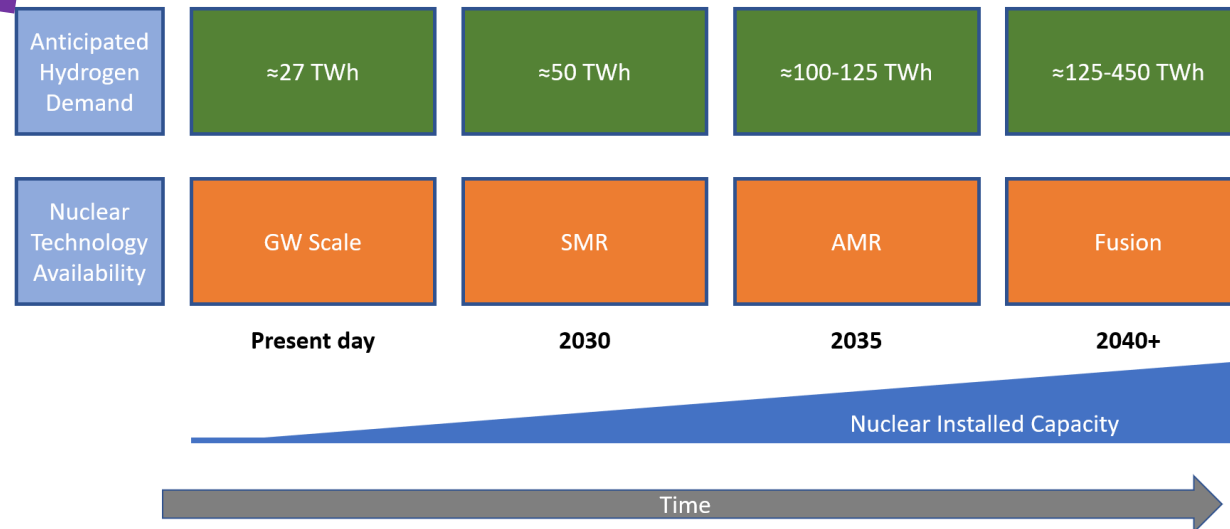
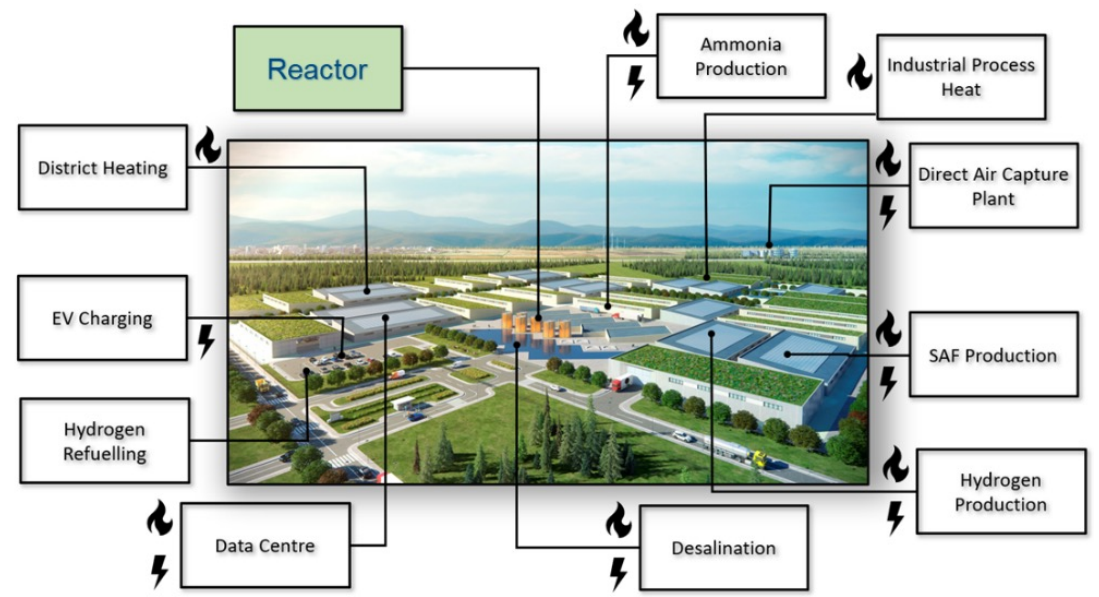
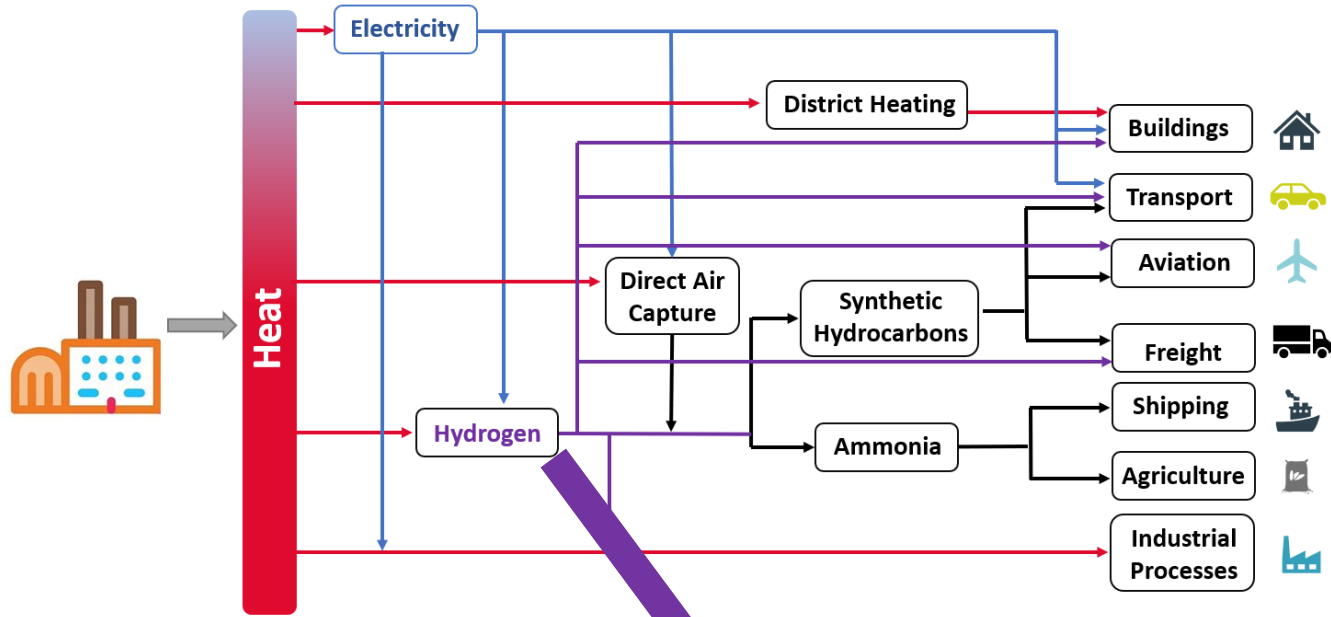


Nuclear Power to Hydrogen and Alternative Liquid Fuels

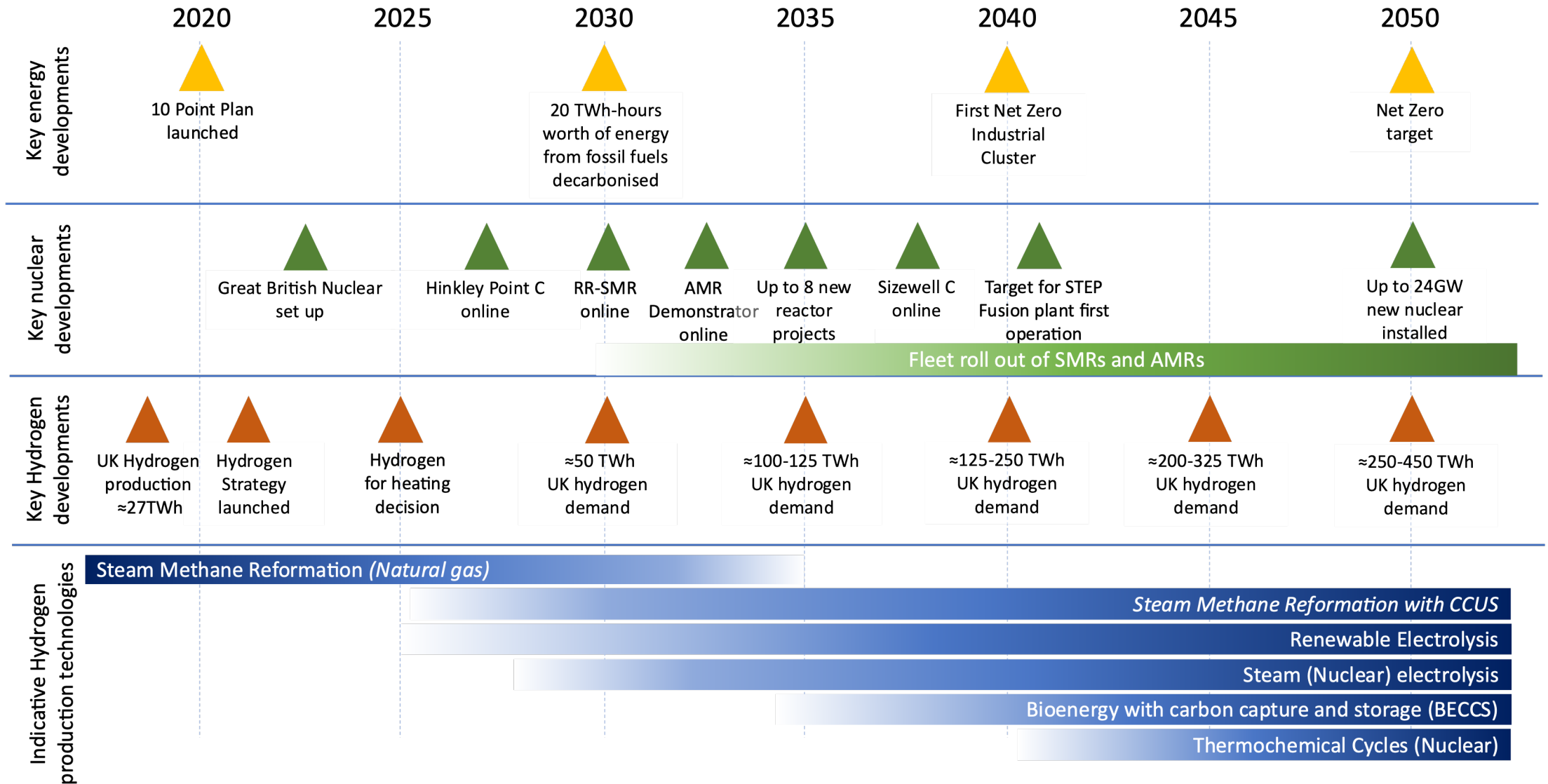
Christopher Connolly

Nuclear Energy Integration

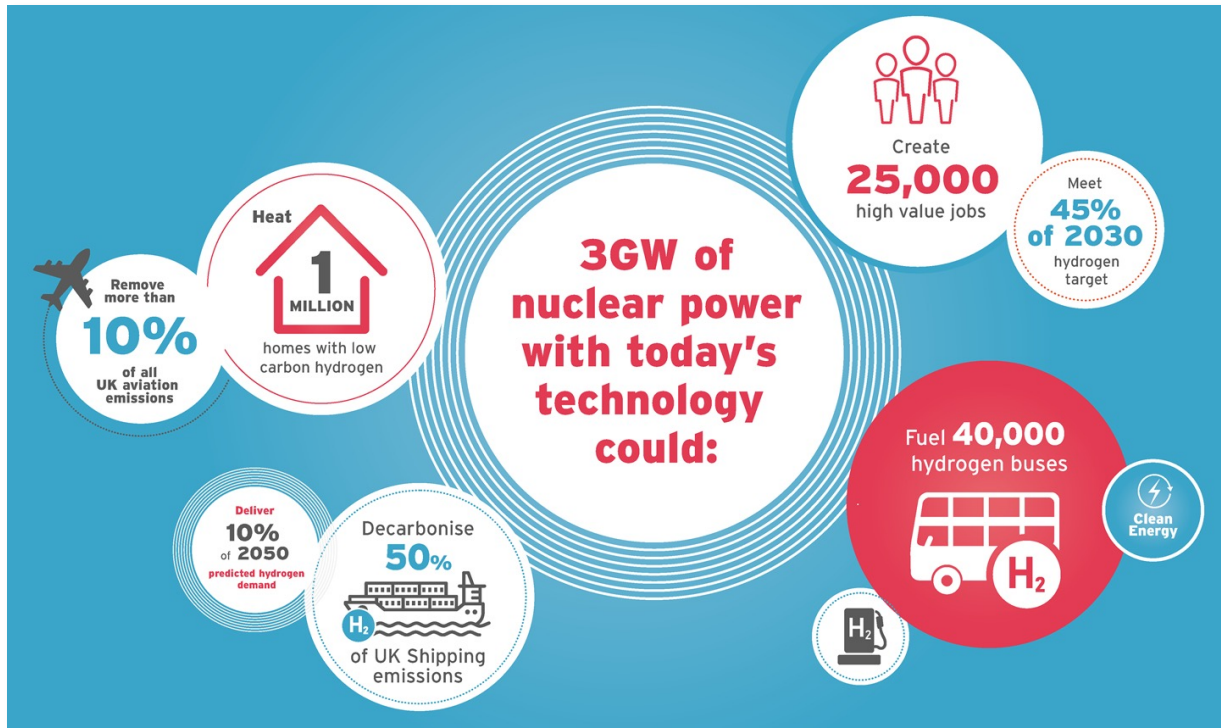


Hydrogen demand data source - UK Hydrogen Strategy

Nuclear Energy Integration



Hydrogen Production



FUEL CELLS FOR SURFACE TRANSPORT

Large scale nuclear power stations could be coupled with electrolyzers today to generate the high purity hydrogen required for fuel cell vehicles. With many of the identified sites for nuclear new build being in or near to industrial clusters, generated hydrogen would be usable locally to decarbonise heavy transport.



DECARBONISING THE GAS GRID

Over 300 TWh of natural gas is used each year for the heating of homes and offices across the UK. This forms one part of the circa 900 TWh of natural gas distributed in the networks each year, all of which could benefit from the scale and predictable supply of NEH from current generation reactors and next generation Small Modular Reactors (SMRs).



NUCLEAR ENABLED HYDROGEN
A role across the energy system

AMMONIA FOR SHIPPING

Decarbonisation of marine transport with ammonia is a growing area of interest globally. The UK could be at the forefront of shipping decarbonisation through the generation of ammonia using hydrogen and heat generated from nuclear power; the heat can uniquely benefit many of the production processes required for ammonia production and be co-located with demand at ports using next generation SMRs and Advanced Modular Reactors (AMRs).



SYNTHETIC AVIATION FUELS

One of the most challenging sectors to decarbonise is flight, where heavy batteries fundamentally limit the range of electric aircraft. Hydrogen generated from nuclear could be co-located with Direct Air Capture and synthetic fuel production processes to generate carbon neutral or carbon negative synthetic fuels for aviation. With predictable costs and production schedules, it would provide the stable supply of fuel needed to enable global flight operations.



Source: Hydrogen Energy Association

Hydrogen Generation

Low Temperature- Electrolysis

Low Temperature Water Electrolysis (TRL 9)

- Same as planned for use with renewables such as wind & solar
- Perceived USP of nuclear energy is the capacity (high GW) and ability to produce constant output
- Deployable today using nuclear generated electricity

High Temperature- Electrolysis

High Temperature Steam Electrolysis (TRL 7)

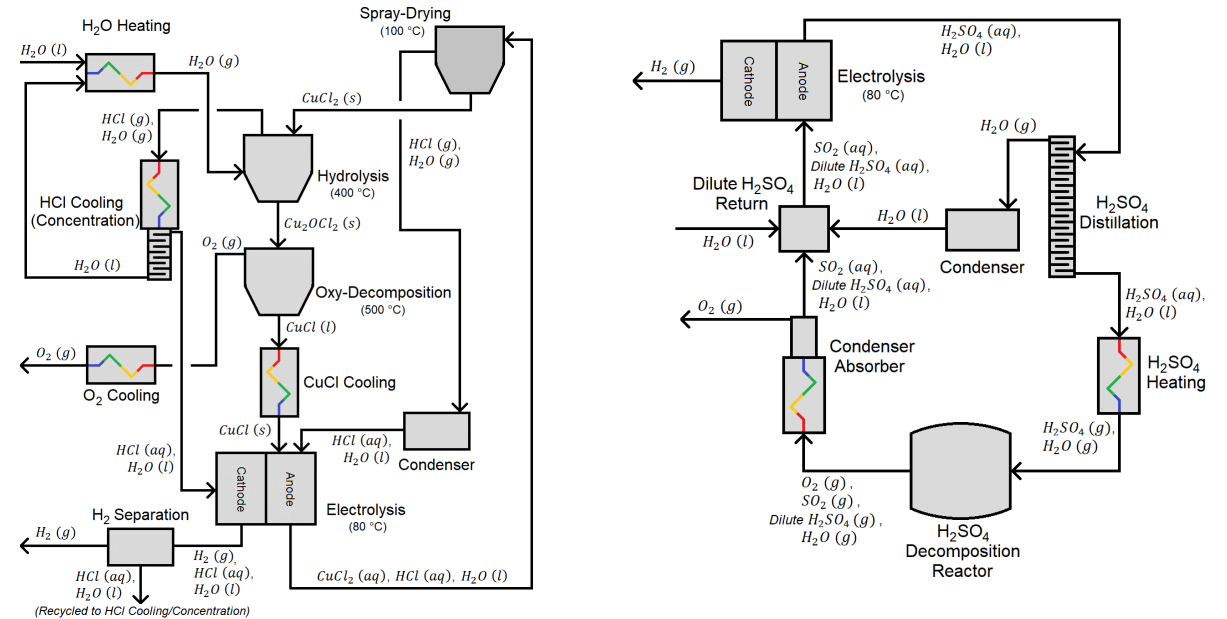
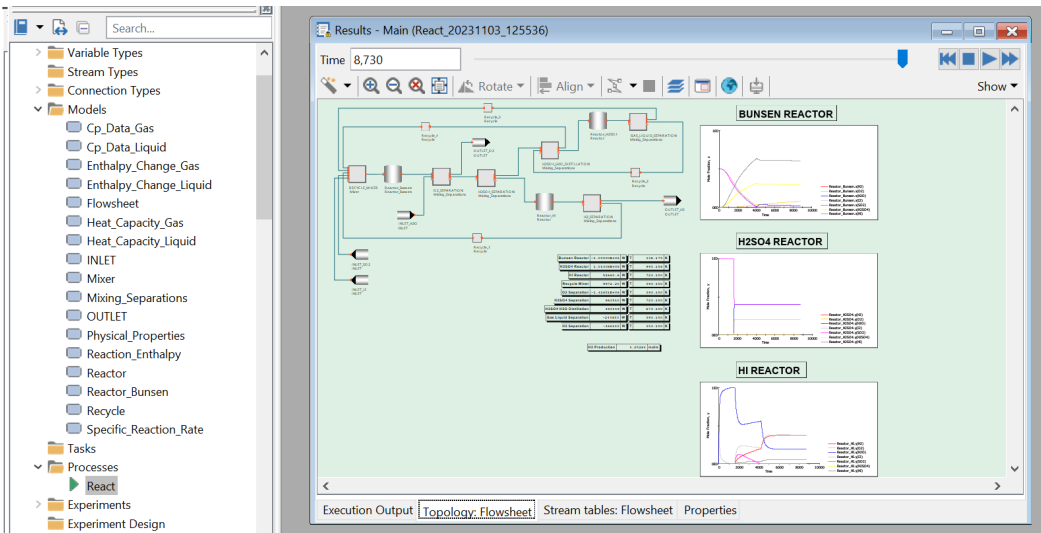
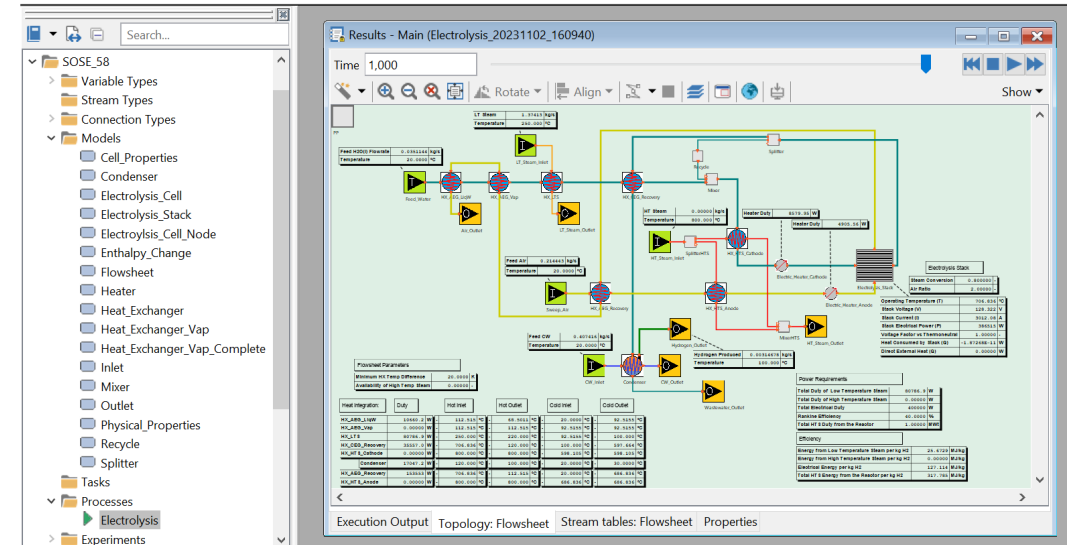
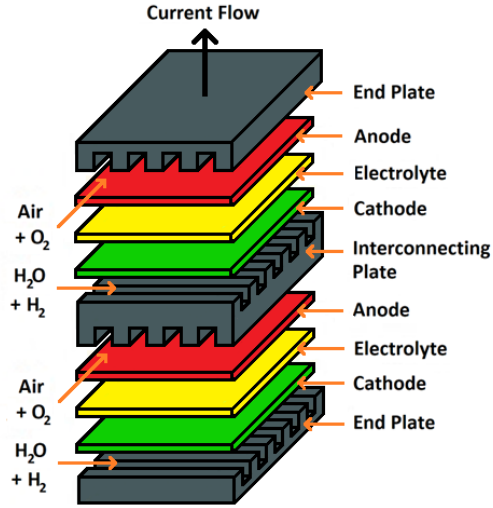
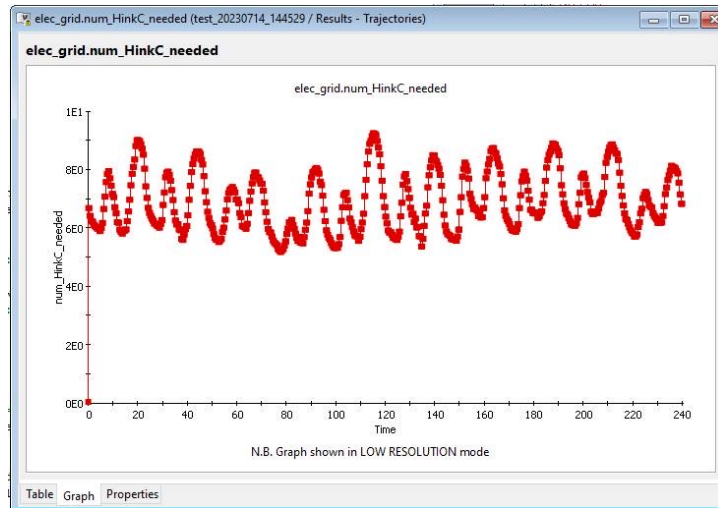
- Thermoelectric process that utilises reactor heat and electricity
- Can utilise waste heat from nuclear electricity production to vaporise feed steam
- Potential advantages when coupled to AMR designs (higher efficiencies)

Thermochemical Cycles

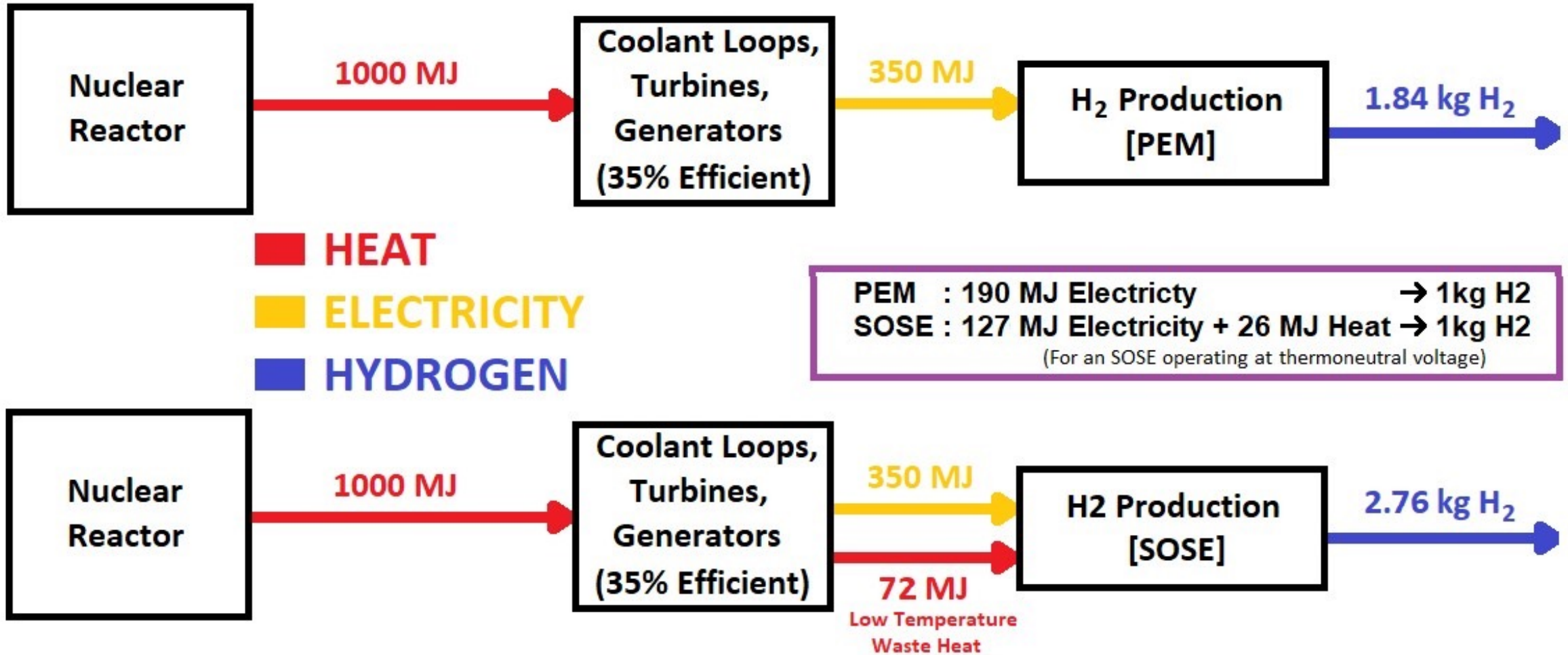
Multi-step and hybrid cycles (TRL <<5)

- Theoretically sound approach, but with large technical challenges to overcome
- Limited research in UK, unlikely to make much impact in short/ near term due to technical 'dead ends'
- Difficult to reliably determine the potential with nuclear derived energy due to low-TRL

Process modelling of coupled hydrogen generation and nuclear systems



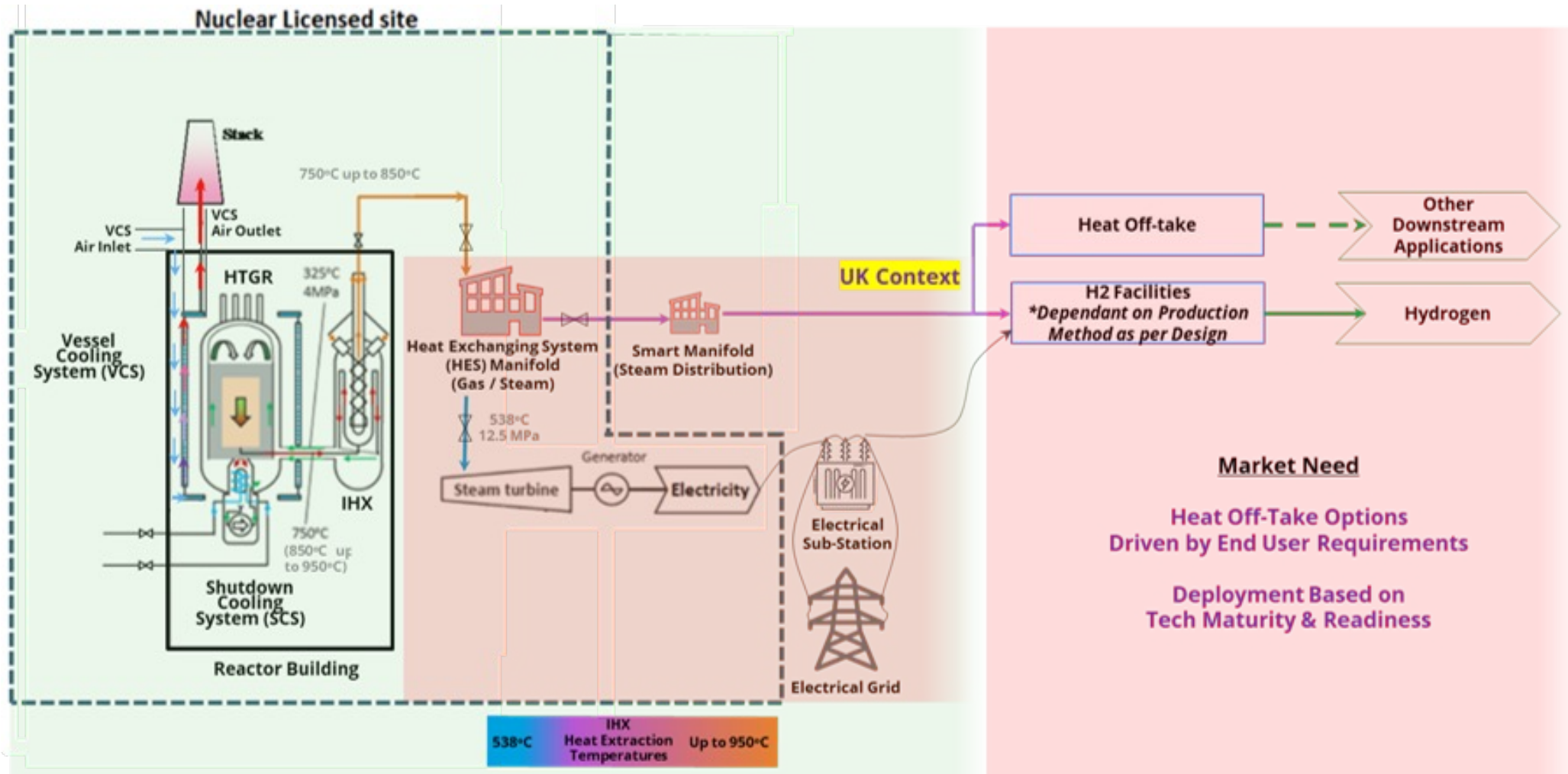
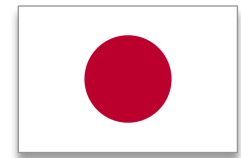
Process modelling of coupled hydrogen generation and nuclear systems



Advanced Modular Reactor- High Temperature Gas Reactor

Christopher Connolly

UKJ-HTGR



AMR Competition



Department for
Energy Security
& Net Zero



Phase A

Phase B

Phase C

HTGR Demonstrator



2022



2023



2025



Early 2030's

Phase A Understood the potential size, type, cost, and delivery method for a HTGR demonstration

Phase B Underway to develop the HTGR solution. Output will be the basis of the detailed design and engineering

Phase C Detailed site-specific design, nuclear site licensing, construction, commissioning and operation of the HTGR demonstration.

Summary

- The UK government has recognised the strong potential for High Temperature Gas-cooled Reactors to decarbonise industry, and has a plan to develop a HTGR demonstrator by the early 2030s
- Heat from HTGRs can be used directly in industrial processes and to generate hydrogen which can be used directly as a fuel to generate heat or for other purposes
- Japan and the UK have unrivalled experience in HTGRs gained from operating the HTTR and commercial fleets of reactors for decades
- The UK can accelerate the deployment of HTGR technology in UK by collaborating with Japan
- The result of our work will benefit the UK, Japan and ultimately the world





INTEGRATED ENERGY SYSTEM
NATIONAL NUCLEAR LABORATORY

SOURCES OF ENERGY	HYDROGEN PRODUCTION & USES	HEAT FROM NUCLEARS	ENERGY STORAGE	ISOTOPIES
<ul style="list-style-type: none"> 1. Nuclear Reactor 2. Fossil Fuel 3. Wind 4. Solar 5. Hydro 6. Biomass 7. Geothermal 	<ul style="list-style-type: none"> 1. Steam 2. Electrolysis 3. Chemical 4. Biological 5. Thermal 6. Photocatalytic 7. Plasma 8. Nuclear 	<ul style="list-style-type: none"> 1. Nuclear 2. Fossil 3. Biomass 4. Solar 5. Wind 6. Hydro 7. Geothermal 	<ul style="list-style-type: none"> 1. Pumped Storage 2. Flywheel 3. Battery 4. Superconducting Magnetic Energy Storage 5. Compressed Air 6. Thermal Storage 7. Molten Salt 	<ul style="list-style-type: none"> 1. Uranium-235 2. Plutonium-239 3. Deuterium 4. Tritium 5. Carbon-14 6. Neutronium

Thank you

National Nuclear Laboratory
5th Floor, Chadwick House
Warrington Road, Birchwood Park
Warrington WA3 6AE
T. +44 (0) 1925 933 744
E. customers@uknnl.com
www.nnl.co.uk