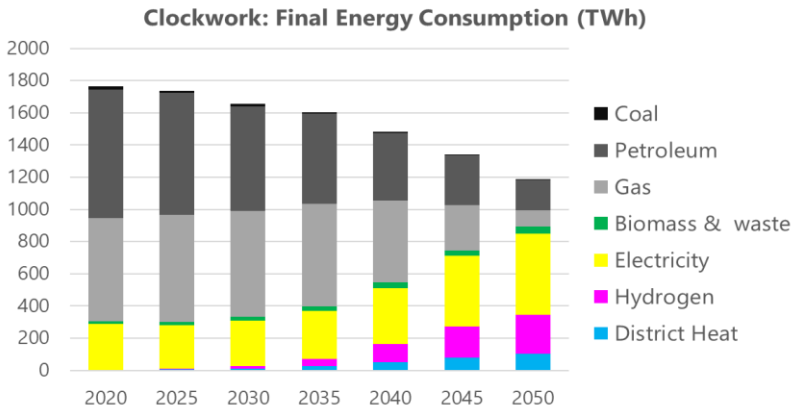

Could mean:

Unabated Fossil Fuel consumption down from **~1500TWh to <300TWh**

Electricity **600-800TWh**

Hydrogen **200-300TWh**

District Heat **Up to 150TWh**

Three zero carbon vectors require unprecedented scale-up to displace fossil fuels for final energy

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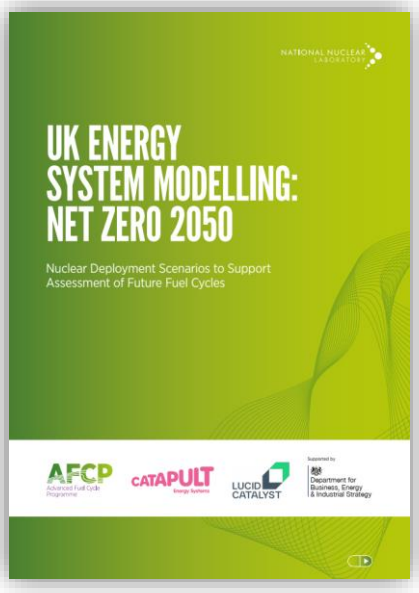

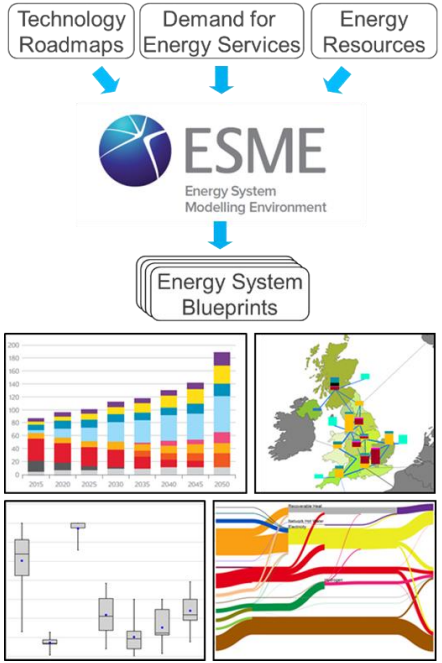

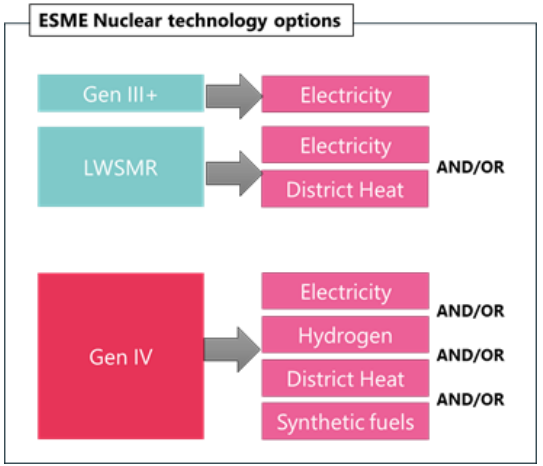

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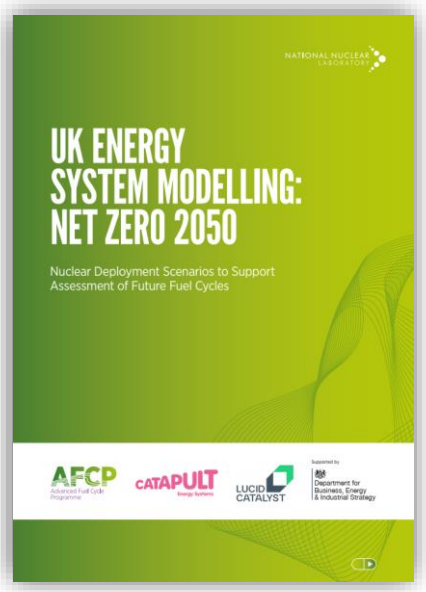
Key themes



Key technologies and findings include:

- **Wind:** Wind remains the key renewable technology in capacity and generation for decarbonising power.
- **Nuclear:** For the nuclear data assumed in this analysis, levels of nuclear deployment were consistently significant and included roles in all three key vectors – electricity, district heating and hydrogen.

For nuclear, the modelling revealed new insights for a range of applications:

- **Cogeneration:** The ability of nuclear to operate in cogeneration is valuable in a future system. Where a common nuclear heat supply system is deployed – both as cogeneration heat and power and cogeneration power and hydrogen – the hydrogen variant is deployed at higher levels.
- **Carbon capture and storage:** When nuclear is deployed, carbon capture and storage (CCS) applications – such as for gas and biomass – are prioritised towards hydrogen production with relatively low deployment for electricity generation.
- **Synthetic fuel:** The study tested liquid synthetic fuel technology for aviation. System analysis demonstrated the system value of such a technology in providing an option to remove emissions from this hard to treat area.
- **A variety of pathways:** Without 'more speculative technology options' – such as CCS 99% carbon capture rates or direct air carbon capture – advanced nuclear is prioritised towards hydrogen production. With speculative measures available, advanced nuclear operation is prioritised towards power generation.

Additionally, the report includes key economic insights, including:

- The modelling and assumptions here could be used to frame and inform market requirements and target costs for future technologies.
- This work introduces nuclear technology that could supply high-volume low-cost and emission-free hydrogen and tested the impact of hydrogen cost in the system. The introduction of such technologies and associated assumptions into the model significantly changes system optimisation solutions for UK net zero.

Roadmapping

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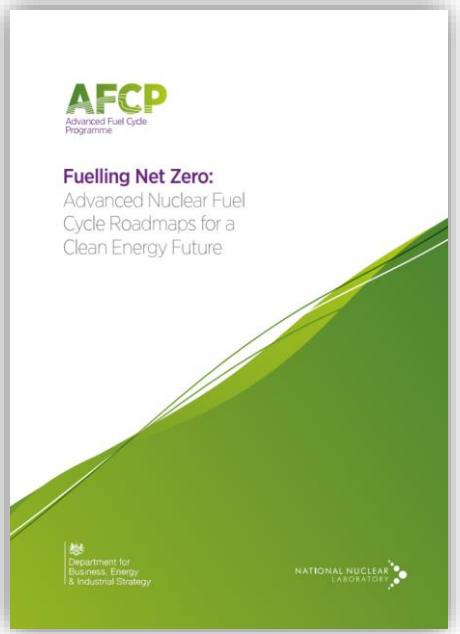

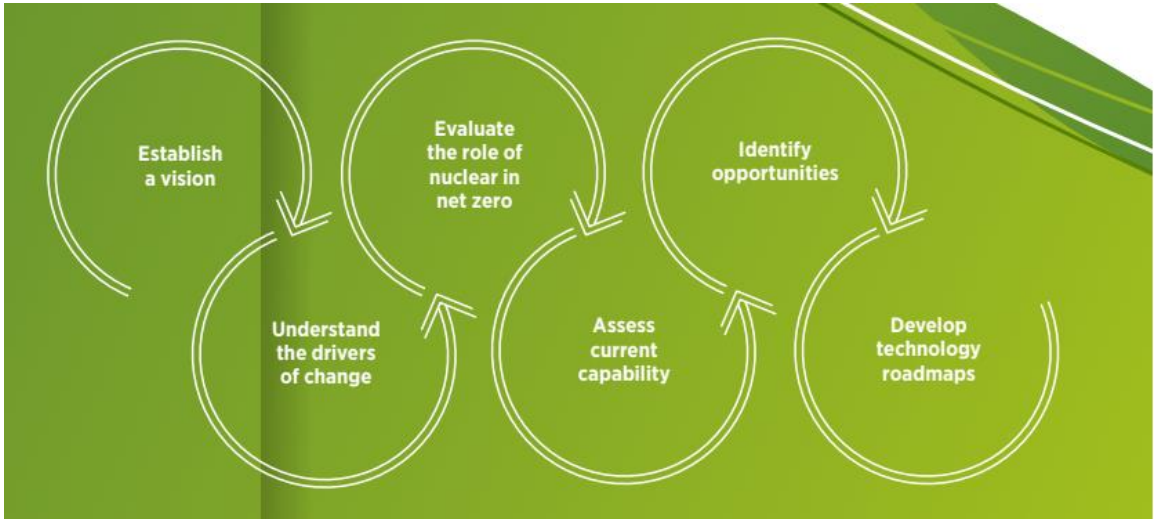

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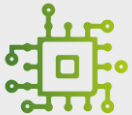
Building on the NIS and subsequent NIRAB and Government publications, AFCP has produced the following 2050 vision statements for UK fuel cycle capability:

- UK supplying the fuel cycle needs of Gen III(+) and advanced nuclear technologies (ANTs)[15], enabling a significant nuclear contribution to achieving net zero in the UK and a sustainable future
- UK industry will have a strong domestic capability from fuel enrichment and manufacture through to recycling and waste minimisation, storage and disposal

This sets out a requirement to develop UK capabilities to deliver the fuel cycle needs of current and future systems in a net zero world.

Drivers of Change

Social
- Alternate uses of nuclear
- Climate change awareness
- Public understanding of nuclear as low-carbon energy



Technological
- Delivery of new nuclear technology
- The rate of technological maturity of advanced reactors
- Innovation and delivery of other low-carbon technologies (low cost, rapid deployment)

Economic
- New nuclear build cost and schedule certainty
- Economics of advanced reactors (Gen IV) and fuel cycle
- Competitiveness of nuclear vs other low-carbon technology
- Cost to consumer bills driving demand
- Economic recovery as key focus following COVID-19

Environmental
- Net zero by 2050
- Sustainability through drive to reduce waste associated with energy production

Political
- Government policy position
- Clean growth policy to decarbonise while benefiting economy
- Net zero in legislation
- Energy security through support for homegrown energy

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Opportunity Areas

Short Term

2020 - 2025

Coated cladding advanced technology fuel (ATF)
supplied to the domestic and international LWR markets

Apply fuel cycle separations chemistry to recovery of commercially valuable isotopes
from reprocessed products:
(eg for medical applications)

Medium Term

2025 - 2035

Revolutionary advanced technology fuel (ATF) concepts
supplied to the domestic and international LWR/ AMR markets

UK developed coated particle fuel (CPF) product supplied to high temperature reactor (HTR)
demonstrator(s) (UK and international) CPF product supplied to emerging domestic and international commercial HTR markets with used fuel management options

Advanced recycle technology to produce future fuels
credible and competitive technical options for advanced reprocessing of LWR (and MOX) used fuels

Americium-241 supply
production of Am-241 for space power and other applications

Long Term

2035 - 2050

Fast reactor fuel cycle
fuel fabrication and supply to a reactor demonstrator and technology demonstration for recycle of used fuels

Advanced recycle of ATF to produce future fuels
credible and competitive technical options for reprocessing of used ATF

Supply of molten salt fuels to reactor demonstrator
and technology demonstration for used fuel management

Vision

2050+

UK supplying the fuel cycle needs of Gen III(+) and advanced nuclear technologies (ANTs), enabling a significant nuclear contribution to achieving net zero in the UK and a sustainable future

UK industry has a strong domestic capability from fuel enrichment and manufacture to recycling and waste minimisation, storage and disposal

Trends and Drivers: These define the context within which opportunities will be realised. This theme encompasses the established vision, drivers of change and understanding of future energy system markets.

Opportunity Areas: These arise from linking current capabilities with future needs. Each roadmap presents a unique advanced fuel cycle opportunity area, with specific applications within the area identified throughout.

Technologies and Capabilities: Realising the applications within each opportunity area will require certain technologies and capabilities to be developed. This theme includes both the existing and future concepts needed to achieve relevant applications.

Enablers: Key actions – which include strategic planning, industry collaboration and Government support – will enable the development of new and enhanced technologies and capabilities.

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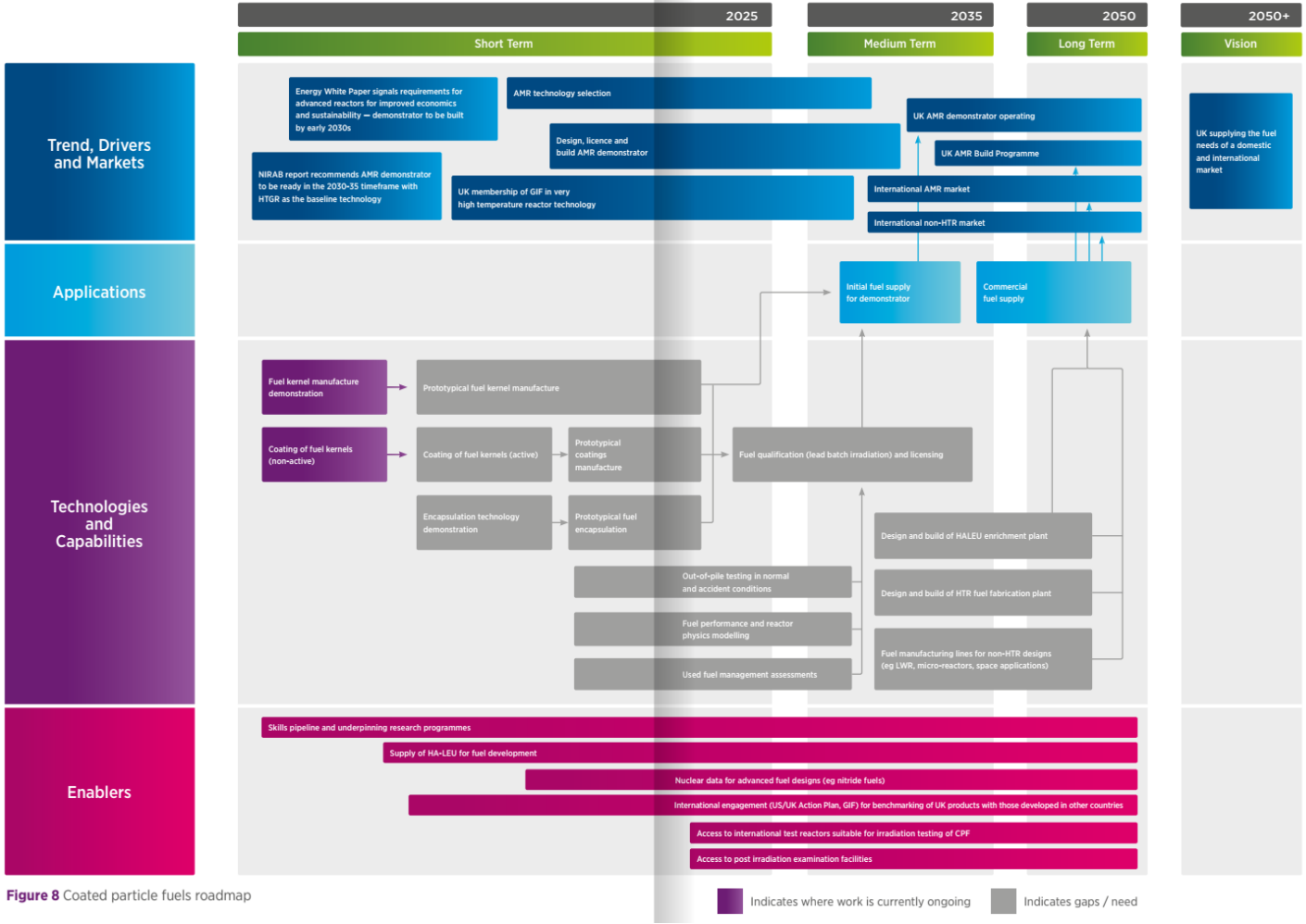

Figure 8 Coated particle fuels roadmap

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A plan that adds up…….

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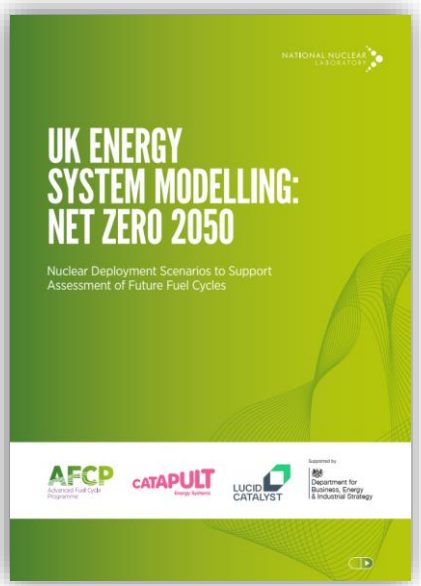
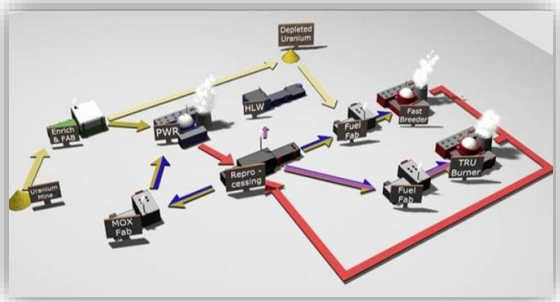
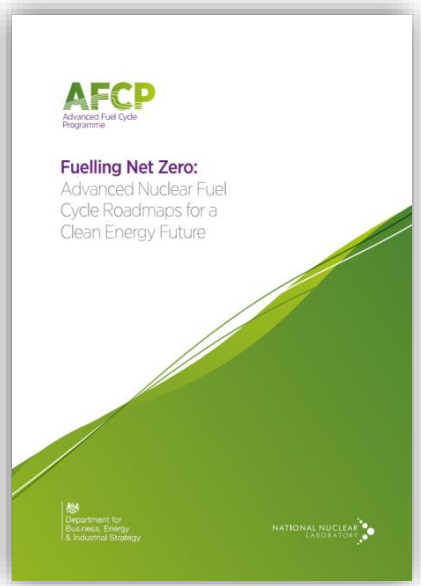
A role for nuclear in the UK



Understand the demand on resources



A roadmap to deliver the capability



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