



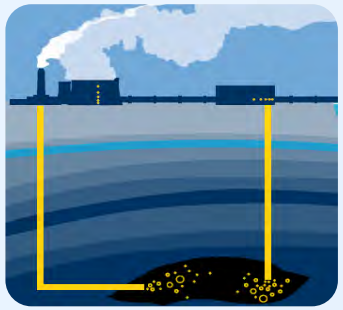



Role of blue hydrogen In the UK: Key learnings from recent activities

6 November 2019

Revised

elementenergy

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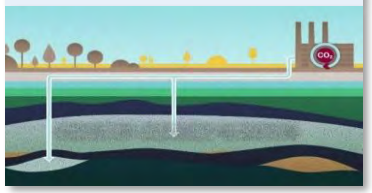
Element Energy, a consultancy focused on the low carbon energy sector

Element Energy covers all major low carbon energy sectors:

CCUS & industrial decarbonisation



Energy Networks

Smart Energy Systems

Hydrogen

Low Carbon Transport

Built Environment

Selected clients:

Public sector

Department for Business, Energy & Industrial Strategy

Committee on Climate Change

EUROPEAN COMMISSION

Transport for London

TRANSPORT SCOTLAND

Birmingham City Council

scottishcitiesalliance

seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND

GREATER LONDON AUTHORITY

NGOs

iea International Energy Agency

European Climate Foundation

UNDP

WORLD BANK GROUP

Public-Private Partnerships

energy technologies institute

UK H_2 Mobility

LowCVP low carbon vehicle partnership

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

Private Sector

OGCI OIL AND GAS CLIMATE INITIATIVE

bp

TOYOTA

NISSAN

equinor

UK Power Networks

HYUNDAI

AIR PRODUCTS

EDF ENERGY

Scottish and Southern Energy

BOSCH Invented for life

British Gas

BOC Member of The Linde Group

NISSAN

Rolls-Royce

ESB Energy for generations

DAIMLER

nationalgrid

zipcar

Recent blue hydrogen projects led by Element Energy

Project	Description	Clients	Year
Hy-Impact Series Hydrogen in the UK, from technical to economic	▪ Hy-Impact is a series of four studies delivered by Element Energy exploring the introduction of hydrogen and CCS to the UK economy, including economic benefits of deployment, production of net-zero hydrogen, hydrogen for power generation and H_2 in Yorkshire & Humber LINK	equinor	2019
Net-zero target: Deep decarbonisation of UK industries	▪ The UK government has asked the CCC for formal advice on the date by which the UK should achieve a net zero GHG/carbon target. Element Energy was commissioned to lead the analysis on net-zero industries considering all fuels (incl. internal fuels), sectors and key technologies LINK	Committee on Climate Change	2019
Hy4Heat: industrial H_2 appliances	▪ Element Energy leads this study, which aims to provide evidence to understand the issues relating to potential future conversion of industry to hydrogen, and to de-risk this opportunity; and to inform strategic options for wider conversion from natural gas to hydrogen. [To be published]	Hy4Heat demonstrating hydrogen for heat	2018-19
Industrial fuel switching competition: Market assessment	▪ Element Energy led the first phase of the Competition, which for all three phases has been allocated up to £20m. The aim is to understand economic potential for industrial fuel switching and CCUS and key barriers. LINK	Department for Business, Energy & Industrial Strategy	2018
Industrial carbon capture business models	▪ BEIS commissioned Element Energy to identify a set of promising business models and incentive mechanisms for the deployment of industrial carbon capture projects. LINK	Department for Business, Energy & Industrial Strategy	2018
H_2 supply chain modelling tool	▪ Project involved gathering an extensive engineering dataset on the cost and performance of technologies across the whole hydrogen supply chain, including the application of CCS. LINK	Department for Business, Energy & Industrial Strategy	2017
Analysis of future heat infrastructure	▪ Project into the costs associated with different pathways to decarbonising heat. The cost analysis considers all levels of the system, including the building level costs, and the distribution and transmission network level. LINK	National Infrastructure Commission	2017

Recent CCS projects led by Element Energy

Project	Description	Clients	Year
Zero Carbon Humber project	▪ Drax Group, Equinor and National Grid formed a partnership to build a zero-carbon industrial cluster and decarbonise the North of England. Element Energy has been supporting the Consortium. LINK LINK	nationalgrid drax equinor	2019
Net-zero target: Fossil fuel production and fugitive emissions	▪ The UK government has asked the CCC for formal advice on the date by which the UK should achieve a net zero GHG/carbon target. Element Energy was commissioned to lead the analysis on decarbonising fossil fuel production emissions and fugitive emissions including methane. LINK	Committee on Climate Change	2019
Shipping CO_2: UK cost estimation study	▪ Study aims to estimate costs of shipping CO2 from different terminals and at a range of scales to geological CO_2 storage sites in the UK, and elsewhere; and to identify the circumstances (scales/capacity/locations/time) in which shipping costs may represent value for money. LINK	Department for Business, Energy & Industrial Strategy	2018-19
Policy Mechanisms to support the large-scale deployment of CCS	▪ Study assessed the barriers to CCUS deployment, and developed policy suggestions to incentivise large scale CCUS take up. The study also explored the key applications of CCUS market mechanisms in different regions such as North America, Europe, Middle East, China and India. LINK	OGCI OIL AND GAS CLIMATE INITIATIVE	2018
Industrial CCS clusters; Power CCUS; CO_2 shipping; Digital technologies	▪ Element Energy and its partners have been commissioned by IEAGHG to assess CCUS globally. 5 separate studies have assessed global deployment of industrial CCS clusters, role of power CCUS globally, CO_2 shipping infrastructure, impact of emerging technologies; and construction of CCUS	ieaghg	2017-19
CCUS deployment at dispersed industrial sites	▪ Project identified and assessed a range of high-level deployment options for Industrial Carbon Capture (ICC) technology on sites isolated from CO2 transport infrastructure, including shipping, onshore pipelines, road transport, rail, hydrogen fuel switching and CO_2 utilization.	Department for Business, Energy & Industrial Strategy	2019
European funds and financing options for industrial CCUS clusters	▪ Element Energy-led study assessed European funds and financing instruments along with multiple public and private sources of capital. The project demonstrated how part-chain ICC and T&S infrastructure projects can be financed. LINK	European Climate Foundation	2017

“Developing carbon capture and storage technology and low-carbon hydrogen is a necessity, not an option”

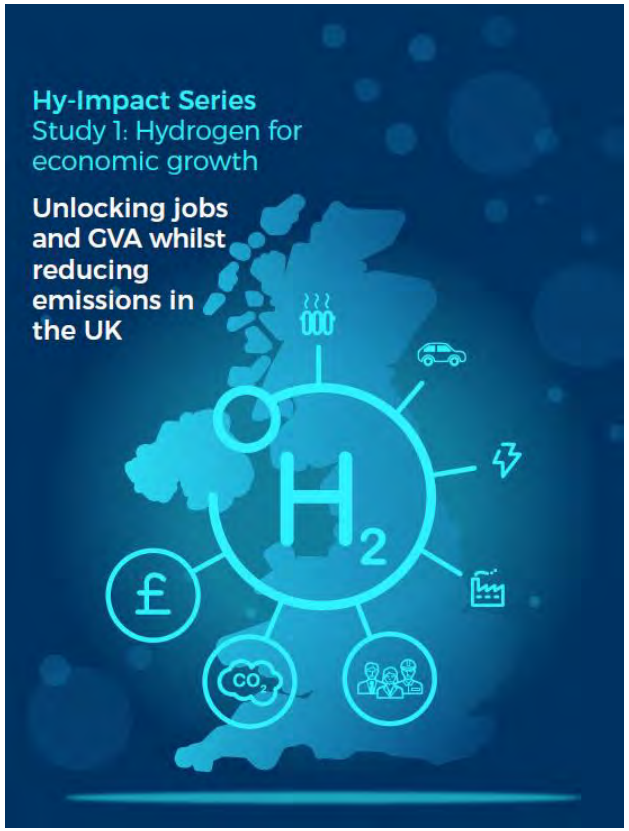
Committee on Climate Change Net-zero Report Press Release May 2019

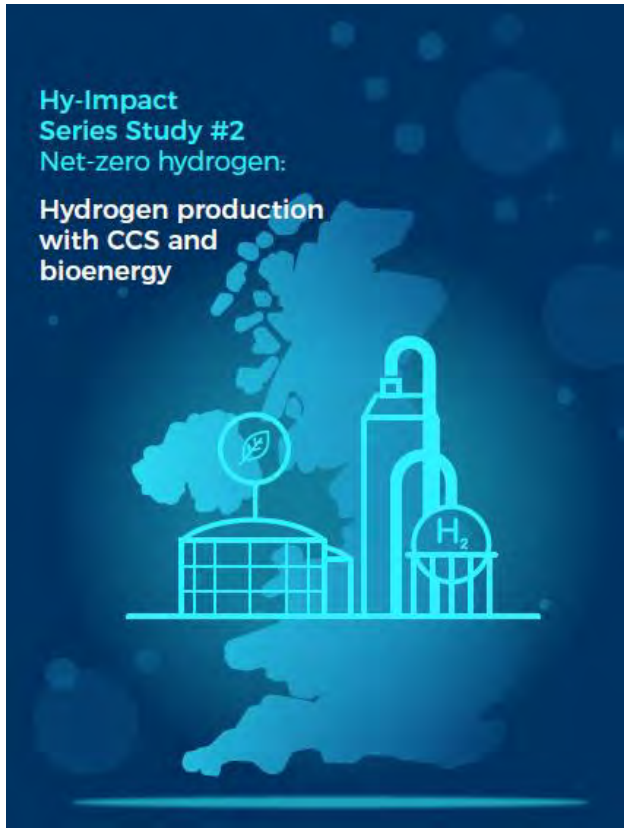
elementenergy

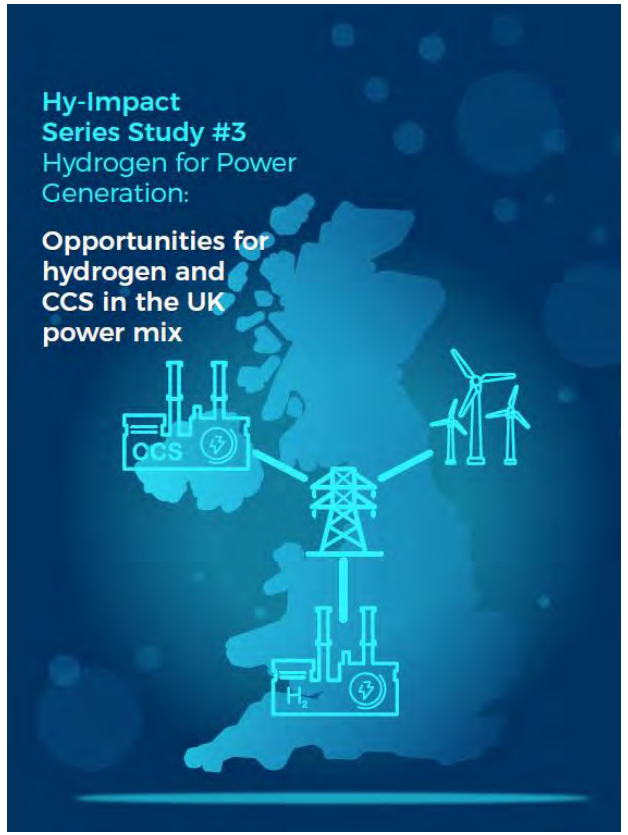
A report for

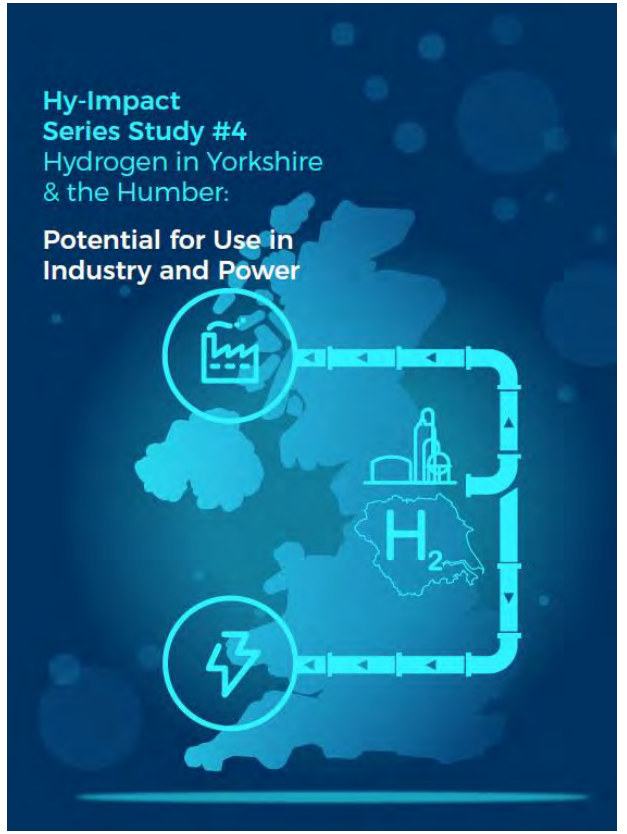
equinor

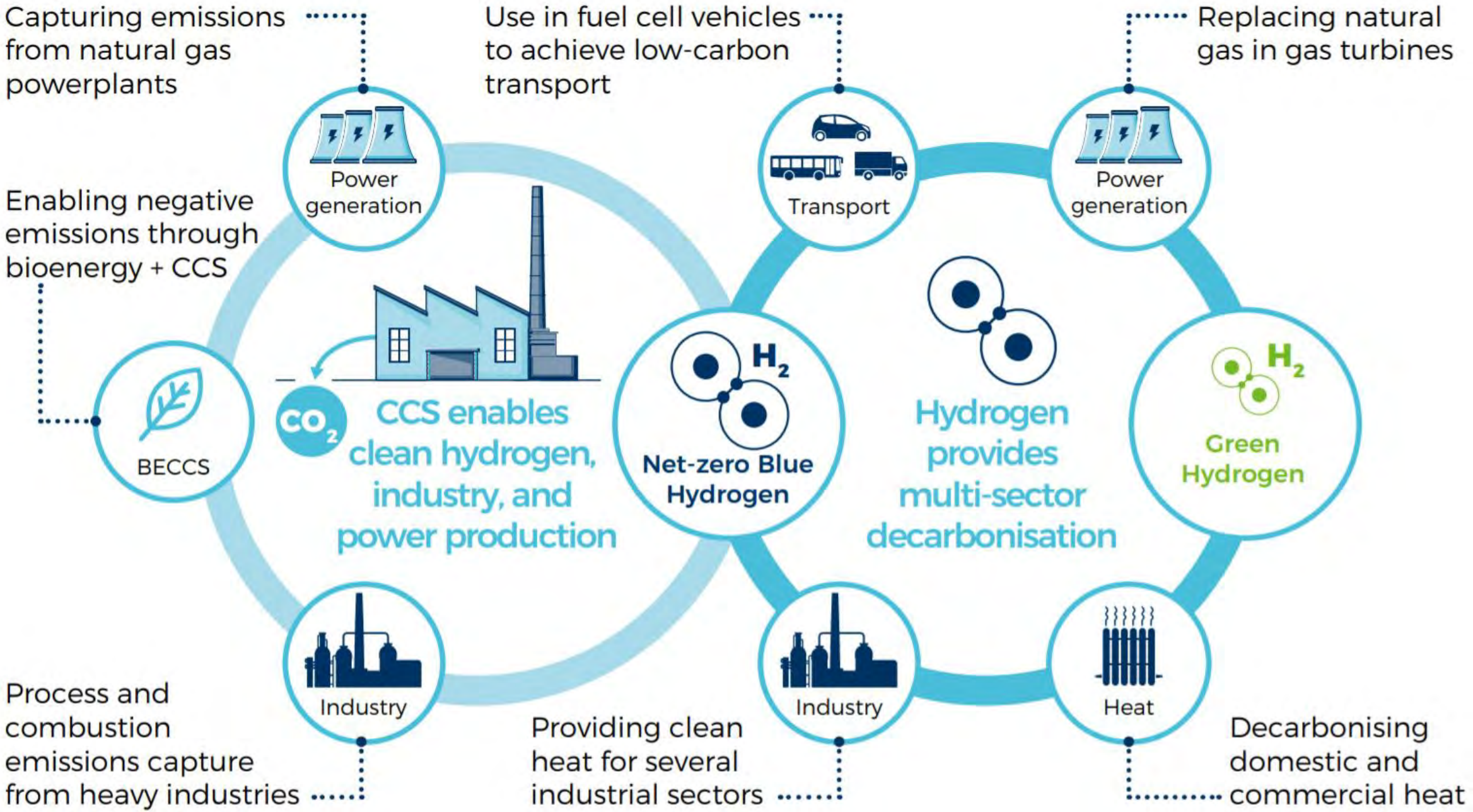
Hy-Impact is a series of four studies exploring the introduction of hydrogen and carbon capture and storage to the UK economy









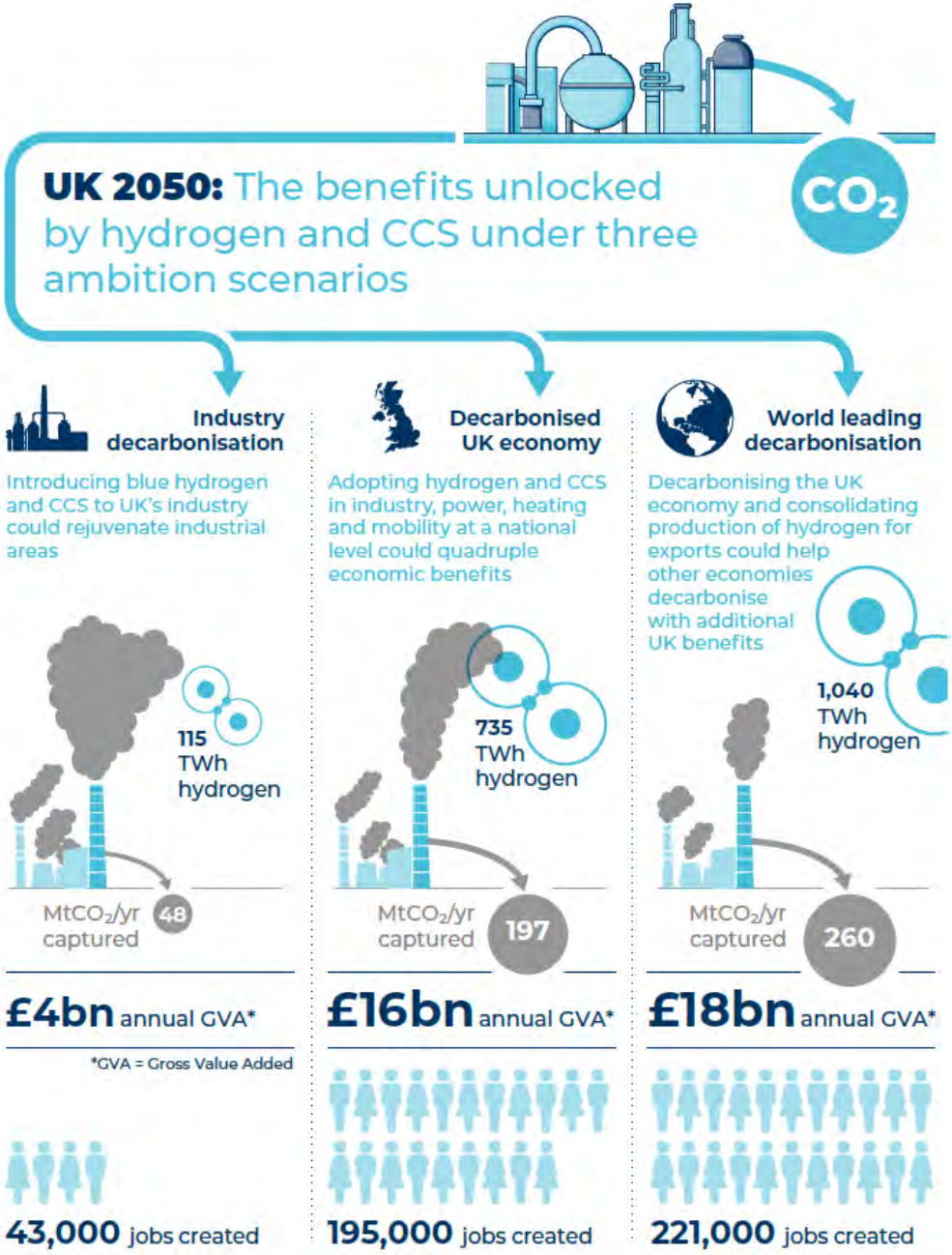


Reference: Element Energy for Equinor, Hy-Impact Series, 2019

Study 1 - Hydrogen for Economic Growth:
Unlocking jobs and value whilst reducing emissions in the UK

£18 billion in value and over 200,000 jobs could be generated by deployment of hydrogen and CCS in the UK economy

This series of studies starts by examining how a future UK economy could benefit from the development of hydrogen and CCS technologies. Three ambition scenarios for hydrogen and CCS deployment were developed to understand the level of investment required and the potential economic, strategic, environmental and employment benefits.

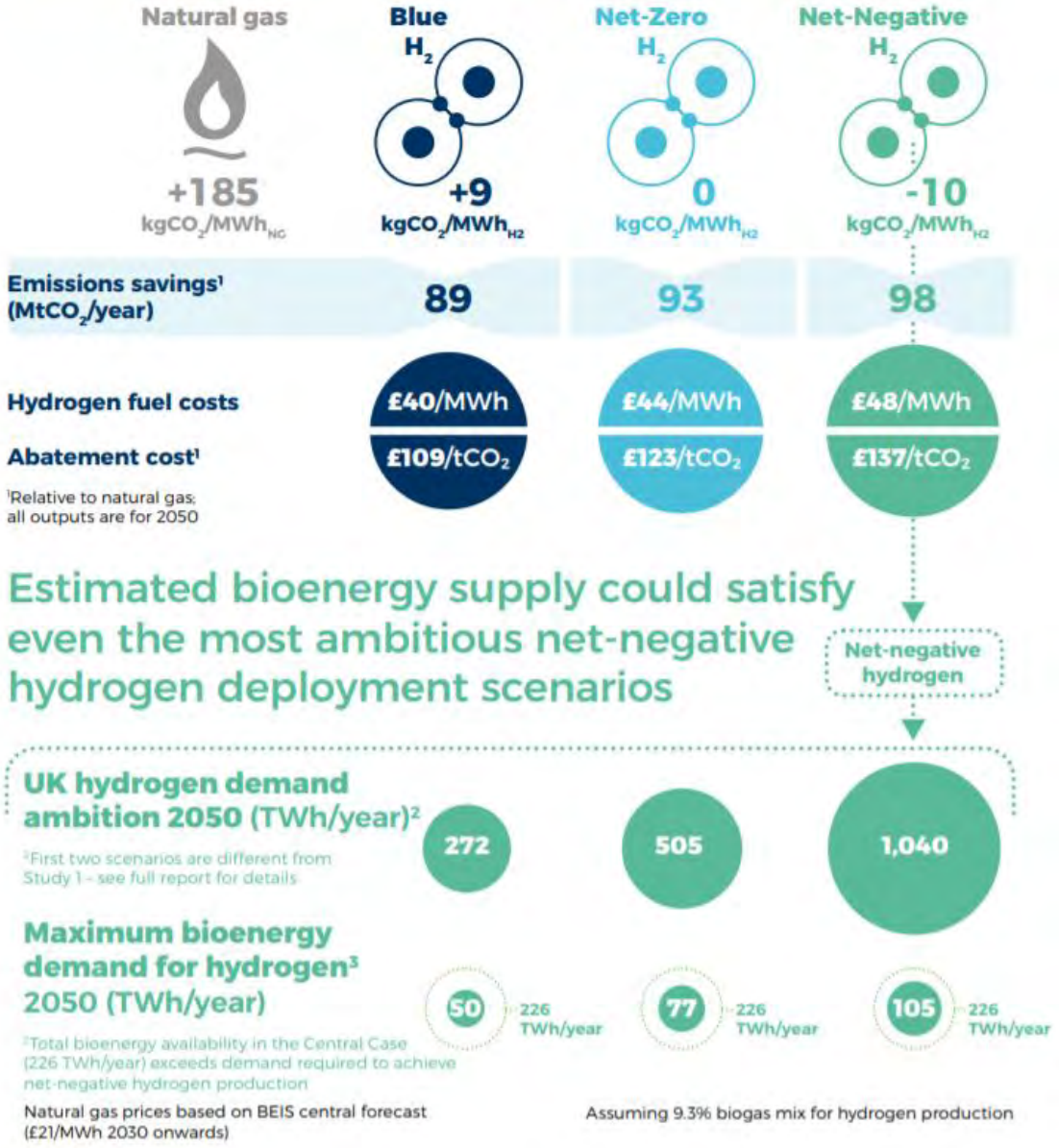


Study 2 - Net-zero Hydrogen:
Hydrogen production with CCS and bioenergy

There is sufficient bioenergy to enable net-negative hydrogen production in even the most ambitious scenario

Net-zero or net-negative hydrogen can be produced by blending biogas into the natural gas feedstock. The second study examines the bioenergy resource required to meet future hydrogen demand, as well as the financial and emissions implications of different decarbonisation scenarios.

Biogas blending has a significant impact on hydrogen production costs and emissions



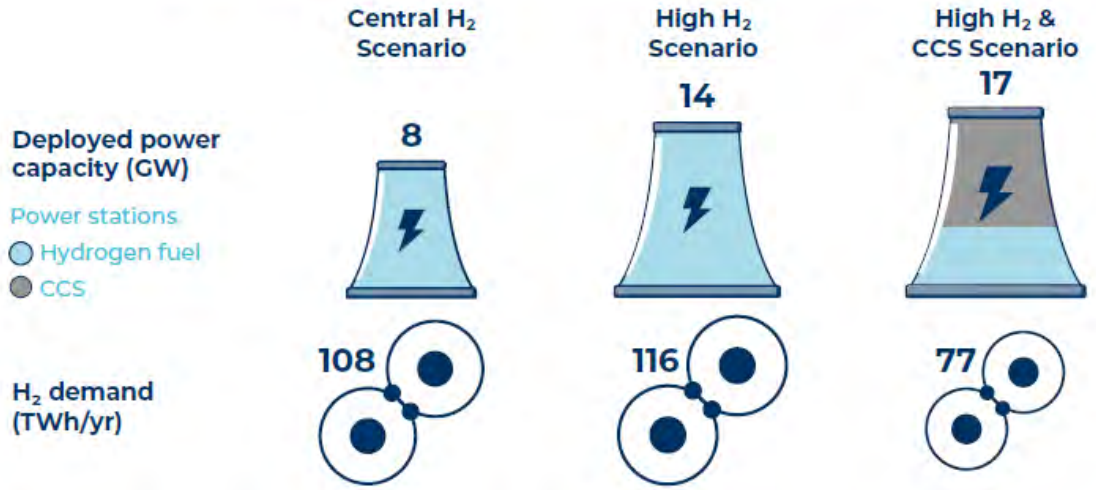
Study 3 - Hydrogen for Power Generation:
Opportunities for hydrogen and CCS in the UK power mix

Hydrogen and CCS power technologies can cost-effectively replace a significant number of planned power generation assets

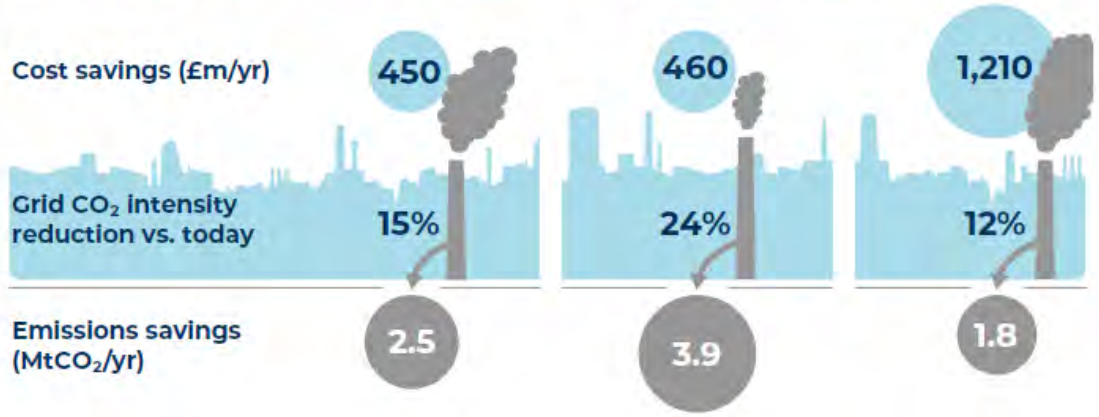
Hydrogen and CCS can be used for low-carbon power generation to diversify the power portfolio, reduce electricity imports and provide resilience to high levels of renewable energy generation. Our work assessed the financial and emissions implications of these generation methods when compared with current and future natural gas and nuclear options.

UK power in 2035 under three low-carbon generation scenarios...

... would require a diversification of technologies with opportunities for hydrogen and CCS...



ydrogen and CCS technologies could reduce grid ensity by 24% and achieve significant cost savings



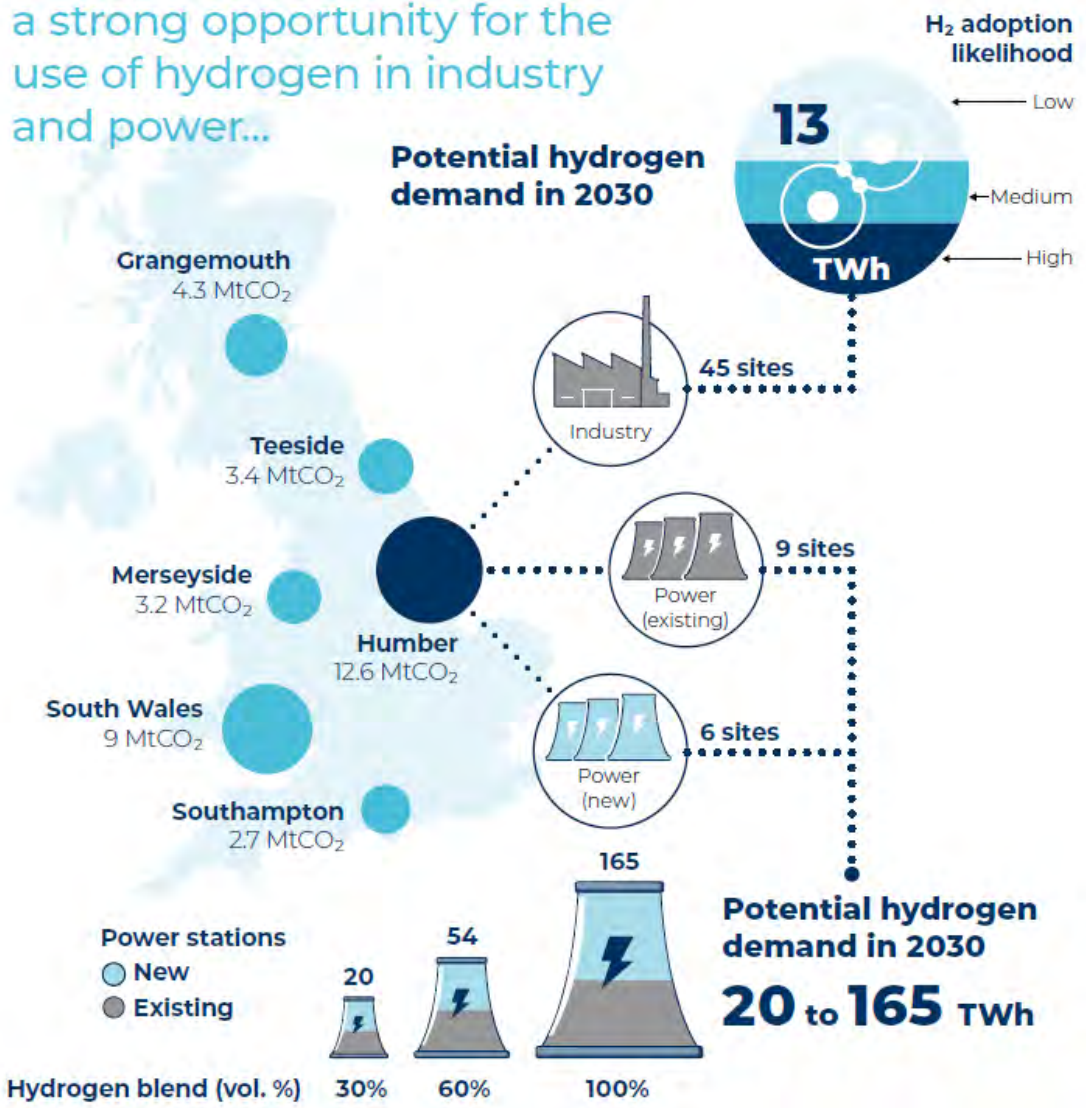
Reference: Element Energy for Equinor, Hy-Impact Series, 2019

Study 4 - Hydrogen in Yorkshire & the Humber:
Potential for use in industry and power

The Humber region could represent an opportunity for early hydrogen deployment, with potential demand of 13 TWh/yr hydrogen in industry and up to 165 TWh/yr in power plants

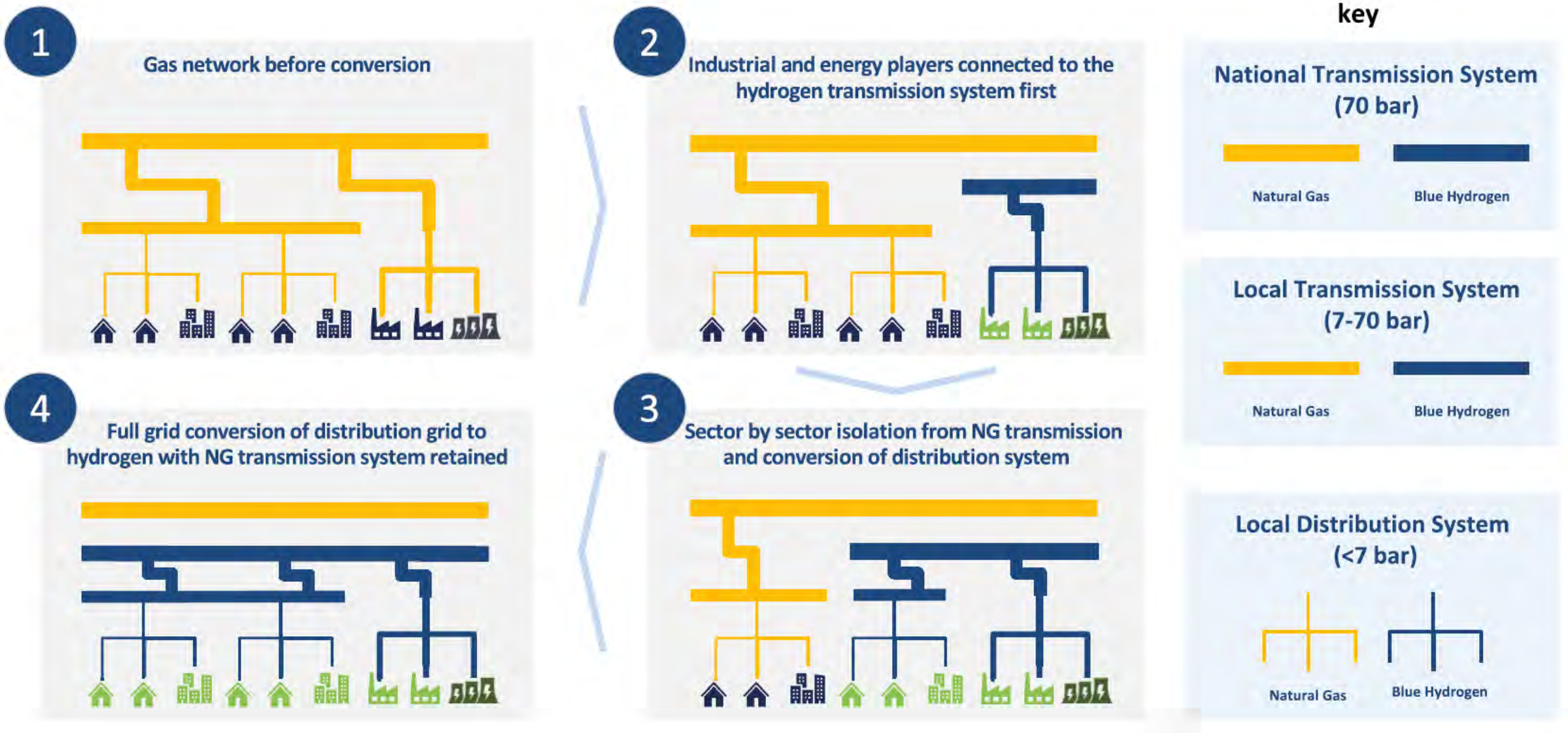
The wider Humber region is the UK's largest industrial cluster by both greenhouse gas emissions and energy usage. Our work identified large industrial and power sites in the region and assessed their potential for use of hydrogen in 2030.

The Humber region presents a strong opportunity for the use of hydrogen in industry and power...



... and could provide a base for early hydrogen economy development

Energy intensive industries can enable the “hydrogen for heat” transition in Europe



Reference: Element Energy for Equinor, Hy-Impact Series, 2019

Hydrogen for industry: no showstopper barriers were identified for hydrogen conversion; however, a wide range of industrial hydrogen equipment should be developed

	Barriers	Enablers	Impacted equipment	Impact Rating
Technical	**Radiative Heat Transfer** – lower emissivity results in decreased radiant heat flux	Further experimental investigation on heat transfer balance, particularly in glass furnaces and kilns. Additives could be used to increase emissivity.	Furnaces, Kilns	●
	Convective heat transfer – lower air requirement reduces the gas volume available to transfer heat.	Flue Gas Recirculation (FGR) increases gas volume, and is also beneficial elsewhere (e.g. NO_x emissions), equipment recalibration for indirect fired equipment.	All equipment	●
	NO_x emissions – may be increased through higher flame temperature.	Technologies to mitigate this include Flue Gas Recirculation (FGR), steam addition and post-combustion treatment. Further work on low NO_x burners may also reduce emissions.	All equipment	●
	Flue Gas Composition – e.g. increased moisture content with H_2 might impact product quality	Product specific tests required for some direct heating applications to evaluate impact and any possible mitigating actions (e.g. adjusting combustion parameters).	Direct fired equipment	●
	Gas Engine Conversion for CHP	Period of R&D, small scale and large-scale trials. May require full replacement with potential new design, rather than retrofit.	Gas Engines	●
	Piping and fittings (leakage risks and embrittlement)	Materials and standards currently exist for hydrogen piping. Site distribution systems would need to be checked for hydrogen compatibility and replaced if incompatible.	All sites	●
	Hydrogen burner development, including materials	Burner materials currently exist, though further R&D by burner manufacturers is required.	All equipment	●

Industry sector	Typical Equipment	Equipment Conversion Cost – Variation with Size (£ '000s)*		Conversion Cost for Typical Equipment (£ 000's)*	
		1 MW	10 MW	Example Size (MW)	Typical Cost
Food and Drink	Steam Boiler	170	690	20	1,040
	Oven	150	490	2	210
Chemicals	Steam Boiler	100	490	20	780
	Furnace	110	530	25	980
Vehicle Manufacturing	Hot Water Boiler	170	690	20	1,040
	Oven	150	490	5	340
	Direct Dryer	140	430	2	200
Basic Metals	Furnace	180	730	40	1,680
Paper	Direct Dryer	150	470	3	260
	Steam Boiler	190	750	20	1,140
Glass	Glass Furnace	200	800	25	1,390
Ceramics	Kiln	160	570	5	390
Lime	Lime Kiln	150	520	15	640
Other NM Minerals	Rotary Dryer	140	430	15	520
Elec and Mech Engineering	Hot Water Boiler	170	690	5	450
	Oven	150	490	3	260
	Steam Boiler	170	690	5	450

*All costs are in thousands of GBP

Several promising business models were identified for industrial carbon capture including hydrogen production – drawing on comparable existing policies

Contract for difference:
CfD on CO_2 price relative to market CO_2 price (e.g. EU ETS) to provide guarantee of revenue

Cost plus:
All properly incurred ICC operational costs are reimbursed through taxpayer funding

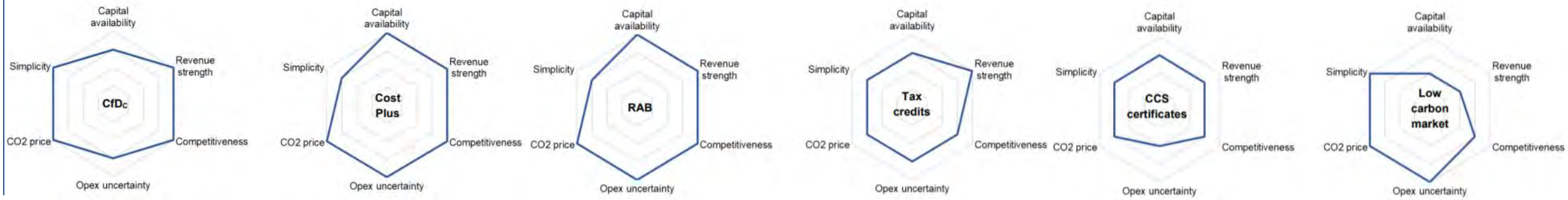
Regulated asset base:
Public regulation allows costs to be recovered through product prices e.g. of Hydrogen

Tradeable tax credits:
CCS tax credits awarded $/t$CO_2$ to reduce firms tax liability (e.g. 45Q) or trade with other firms.

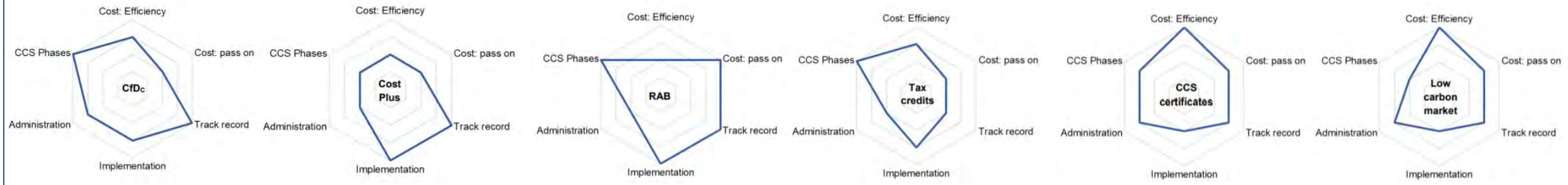
CCS certificates:
Certificates representing tCO_2 abated through CCS, which can be traded and emitters have an obligation.

Low carbon market:
End-use regulation e.g. on buildings to create a low carbon market & achieve product premium

Acceptability to industry evaluation



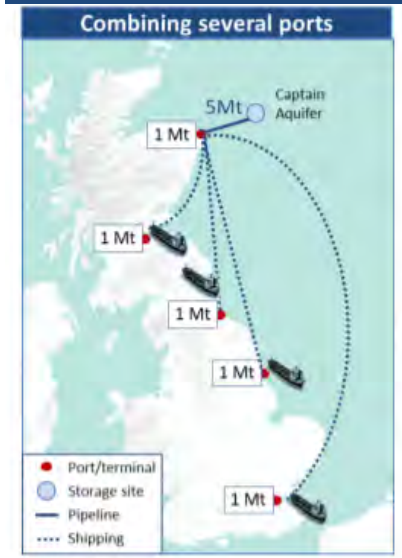
Acceptability to government evaluation

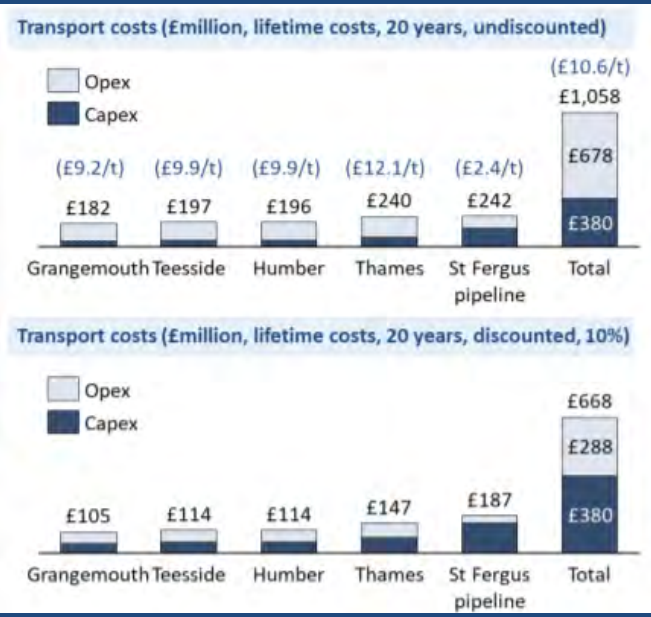


Reference: Element Energy for BEIS, Industrial carbon capture business models, 2018

Shipping can unlock several opportunities for blue hydrogen; however, feasible CO_2 transport and storage business models should be introduced across Europe

Enabling the deployment of multiple clusters in parallel





Enabling short duration CCUS projects of small scale

Enabling cross-border CO_2 transport in Europe and globally

Enabling CCUS clusters without nearby storage options

Reference: Element Energy for BEIS, Shipping CO_2 – Cost estimation study, 2018

Element Energy is a leading low carbon energy consultancy working in a range of sectors including industrial decarbonisation, carbon capture utilisation and storage (CCUS), hydrogen, low carbon transport, low carbon heat, renewable power generation, energy networks, and energy storage. Element Energy works with a broad range of private and public sector clients to address challenges across the low carbon energy sector.

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