CATAPULT Network

ACCELERATING A UK HYDROGEN ECONOMY

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INTRODUCTION

Net Zero is a race to secure our future and the major economies capable of rapid decarbonisation will position themselves with a key advantage in a low carbon global economy. Hydrogen is recognised as a critical energy vector to decarbonise the most challenging areas of the economy. The emergence of new global markets for zero carbon hydrogen presents a major economic opportunity for UK businesses in line with the UK Government's Ten Point Plan for a Green Industrial Revolution.[1] To realise this opportunity, we cannot continue to innovate in traditional sector driven silos and must develop new connectivity across sectors, organisations, places and nations.

The Catapult Network is committed to making this a reality for the UK. With our partners we are creating a dedicated special purpose vehicle - The Hydrogen Innovation Initiative, that will combine our collective strengths, capabilities, national locations and industrial reach. This aims to create a unique partnership that will forge new connections and support strategic national innovation priorities. It will add value to the UK economy by creating new technology supply chains and by maximising its diverse geographical footprint to stimulate regional prosperity. Together the Catapult Network and its partners will accelerate translational research to grow the Hydrogen Economy and the critical role it will play in delivering Net Zero.

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

The global energy system is undergoing change at an unprecedented rate as national commitments to reach Net Zero trigger a race to achieve a low carbon economy and the long-term competitive advantage this will bring. There is a growing consensus amongst industry, academia and governments that hydrogen will be an essential pillar required to reach Net Zero, to address harder to decarbonise industrial sectors and to provide a new medium for energy storage and transportation that does not rely on chemical battery technology. Ironically, hydrogen powered the first internal combustion engines over 200 years ago and we could see things come full circle in the future with hydrogen as a key part of our energy system.

For the UK this means creating a new energy sector within 30 years, capable of delivering energy volumes equivalent to that of our power sector today.[2] This presents a huge opportunity that the UK can capitalise on as part of its green recovery and through export to global markets.

With the development of a bold UK hydrogen strategy, supported by the development of the right public-private funding mechanisms and the full participation of research institutions and industry, the UK can position itself to become a leader in the development of hydrogen technologies across the full value chain and its integration as part of a network of increasingly complex and interconnected smart local energy systems.[3]

Creation of new supply chains to deliver the Hydrogen Economy will provide diversification opportunities for companies considering new growth markets in a post Coronavirus green recovery. It can also leverage the UK's heritage in Oil & Gas and expertise in petrochemical technology, whilst capitalising on the UK's world leading research, design and manufacturing capabilities to unlock economic value, create new supply chains and jobs for the future across all regions of the UK.

Catapult as the Convener and Market Designer

Milford Haven Energy Kingdom

As part of the Prospering from the Energy Revolution Programme, The Offshore Renewable Energy Catapult and Energy Systems Catapult working with Pembrokeshire County Council, Arup, Port of Milford Haven, Welsh Government and Wales & West Utilities are supporting the design of an integrated local energy system incorporating hydrogen across heat, power and transport at Milford Haven in Pembrokeshire.

2 https://es.catapult.org.uk/reports/innovating-to-net-zero/
3 https://www.ukri.org/innovation/industrial-strategy-challenge-fund/prospering-from-the-energy-revolution/

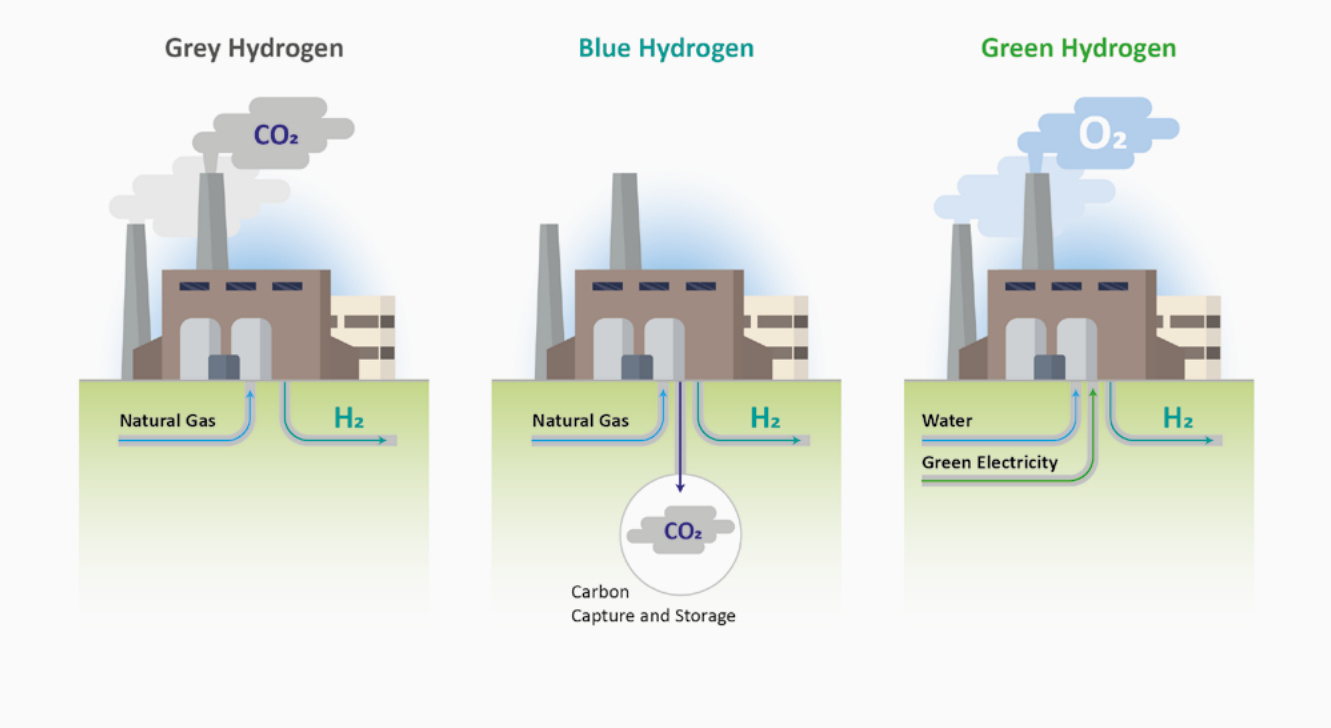
1.

THE ROLE OF HYDROGEN IN A NET ZERO FUTURE

Major global markets for zero carbon hydrogen[4] are expected to emerge over the next decade. The UK is well positioned to support the parallel development of both blue and green hydrogen and to position itself as world leaders in many of the critical technology enablers that will be required. Today production of blue hydrogen is cheaper and therefore currently most cost competitive.[5]

Blue hydrogen can be utilised to drive the early deployment phases of global hydrogen economies and in the development of Carbon Capture, Utilisation and Storage (CCUS) technology needed for blue hydrogen to be low carbon. Green hydrogen can become rapidly cost competitive with scale up and investment in new technology and therefore capable of economic scaled production beyond 2030.[6]

Production of blue hydrogen can leverage the UK's existing offshore infrastructure, experience and the gas reserves in the North Sea and represents a natural transition for decarbonisation of the offshore sector.[7] The UK can leverage its commitment to renewable energy and specifically the huge development potential for offshore wind as a source of clean energy to produce cost effective green hydrogen.[6] The long term role of blue hydrogen in delivering Net Zero ambitions is contingent on the development and demonstrating at scale carbon capture and storage technology, which in turn could drive a new industrial sector.



4 Zero Carbon Hydrogen is hydrogen produced without emitting carbon emissions to the atmosphere
5 https://www.theccc.org.uk/publication/hydrogen-in-a-low-carbon-economy/
6 https://s3-eu-west-1.amazonaws.com/media.newore.catapult/app/uploads/2020/09/09161500/Solving-the-Integration-Challenge-ORE-Catapultr.pdf https://
7 www.theogtc.com/newsroom/news/2020/closing-the-gap-realising-a-net-zero-north-sea/

THE UK SUPPLY CHAIN

The creation of a UK Hydrogen Economy has the potential to reduce energy import dependency and presents opportunities for exporting surplus hydrogen. Industry research estimates the UK's green hydrogen exports from offshore wind could reach £48bn annually with potential for £200bn of gross value added (GVA) and up to 120,000 jobs from the production of green hydrogen and export of electrolysers to overseas markets.[6]

R&D investment in areas such as automotive (road and non-road), aerospace and shipping can create, or safeguard, many more jobs, and could prove critical to the survival of major UK industries. The Hydrogen economy also presents similar opportunities across every existing industrial sector.

The UK also has a number of world leading companies ready to develop technology to deliver the Hydrogen Economy, such as ITM Power[8] (Sheffield), Ceres power[9] (West Sussex), AFC Energy[10] (Surrey), Johnson Matthey[11] (London), INEOS[12] (London), Airbus UK[13] (Bristol), BP[14] (London), GKN[15] (Solihull), Intelligent Energy[10] (Loughborough) and a wide range' and a wide range of industry-led activities through technology centres such as the Advanced Propulsion Centre[16], Aerospace Technology Institute[17], OGTC[18] and National Physics Laboratory[19].

Catapult as the Integrator

Integrated Tidal Energy Generation

Working with the European Marine Energy Centre, the Energy Systems Catapult is helping develop and validate an integrated tidal energy and hydrogen production solution in Orkney and its system optimisation supporting new market opportunities for the ocean energy sector through hydrogen production and energy storage.

8 https://www.itm-power.com/
9 https://www.ceres.tech/
10 https://www.afcenergy.com/
11 https://matthey.com/en/news/2020/world-first-low-carbon-hydrogen-projects-in-the-north-west-win-13m-government-backing
12 https://www.ineos.com/news/ineos-group/ineos-launches-a-new-clean-hydrogen-business-to-accelerate-the-drive-to-net-zero-carbon-emissions/
13 https://www.airbus.com/newsroom/press-releases/en/2020/09/airbus-reveals-new-zeroemission-concept-aircraft.html
14 https://www.bp.com/en/global/corporate/news-and-insights/reimagining-energy/net-zero-teesside-project.html
15 https://www.gknaerospace.com/en/newsroom/news-releases/2021/gkn-aerospace-leads-development-of-ground-breaking-hydrogen-propulsion-system-for-aircraft/
16 https://www.apcuk.co.uk/product-roadmaps/
17 https://www.ati.org.uk/
18 https://www.ogtc.com/ogtc-today/our-purpose/
19 https://www.npl.co.uk/national-challenges/energy-environment/hydrogen

2.

REALISING THE OPPORTUNITY

No breakthrough technology is required for hydrogen to play a major role in our future energy system. However, innovation is critical to overcome technology and integration challenges through the entire value chain that will be required to achieve scale, volume, reliability, efficiency and phased roll out of the enabling infrastructure. A balanced view of how hydrogen will be produced, distributed and utilised is required to enable key policy and regulatory decisions to be made. This will influence the market and allow technology programmes to be launched within each sector, to enable the demand for hydrogen to increase with the expected volume of supply:

- **Generation:** Producing low carbon hydrogen is costly. Significant investment at scale is required to drive the costs down, to ensure delivery of at least 5GW of Hydrogen capacity at an economic cost base by 2030. The integration challenge of the critical trifecta of offshore wind, low carbon hydrogen production and carbon sequestration needs to be solved at scale. Each of these has its own technology challenges whether that be industrialisation, scale, capacity, reliability, system integration and the standards and certification requirements for commercial implementation. The complexity of phased deployment of a hydrogen system, its integration with grid infrastructure and the need to produce low cost, low carbon electricity in balance with hydrogen will be critical in an increasingly integrated and complex system.

- **Distribution:** The challenge of moving hydrogen from point of production to point of consumption is critical. The optimum deployment of hydrogen into priority areas where it will be utilised as a low carbon energy source is currently unclear. Without this, investment in necessary technology programmes for the next generation of hydrogen propulsion aircraft, vehicles, home heating and industrial processes may stall, negating the huge appetite for private investment into these technologies in UK markets.

- **Consumption:** Conversion to hydrogen propulsion is increasingly recognised as the optimum low carbon mobility solution for segments considered more heavy duty such as HGVs, trains, aircraft and potentially marine vessels. However, technology development is required at an accelerated rate to develop the fuel cell technology, hydrogen combustion, storage and balance of plant to make this a viable alternative to electrification.

- **Blue and green hydrogen – integrated with CCUS:** Blue hydrogen is a critical enabler for both the hydrogen economy and to drive CCUS technology forward. It will create new markets and supply chains for low carbon hydrogen and pave the way for green hydrogen to deliver on longer term Net Zero ambitions. In this process, blue hydrogen can also drive the industrialisation of carbon sequestration technology required to eliminate the CO_2 produced during the production process. This can establish the market readiness for sequestration technology that will be required for future

direct air capture technology and other methods to capture fugitive CO_2 emissions from industrial processes as the hydrogen market will increasingly transition from blue to green production methods post 2030.

- **Business models and market interventions:** Continued end-to-end hydrogen innovation in production, distribution and end use technologies are essential but it will also be critical that the associated business models, market regulation and pricing are conducive to creating the right conditions. This will allow the sector to thrive, delivering its full decarbonisation potential. This may involve complex mechanisms that could benefit from access to the latest digital enablement and designed through a 'system of systems' analysis to successfully deal with the inherent complexity.

- **Accelerating innovation:** Coordinated R&D with new ways of delivering public-private partnerships that brings together national and local governments, regulators, industry and investors is required to achieve this at an unprecedented rate. This must ensure the development of the necessary supply infrastructure and the creation of functioning markets for low and ultimately zero carbon hydrogen to build confidence and enable private investment in both production and demand technologies.

Public investment in R&D and supporting incentives has been proven to drive cost reduction and scale the deployment of renewable energy technologies, especially where these advances need de-risking before industry is prepared to invest. Many of the core technologies for hydrogen are at a similar stage of technical and commercial maturity to that of wind and solar energy generation less than twenty years ago. However, creation of a UK Hydrogen Economy and its integration as part of our wider energy system is complicated and will require coordinated public support and strategic oversight from end-to-end with innovations spanning technological, organisational, market, policy and regulation. Effective planning and coordination of hydrogen production, storage and distribution as part of our wider energy system is essential to ensure cost effective, low carbon supply; and achieving synergies between end-uses and avoiding conflicts.

Catapult as the Advisor

Transitioning to Zero-Emission Transport

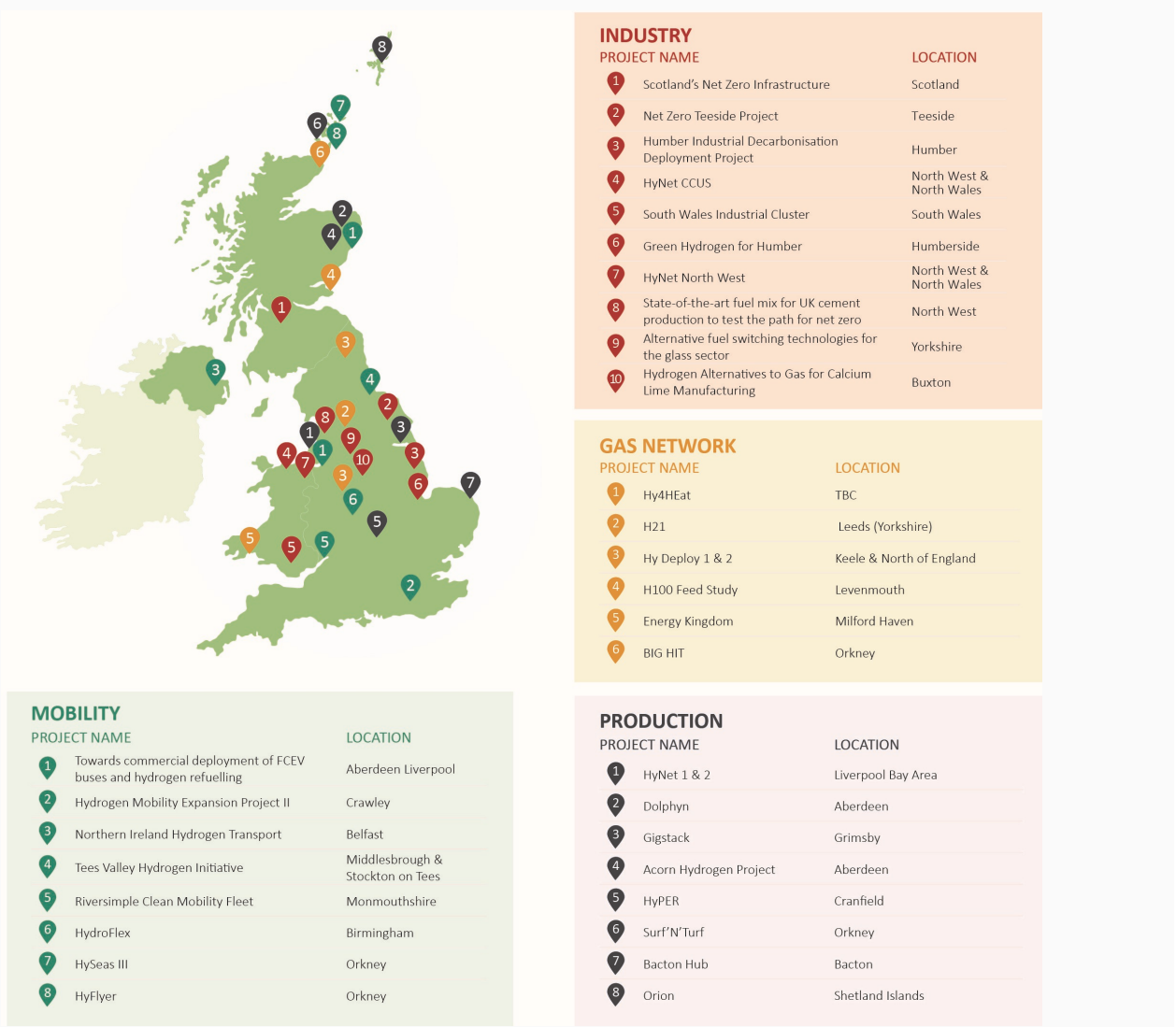
Connected Places Catapult is working with the Department for Transport to investigate decarbonisation options for Heavy Goods Vehicles (HGVs) including the potential role of hydrogen fuel cell vehicles alongside electric road systems (pantograph/ catenary systems) and battery electric vehicles. This research is building evidence on hydrogen's potential future role in transport and innovation opportunities and priorities.

3.

CURRENT ACTIVITY

In recent years the UK has initiated a number of important hydrogen R&D projects and programmes. This includes HyNet,[20] Hy4heat,[21] H21, the Energy Networks Association Gas Goes Green[22] and Low Carbon Hydrogen Supply programmes.[23] In addition, significant academic research programmes are established including the H2FC Supergen research hub, funded by the Engineering and Physical Sciences Research Council (EPSRC) building upon 10 years of UK hydrogen research from several institutions.

A number of key projects are shown below:



INDUSTRY

	PROJECT NAME	LOCATION
1	Scotland's Net Zero Infrastructure	Scotland
2	Net Zero Teeside Project	Teeside
3	Humber Industrial Decarbonisation Deployment Project	Humber
4	HyNet CCUS	North West & North Wales
5	South Wales Industrial Cluster	South Wales
6	Green Hydrogen for Humber	Humberside
7	HyNet North West	North West & North Wales
8	State-of-the-art fuel mix for UK cement production to test the path for net zero	North West
9	Alternative fuel switching technologies for the glass sector	Yorkshire
10	Hydrogen Alternatives to Gas for Calcium Lime Manufacturing	Buxton

GAS NETWORK

	PROJECT NAME	LOCATION
1	Hy4HEat	TBC
2	H21	Leeds (Yorkshire)
3	Hy Deploy 1 & 2	Keele & North of England
4	H100 Feed Study	Levenmouth
5	Energy Kingdom	Milford Haven
6	BIG HIT	Orkney

MOBILITY

	PROJECT NAME	LOCATION
1	Towards commercial deployment of FCEV buses and hydrogen refuelling	Aberdeen Liverpool
2	Hydrogen Mobility Expansion Project II	Crawley
3	Northern Ireland Hydrogen Transport	Belfast
4	Tees Valley Hydrogen Initiative	Middlesbrough & Stockton on Tees
5	Riversimple Clean Mobility Fleet	Monmouthshire
6	HydroFlex	Birmingham
7	HySeas III	Orkney
8	HyFlyer	Orkney

PRODUCTION

	PROJECT NAME	LOCATION
1	HyNet 1 & 2	Liverpool Bay Area
2	Dolphyn	Aberdeen
3	Gigstack	Grimsby
4	Acorn Hydrogen Project	Aberdeen
5	HyPER	Cranfield
6	Surf'N'Turf	Orkney
7	Bacton Hub	Bacton
8	Orion	Shetland Islands

Offshore Wind and Hydrogen: Solving the Integration Challenge, ORE Catapult, OWIC, 2020

20 https://hynet.co.uk/
21 https://www.hy4heat.info/
22 https://www.energynetworks.org/creating-tomorrows-networks/gas-goes-green
23 https://www.gov.uk/government/publications/hydrogen-supply-competition

This level of activity provides a foundation of strength from which the UK can build, however, there is a significant risk of R&D investment and activity being drawn oversees if we do not keep pace with the investments and commitments made by other countries.[24] [25] [26]

Catapult as the Innovator

Faraday Battery Challenge

The High Value Manufacturing Catapult is bringing together the academic and business community in a comprehensive programme of research, innovation and scale up of battery technology from their raw materials and electrochemistry to end of life treatment helping to develop safe, cost effective, durable, lighter weight, high performing and recyclable batteries which will power the next generation of electric vehicles.

24 https://www.dw.com/en/germany-and-hydrogen-9-billion-to-spend-as-strategy-is-revealed/a-53719746
25 https://ec.europa.eu/commission/presscorner/detail/en/FS_20_1296
26 https://www.meti.go.jp/english/press/2017/pdf/1226_003b.pdf

4.

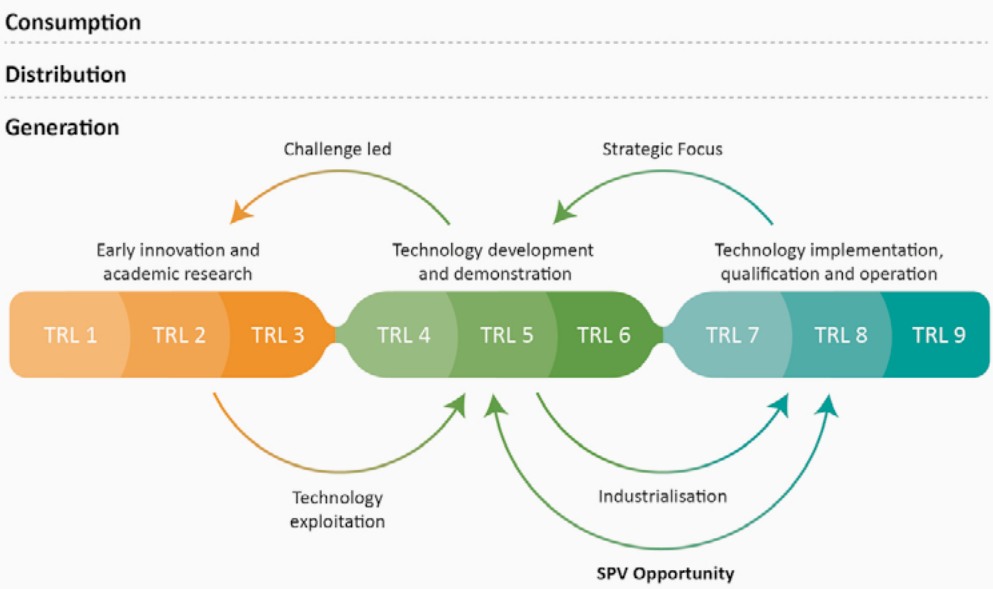
THE ROLE OF CATAPULTS IN HELPING CREATE A UK HYDROGEN ECONOMY

At each stage of hydrogen production, distribution and end use, there are technology, integration and commercial challenges and innovation opportunities. There is a need for a wide range of innovation support, from market intelligence, standards and systems integration, exploratory research and performance validation, to development of new business models and new customer value propositions.

The Catapult Network will play a key role in enabling the cross-cutting innovation that is required for the creation of UK Hydrogen Economy and in realising the economic opportunities from the development of global hydrogen markets. Its innovation centres provide access to a range of world leading facilities and expertise that are able to support the delivery of R&D and bringing together government, academia industry and investors across complex innovation landscapes.

The Catapults will collectively bring their expertise to provide leadership, identify gaps and innovation priorities in the end-to-end hydrogen value chain, and partner with UK innovators and academia to deliver solutions to this emerging global market.

Recognising the opportunity for investment in hydrogen to support economic recovery and Net Zero ambitions, the Catapult Network is creating a new special purpose vehicle - The Hydrogen Innovation Initiative - to support implementation of a UK hydrogen innovation roadmap through a wide range of innovation projects and programmes. This aims to help government and industry collaborate in the creation of a UK hydrogen economy and the coordination and alignment of R&D activity. The Initiative will also help to forge strategic linkages and establish a focal point for a connected innovation backbone.



E2E Hydro-GEN: Accelerated Strategic Innovation Backbone, Catapult Network.

THE CALL TO ACTION

In order to deliver a thriving Hydrogen Economy and to capitalise on the potential economic benefits this presents, the UK must continue to invest in innovation across production, distribution and consumption of hydrogen to accelerate R&D and innovation, to forge new linkages across sectors and to accelerate exploitation routes for technology. Building on the Governments commitment to hydrogen innovation through its £1bn Net Zero Innovation Portfolio, a coordinated hydrogen innovation roadmap and supporting innovation programmes can help to create new supply chains and to lead the 'next-generation' of hydrogen technologies, delivering huge economic value to the UK economy as we drive to Net Zero.

LEAD

Working with industry, government and the research community to co-create a strategic approach to innovation that accelerates the hydrogen economy and its integration as part of the wider energy system.

INVEST

Support the development of key UK companies with the potential to develop globally competitive products or technology, forming the foundation of world leading UK supply chains.

FUND

Provide strategic funding that creates exploitation routes for key critical technologies and accelerates the development through scale up and to industrial deployment.

CONNECT

Support the creation of new linkages between sectors to drive efficient, complimentary development and maximise technology exploitation.