Integrated Energy Systems and the pathway to Net Zero by 2050 (a UK context)

2nd June 2022

Dr Paul Nevitt, Science and Technology Director

SNETP Forum 2022

Technical Session 6 "Nuclear to mitigate climate change including non-electricity applications"

Not Protectively Marked

UK Context

UK becomes first major economy to pass net zero emissions law

New target will require the UK to bring all greenhouse gas emissions to net zero by 2050.

From: Department for Business, Energy & Industrial Strategy and The Rt Hon Chris Skidmore MP

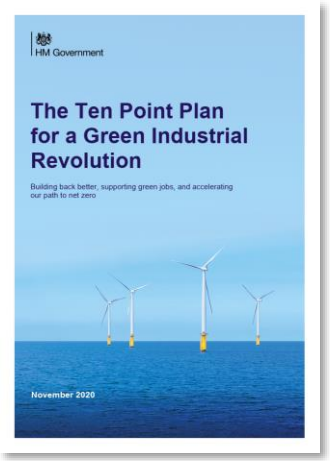
Published 27 June 2019

Chris Skidmore signs legislation to commit the UK to a legally binding target of net zero emissions by 2050

Net ZERO documents at a glance

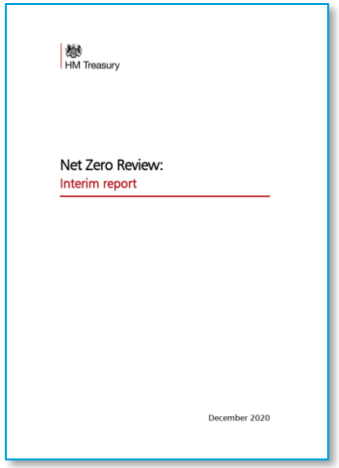
NATIONAL NUCLEAR LABORATORY

Since the publication of the 10 Point Plan, HMG has published a suite of Net Zero and other policy documents.

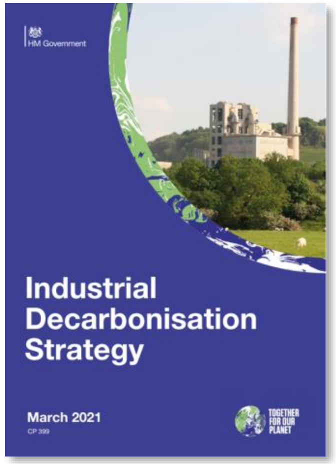


https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

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



https://www.gov.uk/government/news/net-zero-review-publishes-initial-analysis-of-green-transition



Industrial decarbonisation strategy - GOV.UK (www.gov.uk)

Transport decarbonisation plan - GOV.UK (www.gov.uk)

UK government launches plan for a world-leading hydrogen economy - GOV.UK (www.gov.uk)

Heat and buildings strategy GOV.UK (www.gov.uk)

ENERGY SECURITY STRATEGY

[Major acceleration of homegrown power in Britain’s plan for greater energy independence - GOV.UK (www.gov.uk)]

***The strategy will see a significant acceleration of nuclear, with an ambition of up to 24GW by 2050** to come from this safe, clean, and reliable source of power. This would represent up to **around 25% of our projected electricity demand**. Subject to technology readiness from industry, **Small Modular Reactors will form a key part of the nuclear project pipeline**.*

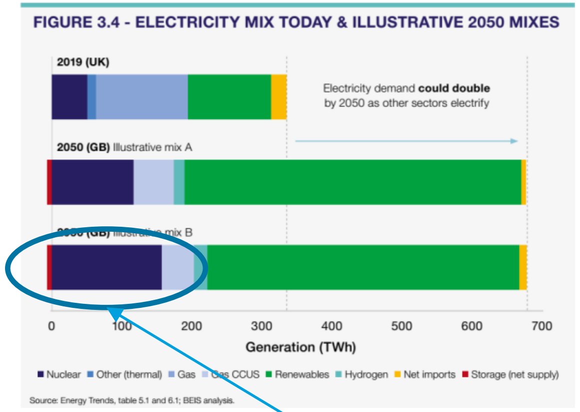
***A new government body, Great British Nuclear, will be set up** immediately to bring forward new projects, backed by substantial funding, and we will launch the £120 million Future Nuclear Enabling Fund this month. We will work to progress a series of projects as soon as possible this decade, including Wylfa site in Anglesey. Th*
delivering up to eight reactors, equivalent
year instead of one a decade, accelerating
Britain.

Energy White paper

Published 14 December 2020

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

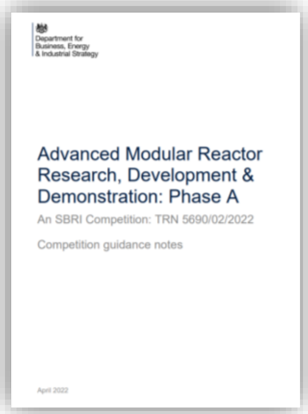
- **We will publish a dedicated Hydrogen Strategy in early 2021 which positions the UK as a world leader in the production and use of clean hydrogen.**

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
CCU
rene

Net Zero Innovation Programme

£1 billion NZIP

UK AMR (HTGR) RD&D programme


Department for Business, Energy & Industrial Strategy

Advanced Modular Reactor Research, Development & Demonstration: Phase A

An SBRI Competition: TRN 5690/02/2022

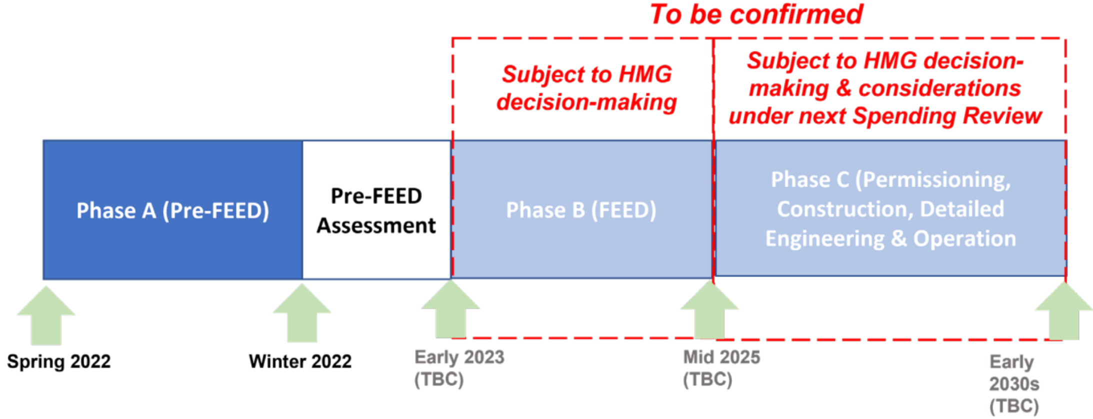
Competition guidance notes

April 2022

https://www.gov.uk/government/publications/advanced-modular-reactor-amr-research-development-and-demonstration-programme

- The AMR RD&D programme aims to demonstrate High Temperature Gas Reactor (HTGR) technology by the early 2030s, in time for any potential commercial AMRs to support net zero by 2050.
- This HTGR demonstration, which will be sited in the UK, should be shaped by end-user requirements, and should incentivise private investment in HTGRs by removing technical risk. It should have innovation at the centre of its design, build, and application.
- Department for Business, Energy & Industrial Strategy (BEIS) is providing up to £2.5 million (Phase A) in innovation funding to support the development and demonstration of High Temperature Gas Reactor (HTGR) technology in the UK

LOT	DURATION	FUNDING[4]	RESEARCH QUESTION
1 - REACTOR DEMONSTRATION	6 months	Up to 4 Pre-FEED studies will be awarded with up to £500k available for each project.	What is the optimal way to demonstrate Advanced Modular High Temperature Gas Reactor technology, to reduce risk for potential investors, and maximise UK benefit, and thus enable the option for commercial HTGR solutions to impact the UK's 2050 Net-Zero target?
2 – FUEL DEMONSTRATION	6 months	Up to 2 Pre-FEED studies will be awarded with up to £250k available for each project.	What is the optimal way to ensure that the UK supply chain can deliver Coated Particle Fuel (CPF), and maximise UK benefit, to support an Advanced Modular High Temperature Gas Reactor demonstration *and* be scalable to meet potential subsequent commercial demand?



To support Phase A, the Office for Nuclear Regulation (ONR) and the Environment Agency (EA) have been allocated up to £830,000 to continue to build and maintain their capability on advanced nuclear technologies.

Phase A

A share of up to £2.5 million for Feasibility or Preliminary Front End Engineering Design (Pre-FEED) studies over a potential 6 month period.

Phase B (tbc)

A FEED study to be used as a basis of the detailed design and engineering and include accurate total investment & lifecycle cost, how this would be sited and include overall project delivery planning.

Phase C (tbc)

Could incl
design, pl
environm
licensing,
and initial
demonstr

Full UK Energy System Assessment

Net zero is very difficult!

NATIONAL NUCLEAR LABORATORY

Slower **aviation** demand growth.

Reduced **meat/dairy** consumption.

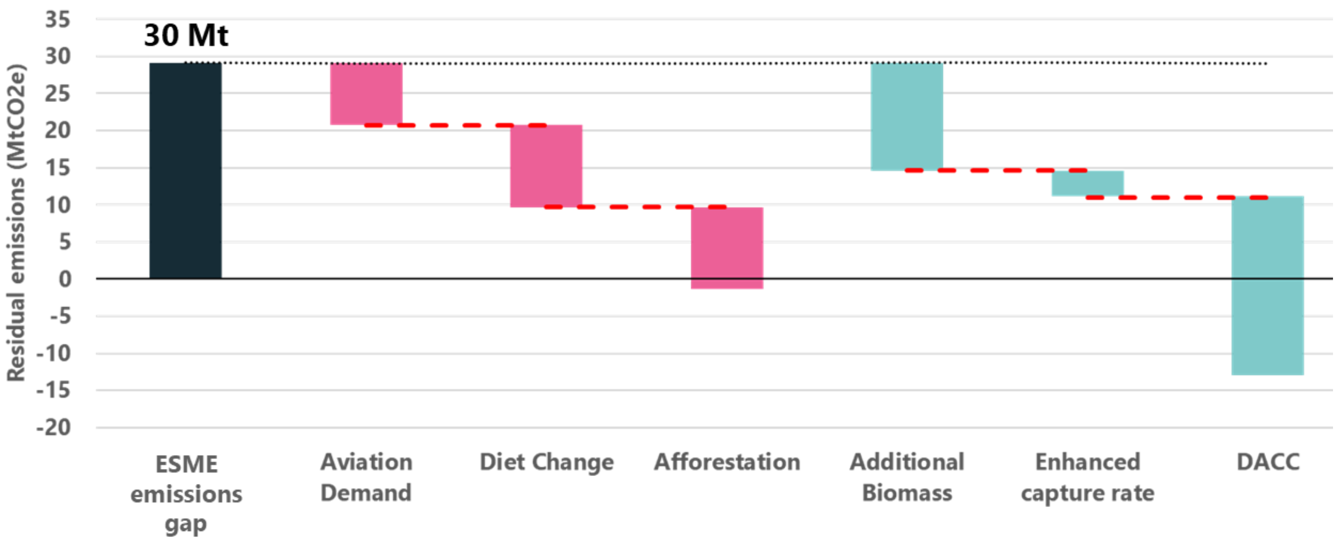
Increased **afforestation**.

Increased **biomass** crops.

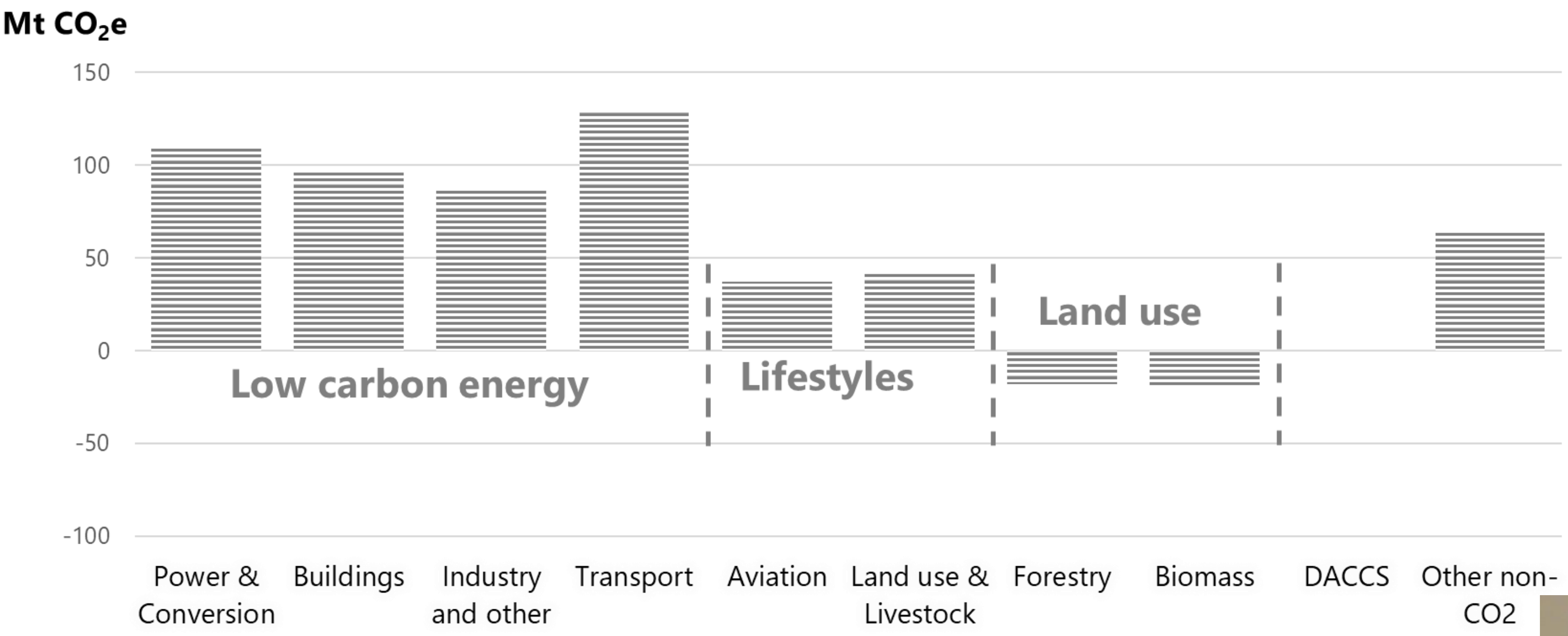
Higher **CCS capture rates**.

Direct air capture.

Speculative measures



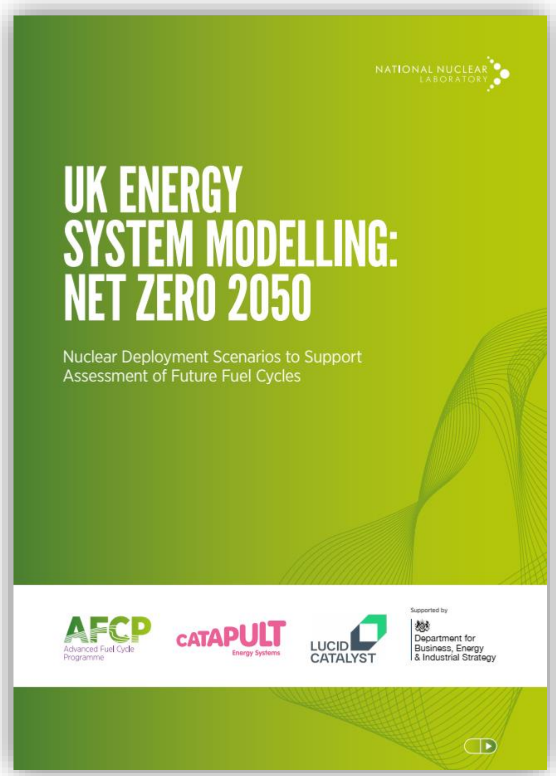
Emissions: 2015

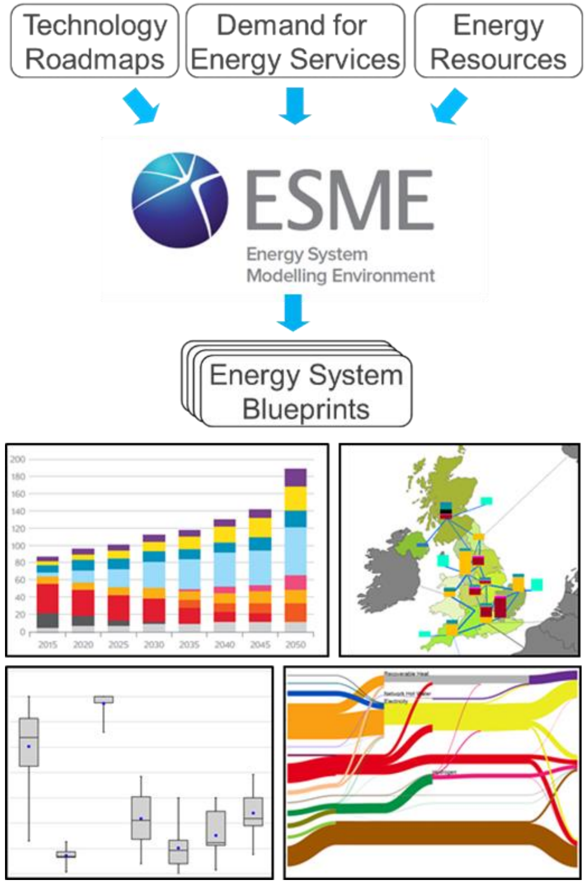


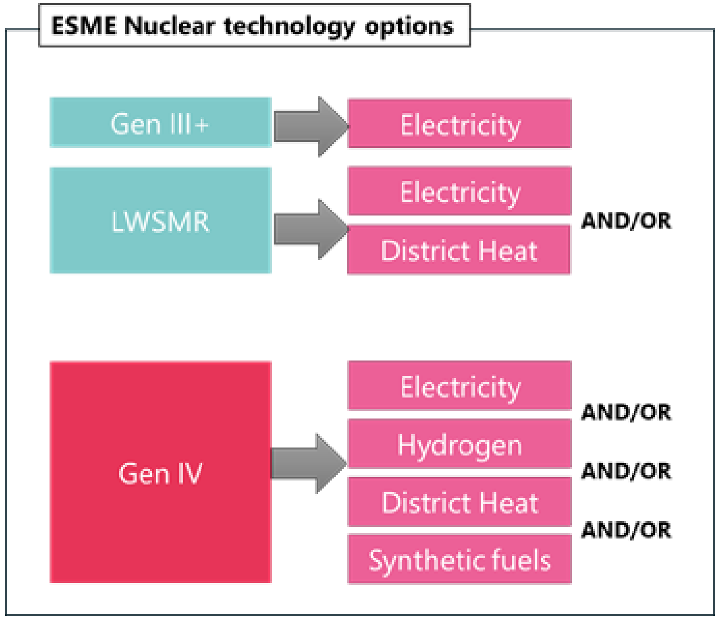
Emissions: 2015, Clockwork 2050, Patchwork 2050

Integrated energy systems

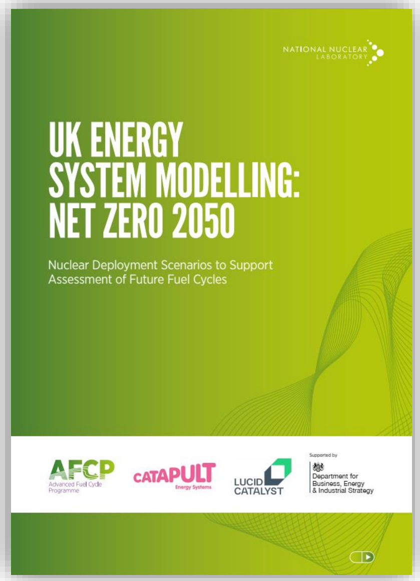
NATIONAL NUCLEAR LABORATORY

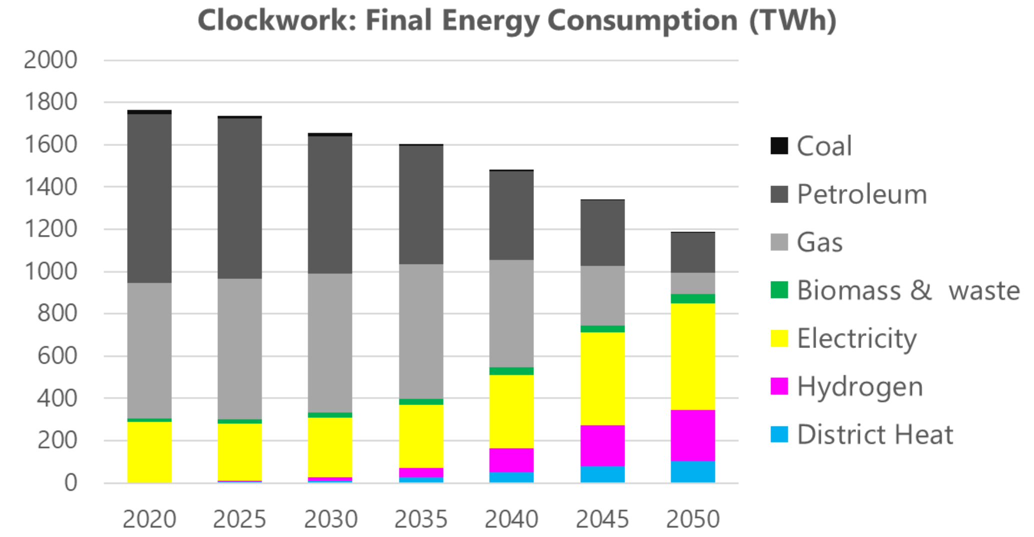






NATIONAL NUCLEAR LABORATORY





Could mean:

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

Electricity
600-800TWh

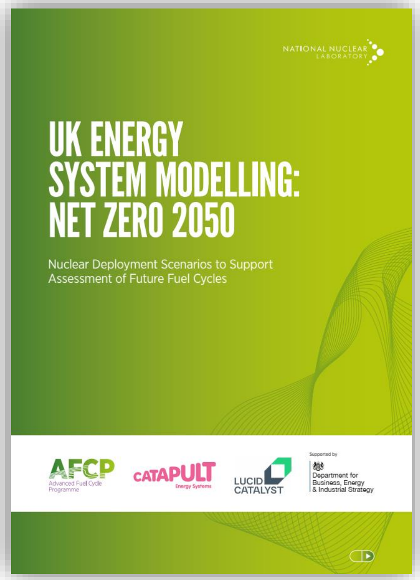
Hydrogen
200-300TWh

District Heat
Up to 150TWh

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

Key themes

NATIONAL NUCLEAR LABORATORY



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:

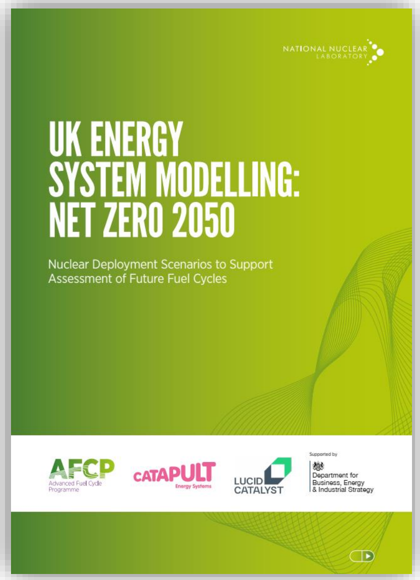
- **Cogeneration:** The ability of nuclear to operate in cogeneration is valuable in a future system. Where a common nuclear heat supply system is deployed – both as cogeneration heat and power and cogeneration power and hydrogen – the hydrogen variant is deployed at higher levels.
- **Carbon capture 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.

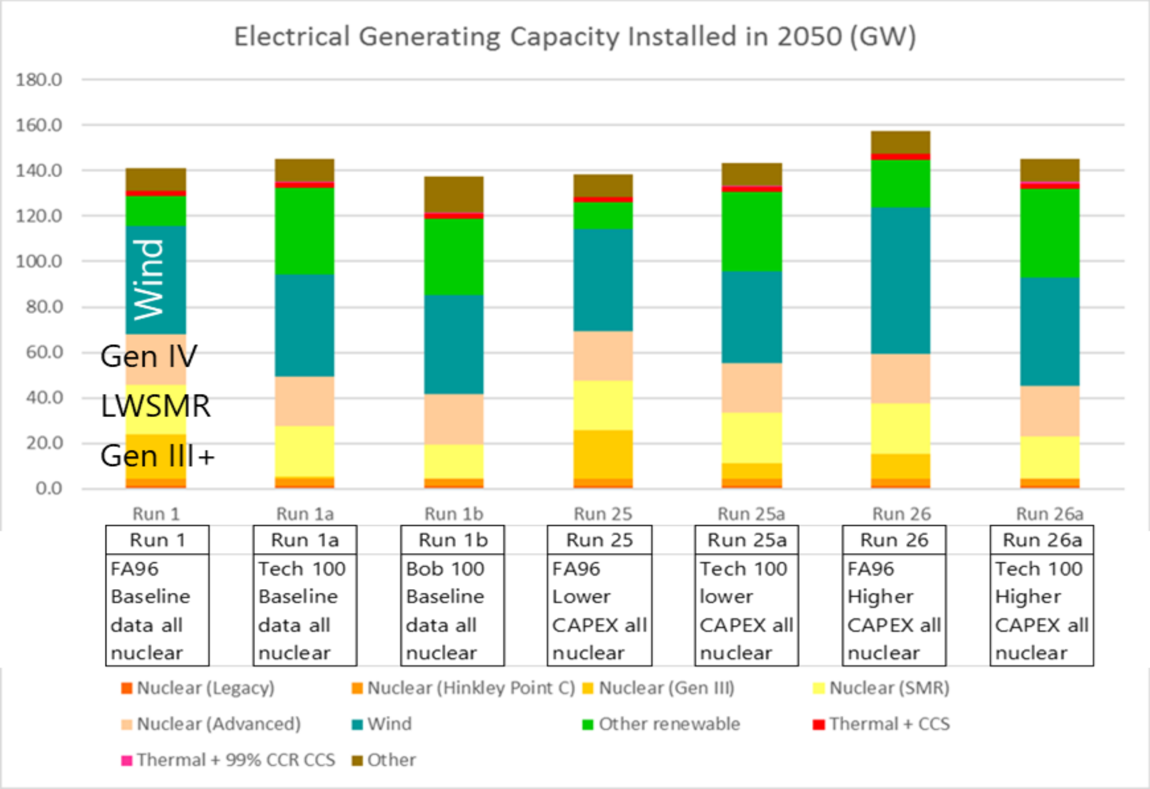
Additionally, the report includes key economic insights, including:

- 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 impact of hydrogen cost in the system. The introduction of such technologies and associated assum significantly changes system optimisation solutions for UK net zero.

Electricity

NATIONAL NUCLEAR LABORATORY





With “speculative” technologies & behaviours

Capex sensitivities

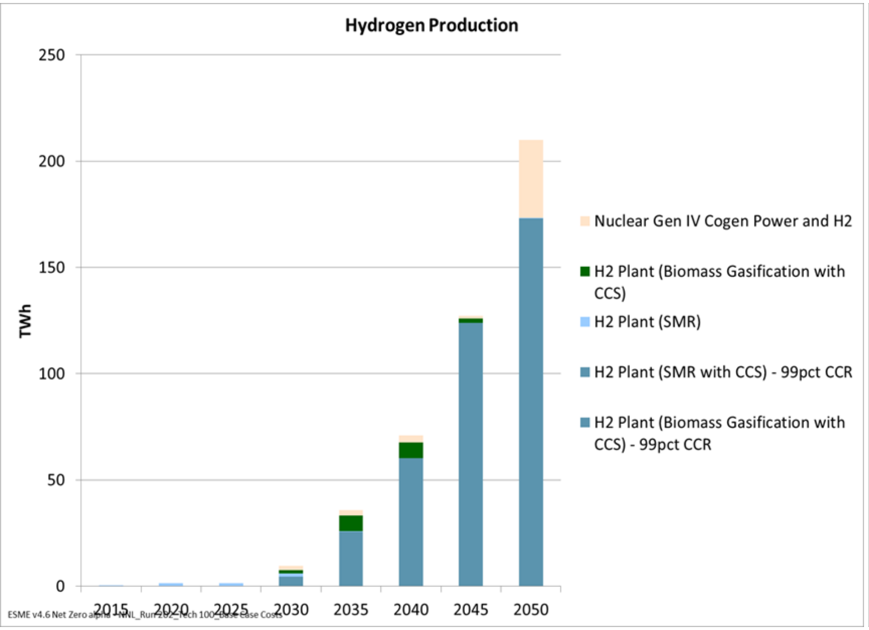
hydrogen

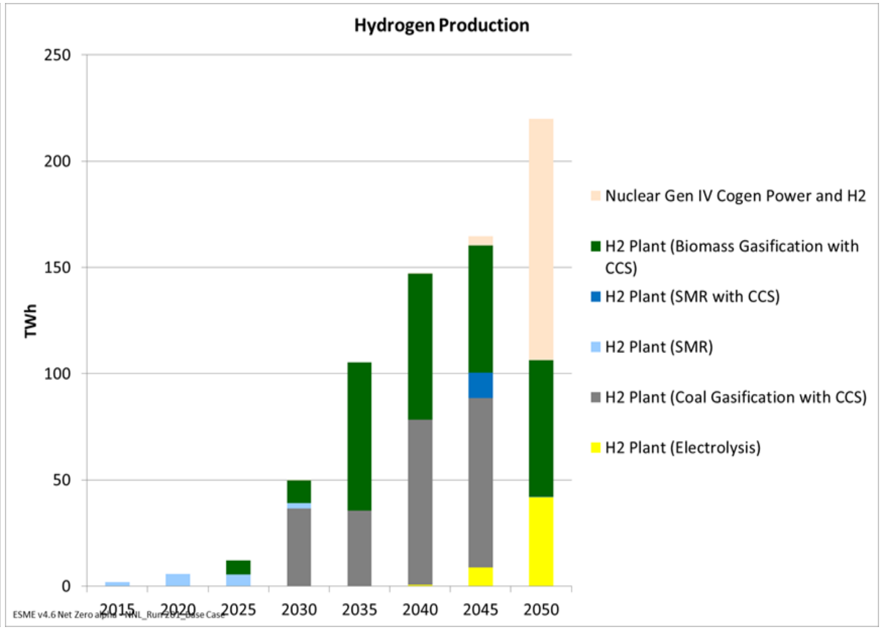
NATIONAL NUCLEAR LABORATORY

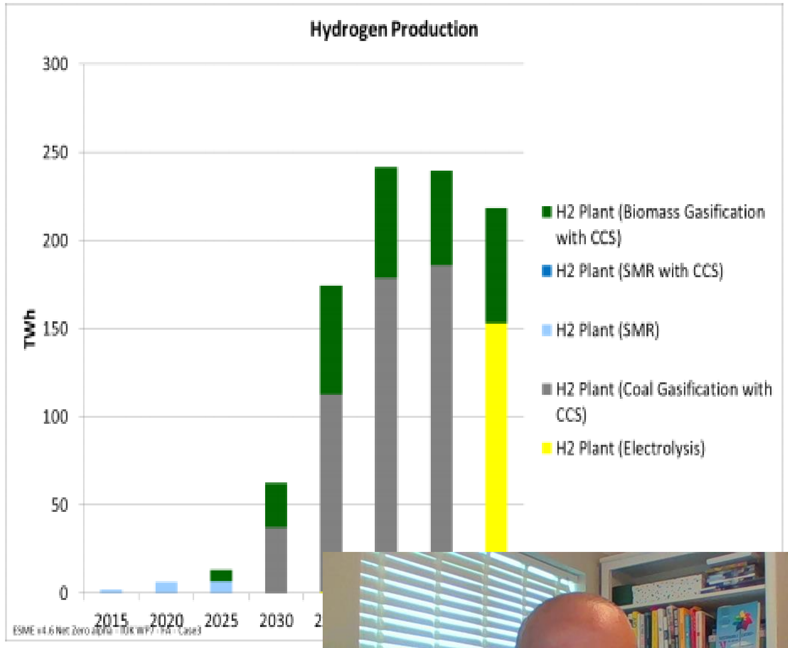
When available 99%CCS dominates with a small role for advanced nuclear and thermochemical production

Without 99%CCS, advanced nuclear with thermochemical production dominates.

In the absence of 99%CCS and advanced nuclear with thermochemical production, electrolysis from low carbon sources (including nuclear) dominates

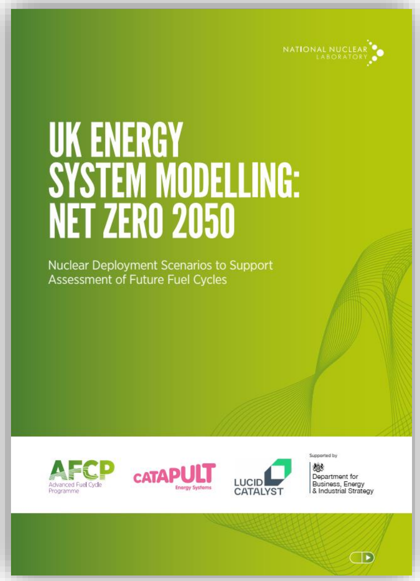


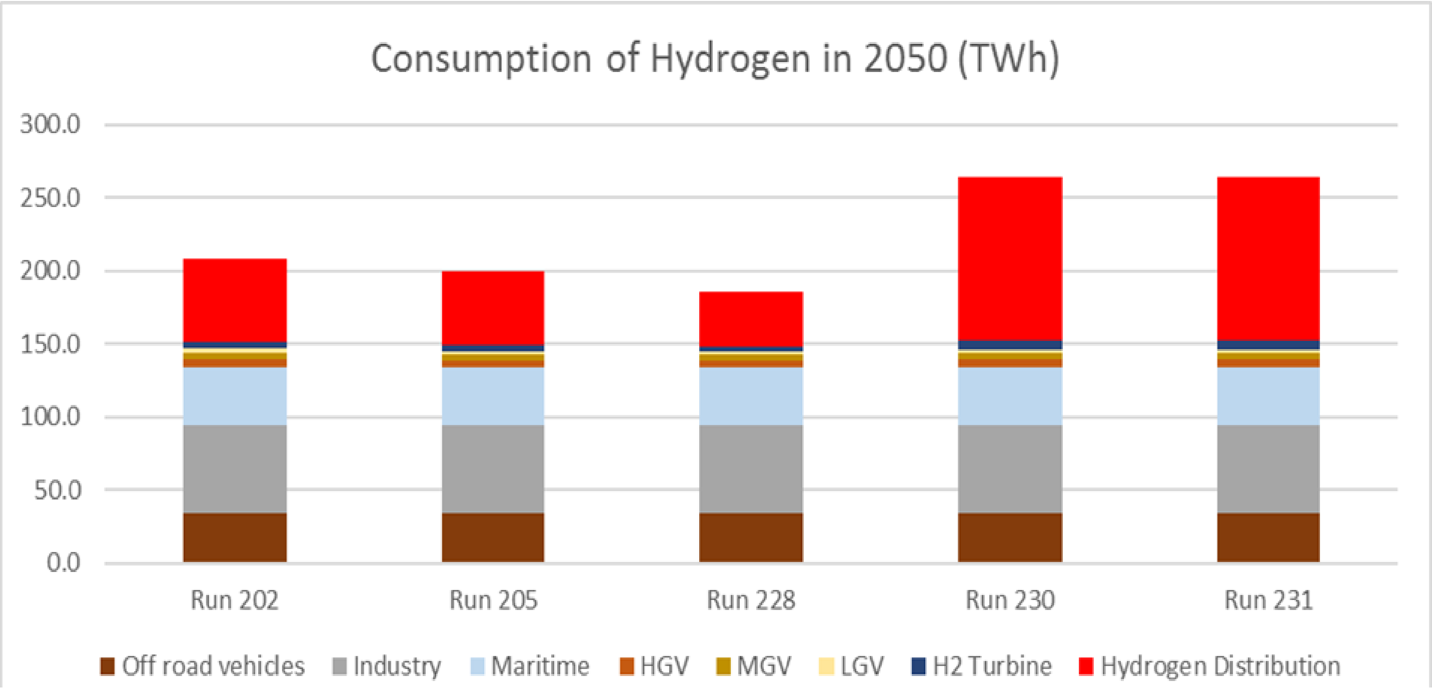




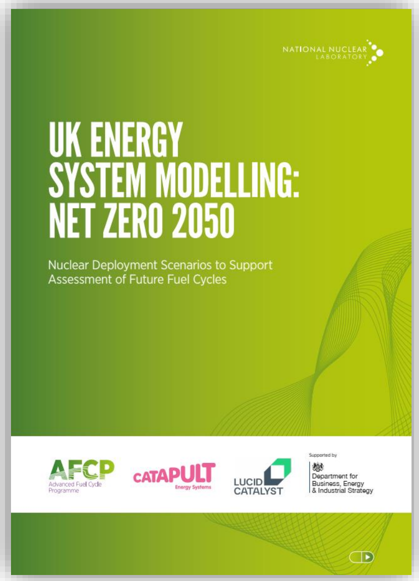
hydrogen

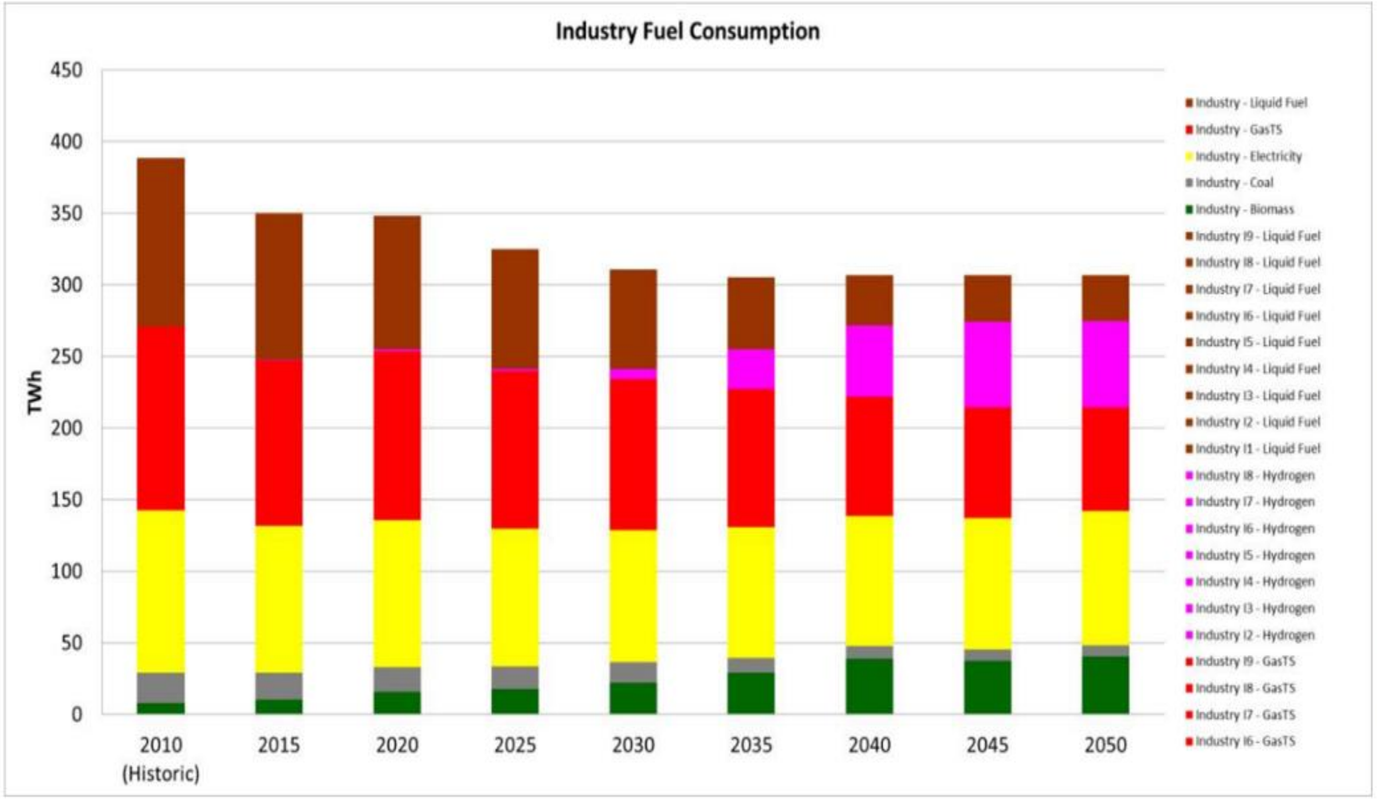
NATIONAL NUCLEAR LABORATORY





Industry fuel consumption





Industry Sectors and Processes:
I1 Industry (Iron, Steel, Metals)
I2 Industry (Chemicals)
I3 Industry (Metal Products)
I4 Industry (Food, drinks, tobacco)
I5 Industry (Paper, printing, publishing)
I6 Industry (Other w/o Cement)
I7 Industry (Cement)
I8 Industry (Refining)
I9 Industry (Agriculture)

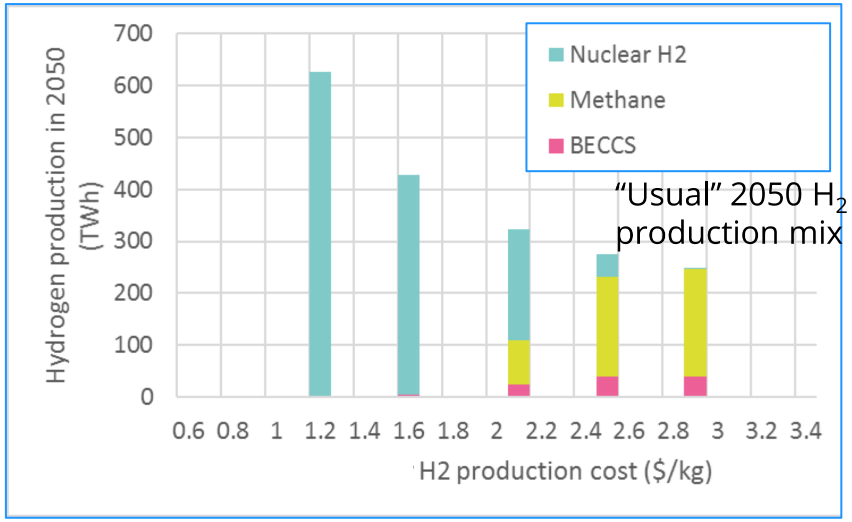
HTP - High Temperature Process
LTP - Low Temperature Process
Mot - Motors
SpH - Space Heat
DaS - Drying and Separation
Other

Sw = Switching (relative to baseline mix)

Further modelling indicates potentially transformation role of: low-cost hydrogen option…

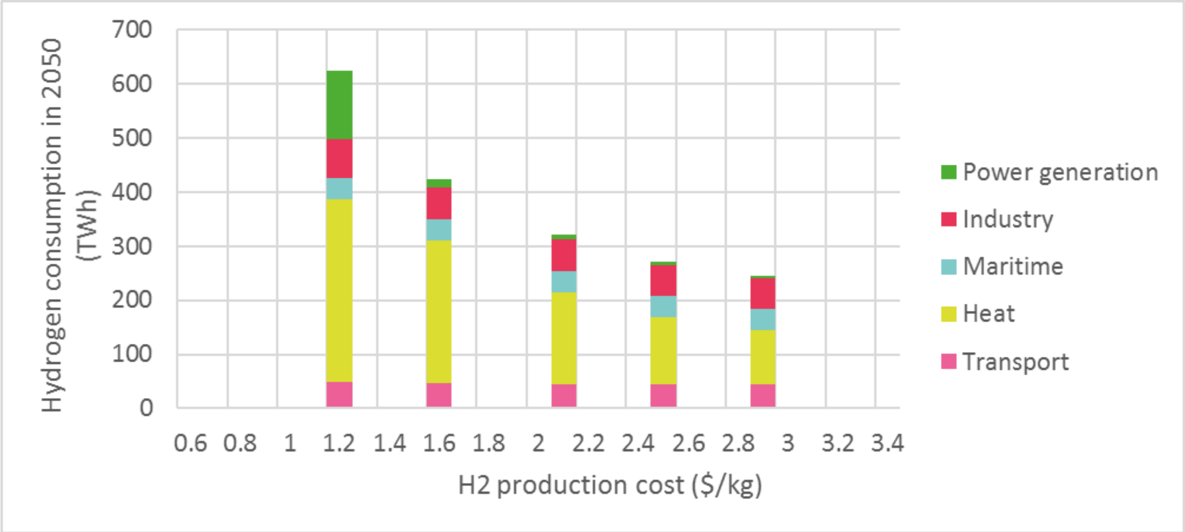
NATIONAL NUCLEAR LABORATORY

H2 Production



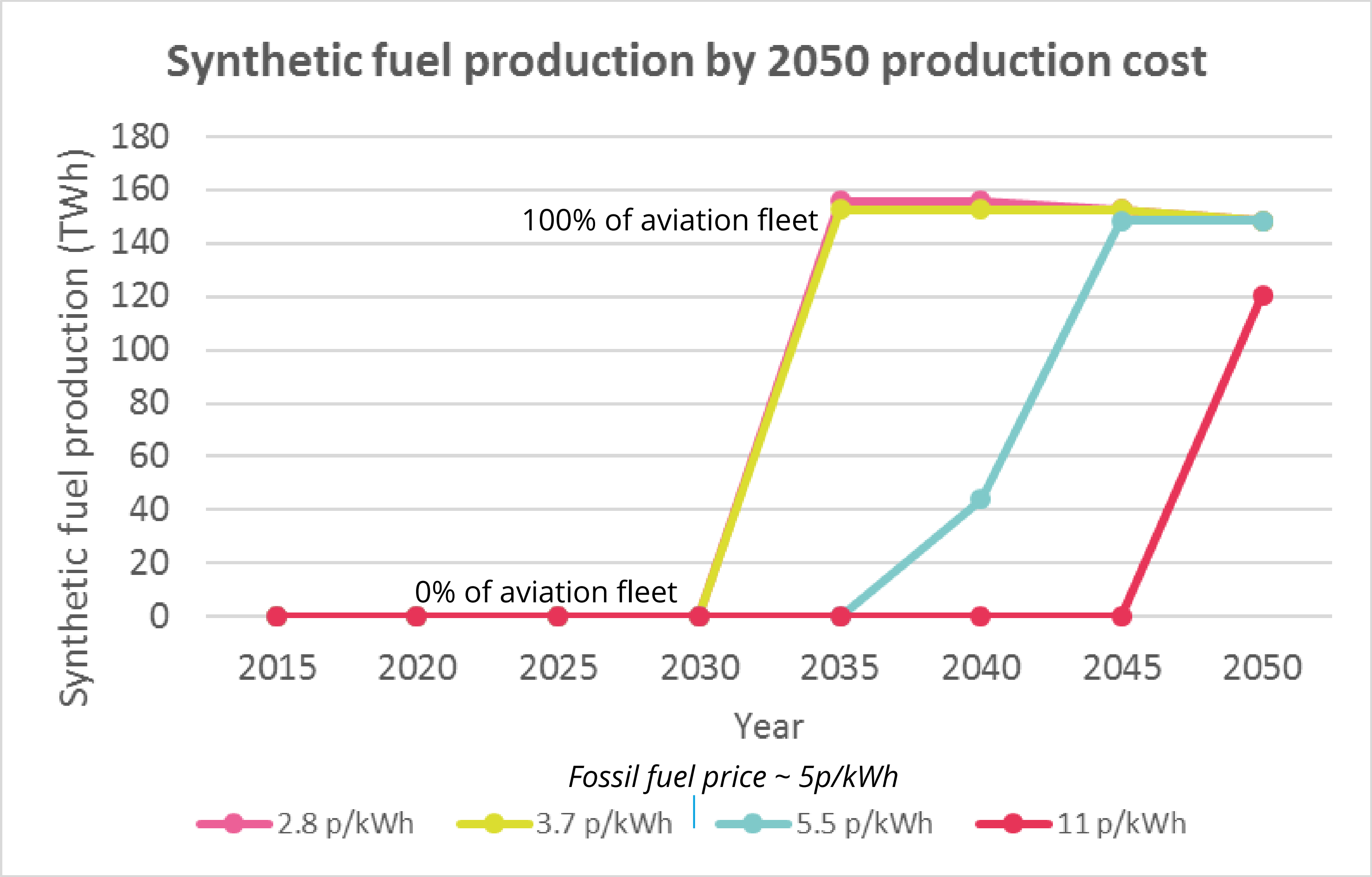
- Emergence of low-cost zero emission hydrogen first substitutes for blue H_2 production and then drives greater economy-wide hydrogen usage
- Notable increases in H_2 usage for domestic heat supply (up to as much as 300 TWh.H_2) and for electricity generation
- If cost targets realised (< $2/kg), potential for significant adjustment to standard "optimal" Net Zero system designs

H2 Consumption



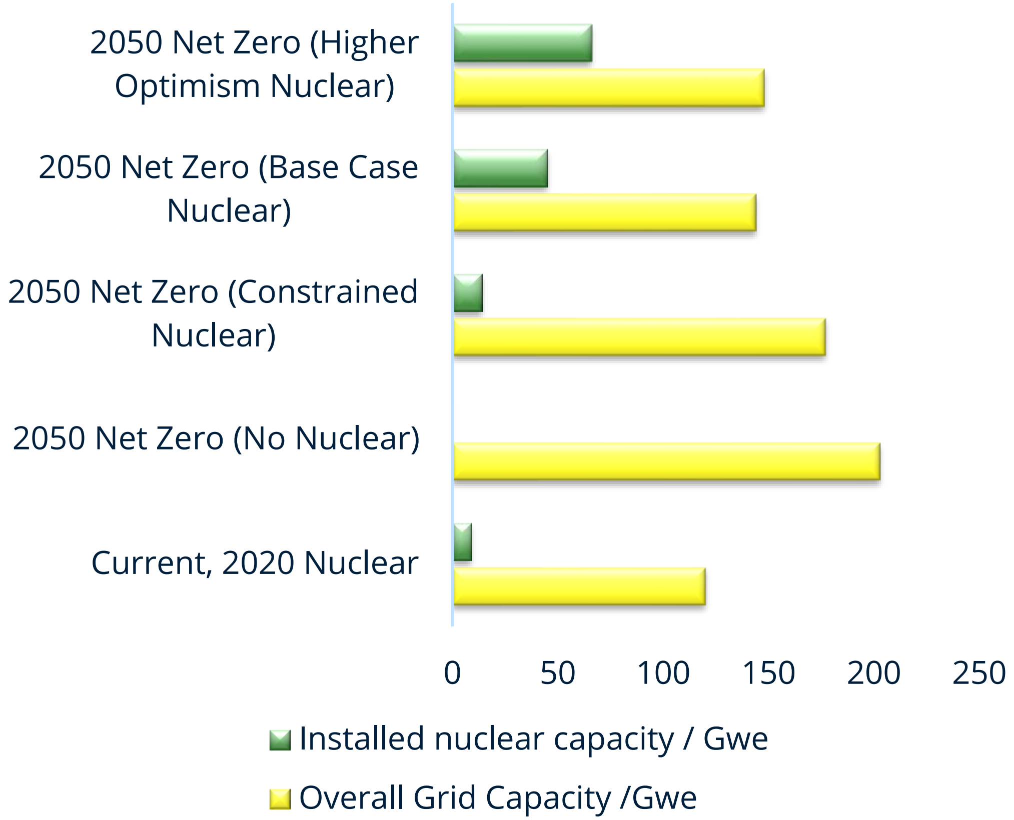
- In heat, H2 boilers relatively low cost, so H2 for heat highly sensitive to fuel cost
- In power, similarly, low cost H2 turbines more attractive with lower H2 fuel costs
- Transport applications more stable (refl cost of vehicles)

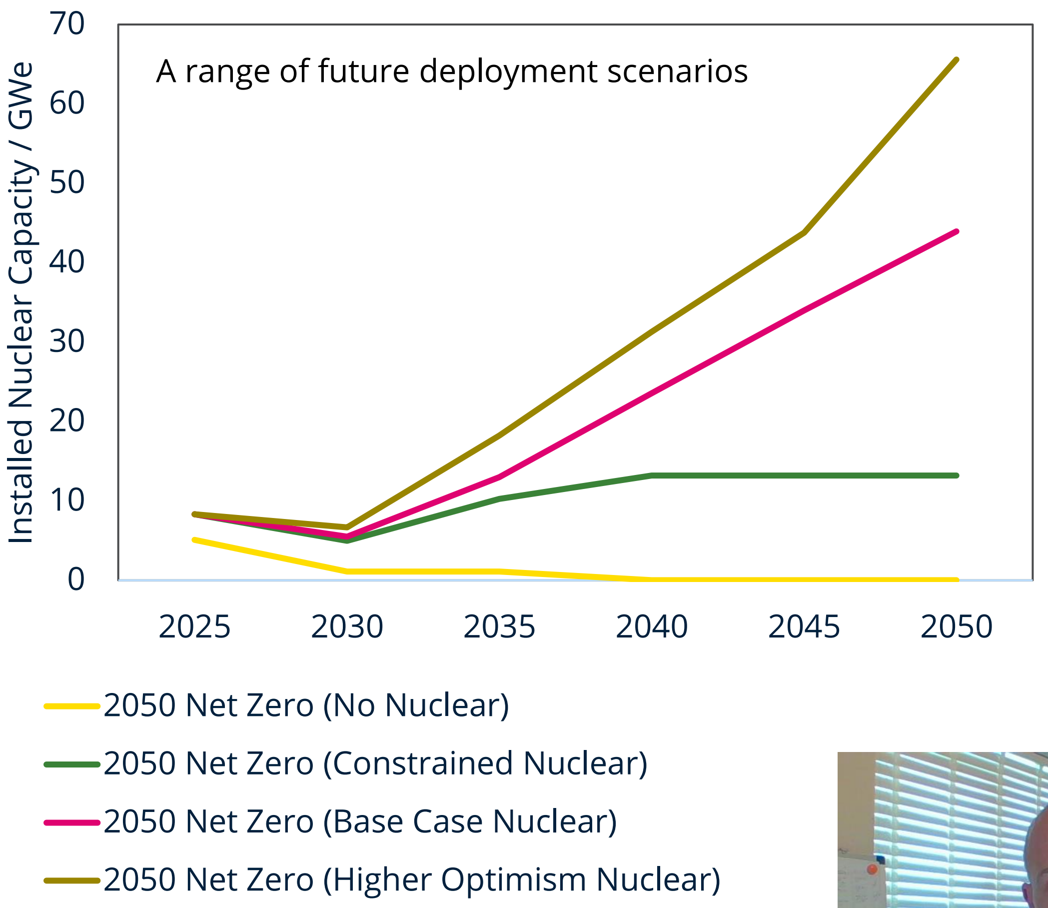
...and nuclear to liquid synthetic fuel option



- Delivered liquid synthetic fuel prices below fossil aviation fuel leads to a transition even in the absence of CO_2 targets
- At target costs (< 5p/kWh), entire aviation fleet switched to operate on synthetic fuel
- **Carbon-neutrality of aviation fleet offers headroom so that most expensive decarbonisation steps (e.g. heavy vehicles, Greenhouse Gas Removal) can be deferred or avoided**: major system change compared with Net Zero alternatives

Nuclear to mitigate climate change including non-electricity applications deployment





Thank you

National Nuclear Laboratory
5th Floor, Chadwick House
Warrington Road, Birchwood Park
Warrington WA3 6A
T. +44 (0) 1925 933
E. customers@uknn

www.nnl.co.uk